L. B. Cebik W4RNL
5105 Holston Hills Road
Knoxville TN 37914

Watch That Signal!

Haul out your old oscilloscope and turn it into a signal monitor. The conversion is easy and the price is right.

An external view of the adaptor shown in Fig. 8, with shielded connections to the rear of the scope and onward to the vertical deflection plates.

Oscilloscope adaptors for rf have been around a long time. They became popular with the advent of SSB and inexpensive scopes after the end of World War II. Today, many of the leading ham equipment manufacturers, including Heath, Yaesu, and Kenwood, provide matching scope units for monitoring transmitted—and in some cases, received—signals. The equipment is excellent, but so is the price tag. There are cheaper ways to have an effective monitor, especially if you are interested only in seeing your transmitted signal. All you need is a cheap working scope and a simple adaptor. Fig. 1 shows in simplified form what we need.

As simple as this scheme is, relatively few hams monitor their transmitted signals or use monitors for making adjustments. The part of the equation that stops most hams is probably the scope itself and not the adaptor. There are several good working designs, and we shall look at a few before closing. However, the idea of owning and then modifying an oscilloscope still creates anxiety in many hams. So let's begin by looking at what makes a good scope for rf work.

Choosing a Scope for Rf

Current scope specifications make the units of even fifteen years ago look barbaric by contrast. The modern scope has triggered sweep calibrated in fractions of a second per division on the scope face. We can no longer create some

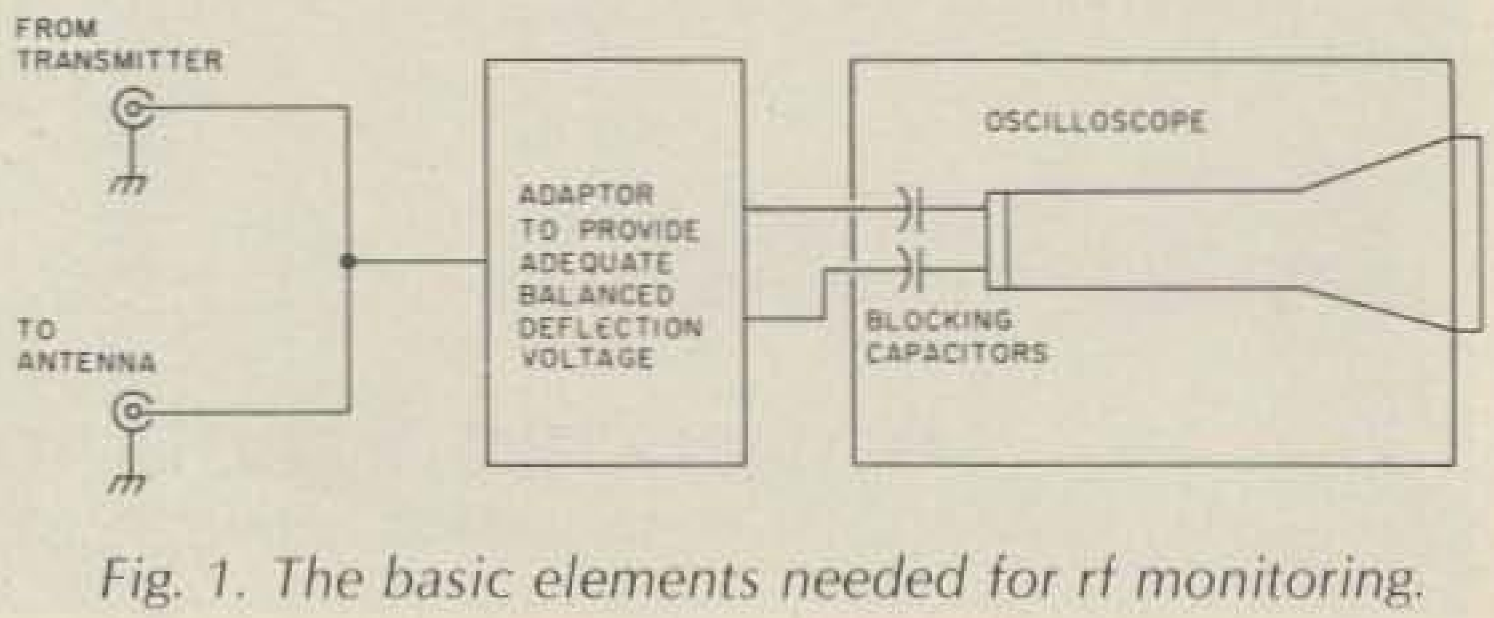


Fig. 1. The basic elements needed for rf monitoring.

of the funny pictures of yore because the recurrent sweep, calibrated in frequency, is gone. Virtually all scopes are solid state. Dual-trace capability is the rule rather than the exception. The frequency limits of the vertical amplifier have gone out of sight. Except for very expensive lab scopes, a 5-MHz limit was rare twenty years ago; today, the limit is fast approaching 100 MHz, with 20- and 30-MHz units common. One other thing has kept pace with the rising specifications: the price.

Modern scopes are excellent. If you own one, then rf monitoring is a simple matter of taking an exceedingly small sample of your transmitted signal and feeding it directly into the vertical amplifier of your scope. You need no adaptor. Unfortunately, few of us have the money for a 30-MHz scope that will get only an occasional workout in the shack. Indeed, if we have access to such a piece of equipment, it will most likely go on the test bench where it will be used more regularly.

If we do buy an older scope, our tendency is to choose one of recent vintage. This would be a solid-state scope with at least one MHz, and perhaps five, as the vertical amplifier limit. It would have recurrent sweep and single trace.

I should have stopped the moment I mentioned solid state! Although there are good solid-state scopes capable of handling the 50-odd volts of rf that we shall put into the case with at least an inch or two of lead, few of the cheap units have sufficient shielding between the amplifier boards and the neck of the scope tube where our leads are needed. The odds of popping one or more transistors is very great. We can add shielding, but our chances of successfully eliminating all rf danger are slim to nonexistent. Modern solid-state monitors begin with this problem as a design consideration, and it may be easier to build a scope from scratch than to rebuild a solid-state unit that was never intended for rf service.

Tube-type scopes of the next preceding generation do not suffer the problems of solid-state scopes. A few volts of rf in the case will not injure the tubes or other components. A hamfest will turn up many of these scopes for sale. The main item of concern is the quality of the cathode-ray tube and the power transformer. Both are difficult to replace and costly at best. If the scope puts out a bright, well-defined trace with the intensity control at the halfway point, then other faults can be repaired with the investment of troubleshooting time rather than money.

For an rf monitor at the operating desk, I prefer a smaller scope to the round-faced five-inch models. Toward the end of the tube era, a number of compact three-inch units appeared, including the Eico 435 and 430. The 8½" by 6" by 11" audio frequency 430 cost $69.95 in kit form in 1965, and it may be worth half to two-thirds of that price at a hamfest if it is in excellent condition. If you prefer a larger scope face, there are numerous Dumont and Heath models (among others) that can be picked up for a song and a few greenbacks.

Getting a scope is half the battle. Modifying it for direct rf input is simple. Locate the vertical deflector plate terminals on the scope tube socket. As close as possible to these terminals, install a pair of connectors on the rear panel of the scope. Phono connectors work well if you use thin coax for the leads from the adaptor (one lead for each terminal, since the signal will be balanced). Pin jacks or similar connectors will work if you use twinlead or other balanced lines from the adaptor; however, shielded leads are best, especially with higher power.

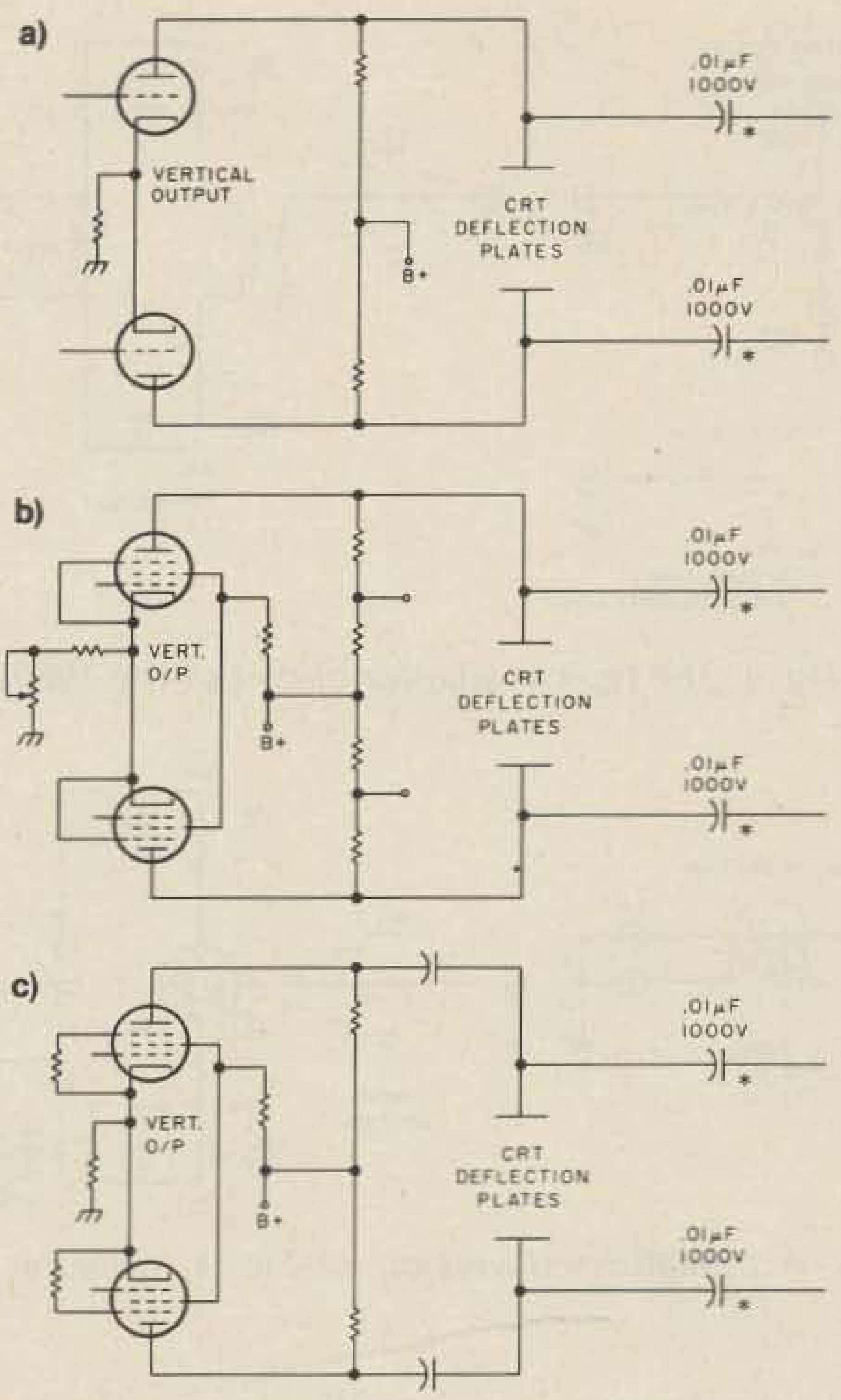


Fig. 2. Rf connections to typical vertical amplifier circuits. (a) Triode dc-coupled output stage. (b) Pentode dc-coupled output stage. (c) Pentode ac-coupled output stage.

Between the socket terminals and the jacks, install .01-µF disc ceramic capacitors of at least 1000-volt rating. Keep the leads as short as possible, and try to keep the capacitors at right angles to anything to which you might couple signal. Many scopes used to have accessory jacks on the rear panel for any number of improbable uses (for example, dc voltages to power units under test if they by chance happened to require exactly the voltages provided at a very limited current). If these are close enough to the scope tube socket, then mechanical work will be further minimized.

Fig. 2 shows the connections schematically, along with some typical vertical amplifier connections to the same socket pins. In most cases, you will need no other work on the scope. It will operate normally when rf is not present. When using the scope to monitor your transmitter, keep the vertical gain at minimum, and if you have input attenuator positions, set them at maximum. For monitoring, we simply bypass the vertical amplifier and generate the voltage needed to deflect the trace vertically by other means.

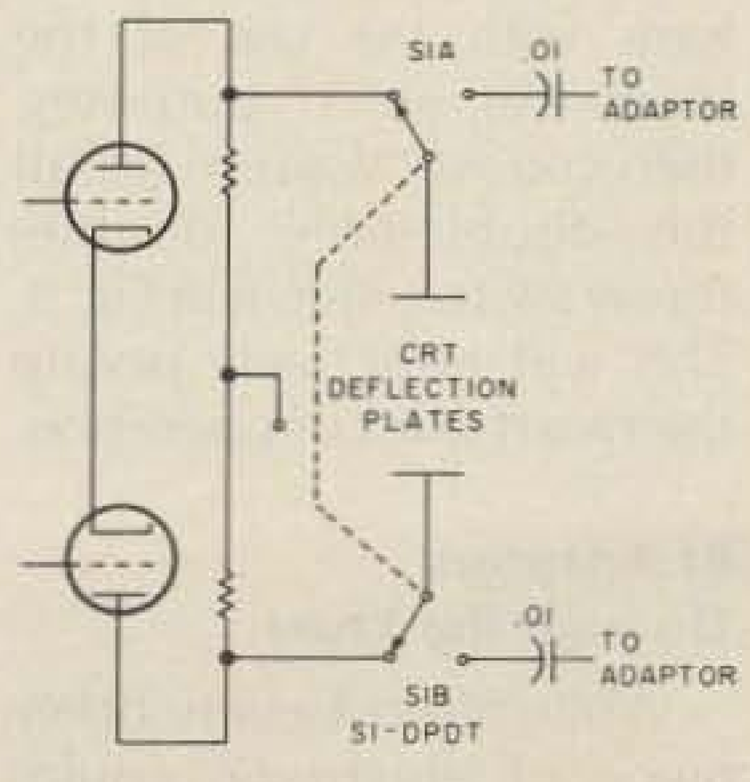


Fig. 3. Isolating rf and normal scope signals.

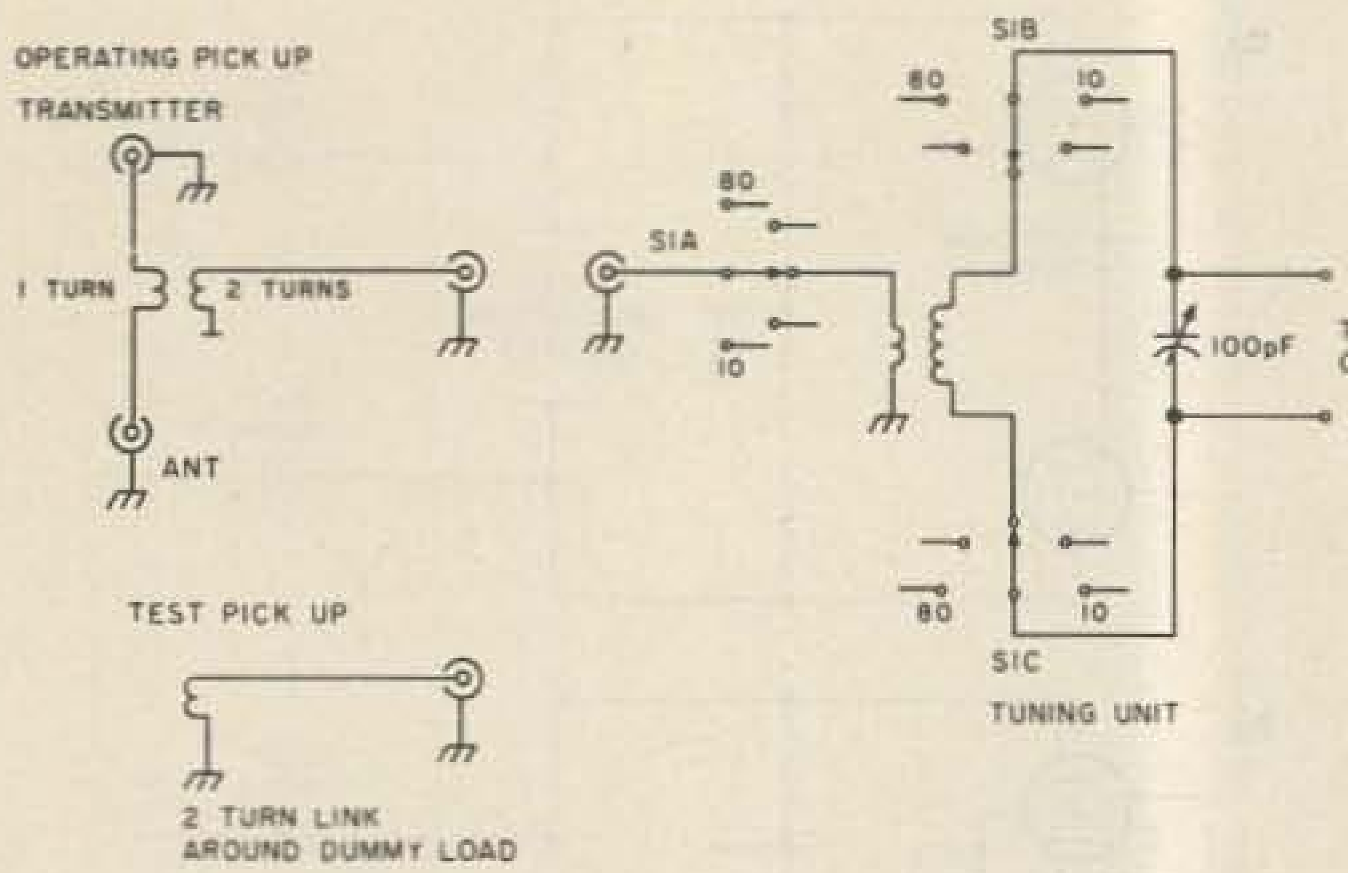


Fig. 4. The typical adaptor circuit of the 1960s.

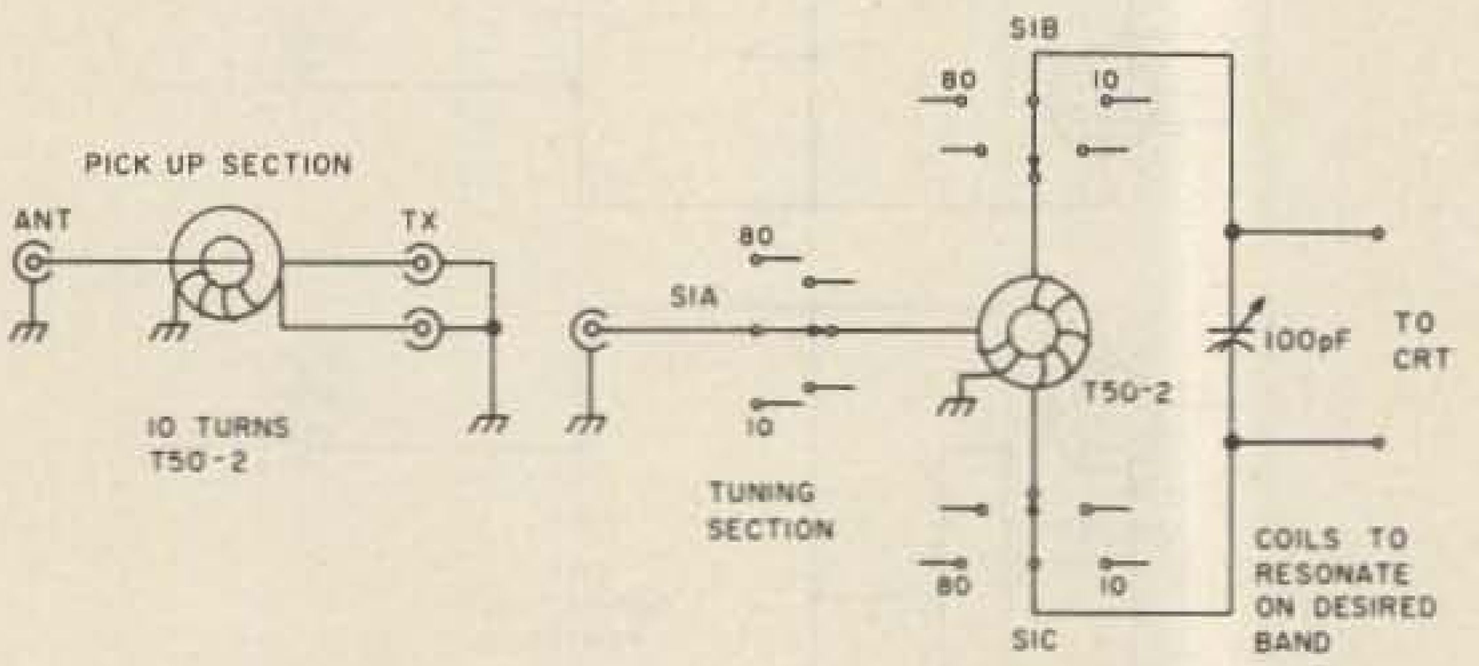


Fig. 5. A miniaturized version of Fig. 4, utilizing toroid cores.

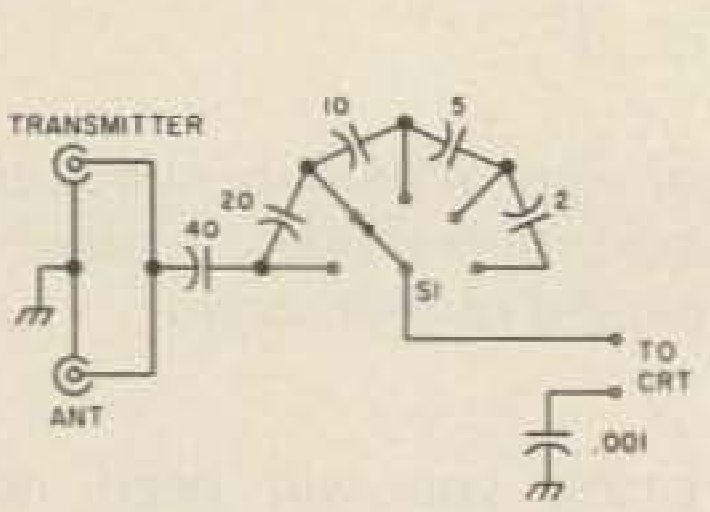


Fig. 6. A simple rf scope adaptor in wide use today.

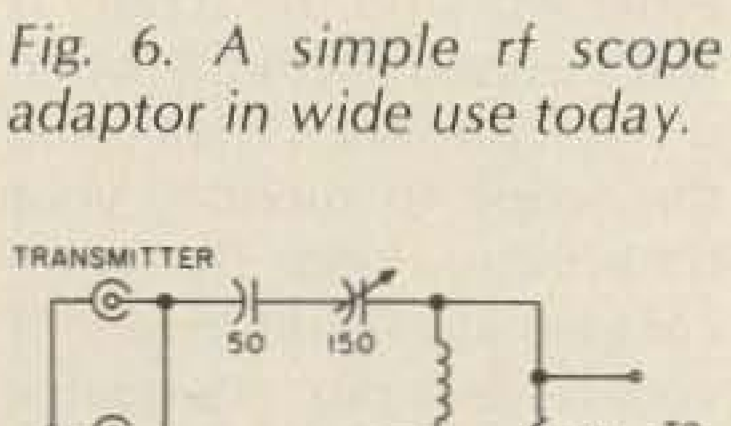


Fig. 7. The VE7CGK adaptor.

If you encounter problems with the use of the scope for non-rf purposes, then you will want to install the double-pole, double-throw switch shown in Fig. 3. This will effectively isolate the two modes of operation.

Rf Adaptors Through the Years

While almost every other piece of electronic equipment has grown more complex through the years, rf adaptors for oscilloscopes have grown simpler. I have built most of the designs, discarding them as a more compact arrangement became available. My present unit fits in a 2"×2"×4" aluminum box mounted on the back of my scope, with only one switch to manipulate. The photo shows how compact the adaptor can be. We may never reach the ultimate miniaturization in anything, but if another adaptor design comes along, I will hesitate before replacing the present unit.

Most early designs used tuned circuits, one for each band. Fig. 4 shows the general design which was fairly standard for about a decade. There were two separate boxes: a pick-up unit and a tuning unit. The pick-up box contained a one-turn coil running between the input and output coax connectors, with a two-turn link running to the tuning unit. The idea was to minimize the impedance bump in the transmitter transmission line.

The tuning unit went through stages of evolution. Initial designs were open breadboards. You were expected to tack-solder a coil each time you changed bands. Plug-in coils followed, but they required you to open the shielded box which was added to the design. In 1970, W1KLK mounted all the coils on a rotary switch (*QST*, October, 1970, p. 36). He also used the smallest diameter coils I had seen to that time, ranging from ½ inch for 10 meters to 1¼ inches for 80.

The principle of the design was to generate the necessary deflection voltage through the high Q of the tuned circuit. The tuning capacitor, insulated from the front panel and the operator's hand, provided peaking when tuned to resonance. If the voltage provided too much deflection (somewhat a rarity with older, less sensitive cathode-ray tubes), detuning the circuit attenuated it effectively. Despite its size, the unit worked very well.

The same design can be significantly miniaturized through the use of toroid cores for the inductors throughout, as shown in Fig. 5. The schematic diagram is essentially the same, although some changes have been made in the drawing to indicate the mechanical changes. A short straight line with Teflon™ insulation runs between the coax connectors and through a half-inch core. I have used from 6 to 20 turns of #28 wire in the secondary without disturbing the line impedance seriously. The tuned circuit coils in the aggregate take less room than the switch on which they are mounted. Although a three-section switch is shown, I have also used a two-section switch, with one side of each coil (and the capacitor) to a common. This did not seriously upset the balance of the output. The entire unit can be mounted in a single box with a partition between the pick-up and tuning sections.

Recent Adaptor Designs

More recently, designers have realized that tapping a 50- or 75-Ohm coax line would cause no significant problems if the tap impedance was fairly high. This has resulted in the use of almost direct connections between the rf line and the scope tube. Fig. 6 shows a generalized idea of the scheme. The switch controls a selection of capacitors arranged to successively double the reactance and lower the signal level seen by the scope plates. Since the scope deflection plates require a balanced input, the ground side is elevated off ground. The system is perfectly adequate for most monitoring purposes, although a better balance is easily achieved.

In 1979, VE7CGK presented an interesting scheme (*73*, June, 1979, p. 110); it is shown in Fig. 7. His balun used an ordinary 2-inch-diameter antenna core. The swamping resistor across the core is non-critical in value, and anything with up to a three-to-one ratio to the value given seems to work. It evens the frequency response by lowering the Q of the coil. However different his coupling scheme appears to be from that in Fig. 6, it is electrically identical. He has used a variable capacitor (with a series fixed capacitor) to replace the switch. Like all the units shown, his works well, with one exception. It is difficult to find a variable capacitor with a 150-pF top value that will go below 10 pF minimum. The 5-pF value in Fig. 6 is needed when viewing kW signals on a sensitive scope tube.

The final design that fits into the small box shown in the photo combines the best of these two designs with some miniaturization thrown in. Fig. 8 shows the circuit. The capacitor section is standard. The balun is

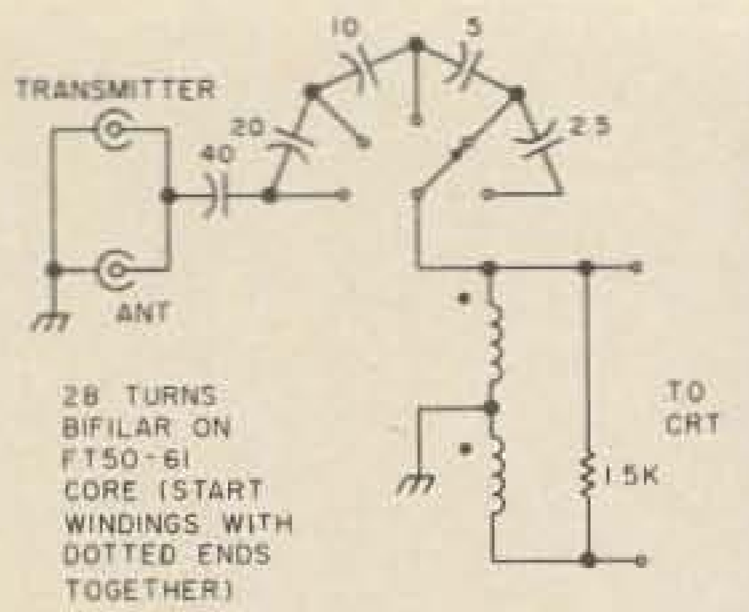
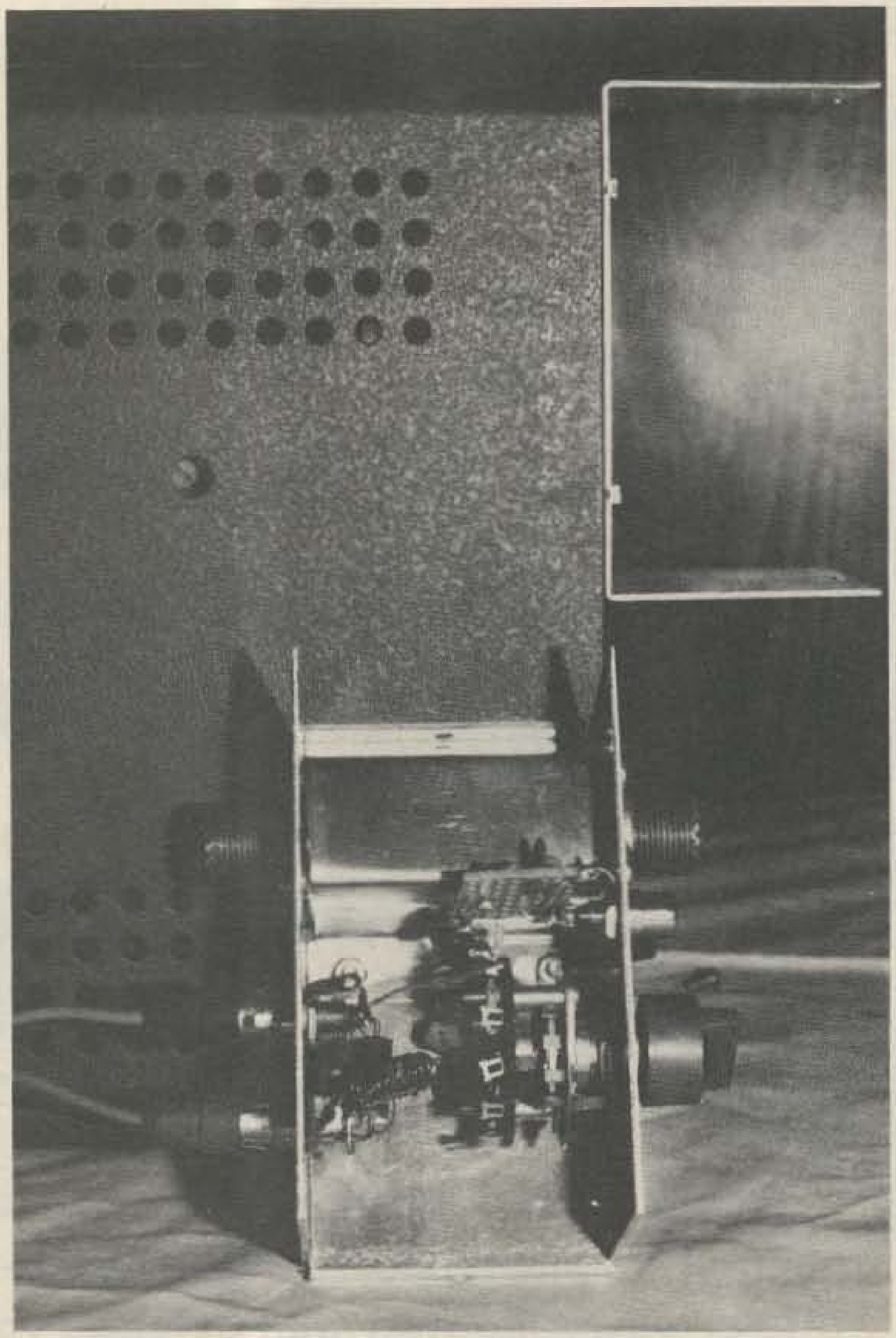


Fig. 8. The hybrid miniature scope adaptor.

wound on an FT 50-61 core and is designed for about 1200-Ohms impedance at 3.5 MHz, or about 54 microhenries per section. Twenty-eight turns bifilar, connected as shown, meet the requirement.

Construction is simplicity itself. As Fig. 9 shows, the switch is mounted on one side of the U-shaped channel of the box, the output jacks on the other. A thin aluminum cover with a hole for the capacitor lead covers the wire between coax connectors. The remaining part of the box mounts on the rear of the scope, so the unit is almost a plug-in device. Leads from the adaptor to the scope are kept short, partly by careful thought beforehand on parts arrangement. Construction can vary according to what is convenient in terms of your scope. The only rules to follow are the usual ones about short leads for rf.

The response of this adaptor is smooth across the ham bands from 80 to 10 meters, with no significant difference in the deflection of equal power signals among bands. Nor are there any peculiar peaks or other odd quirks. In short, the adaptor does its passive task tamely but effectively. Position 2 on the switch is used for the normal 100-Watt output from the rig and yields over an inch of deflection. Position 1 permits viewing of much lower power signals. The output from my SB-200 produces about an inch and a half of deflection in position 4, thus confirming that



Interior view of the adaptor shown in Fig. 8. The metal shield near the top covers the through line from transmitter to antenna, while the switch holds the capacitor-divider. The broadband transformer balun is mounted between the output jacks at the lower right. The small perfboard holds an envelope detector for synchronizing the scope's sweep.

the capacitor choice is adequate for the most common range of ham signals. The scope which the adaptor feeds, incidentally, is an Eico 430.

Using the Adaptor

Synchronizing the monitored signal to the scope sweep is desirable but not essential to the observation process. It is useful and pos-

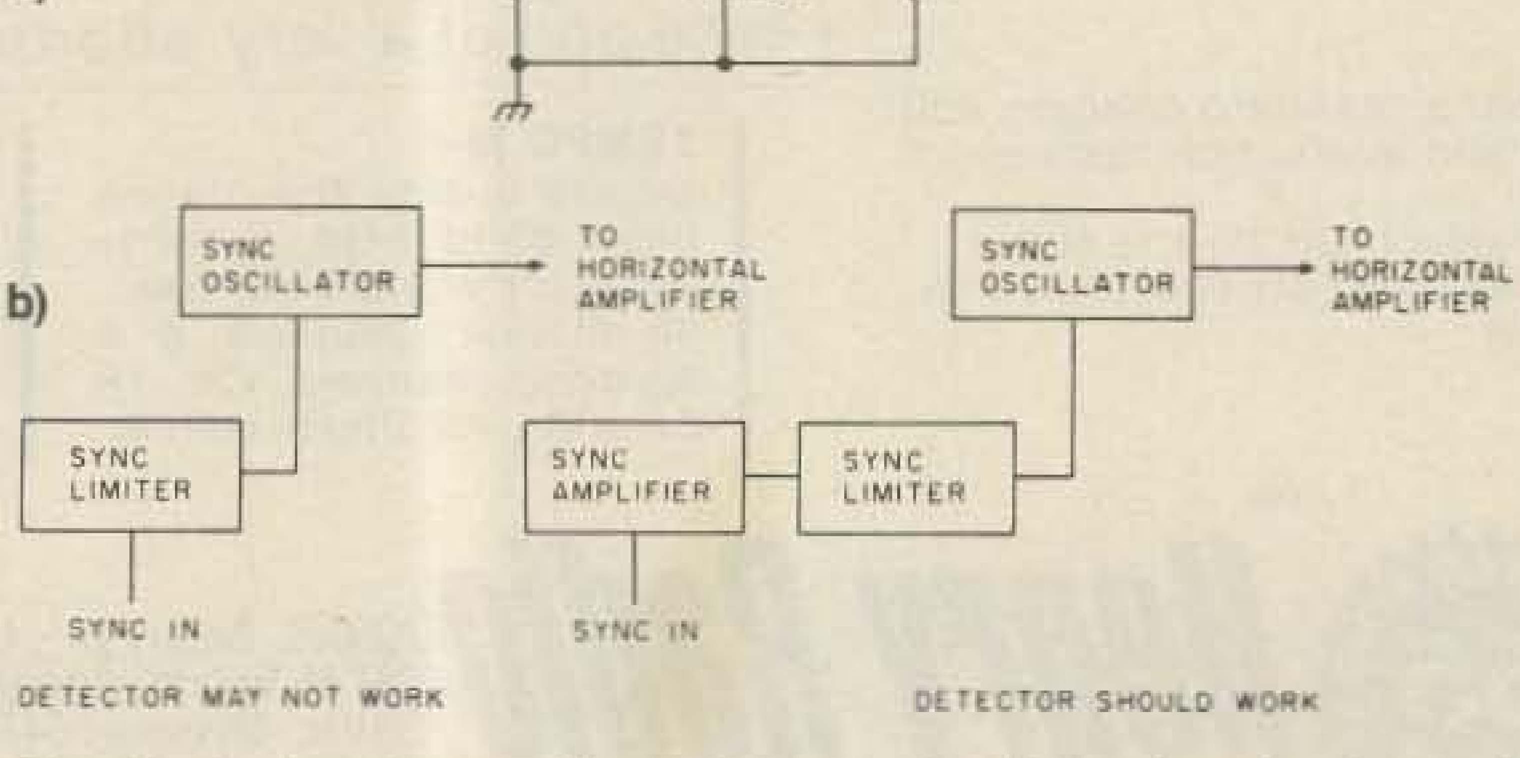


Fig. 10. A simple envelope detector for linearity checks and sync. (a) Envelope detector. (b) Scope sync systems.

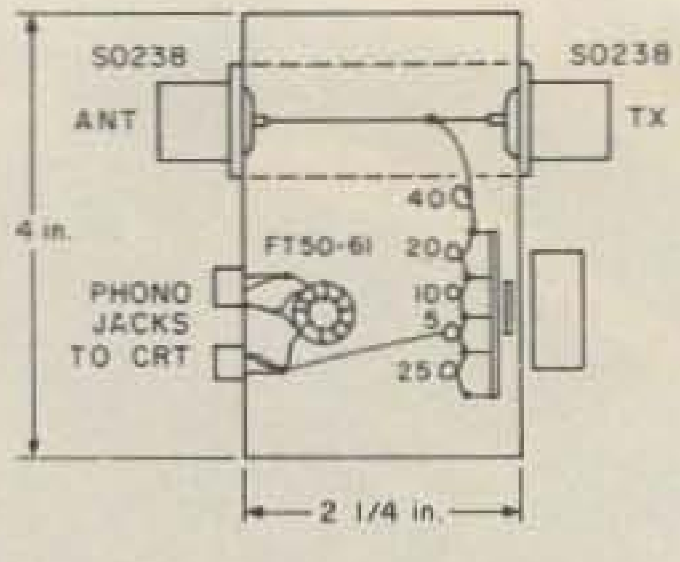


Fig. 9. Physical layout of the hybrid scope adaptor.

sible with CW dots or dashes sent at a constant rate (easily done with an electronic keyer) and with two-tone tests on SSB. For the usual Christmas-tree pattern seen in casual monitoring of SSB or for AM trapezoidal patterns, sync is useless. Nonetheless, the technique for deriving a sync voltage is simple in principle and deserves mention.

Fig. 10(a) shows a simple AM detector typical of those found in rf probes. With the isolating resistor, its output is very low, too low to drive the external sync connections on many scopes. The problem becomes clear in Fig. 10(b), block diagrams of two types of sync inputs. In one case, external sync is amplified before going to the sync limiter. In the other, sync voltage goes directly to the limiter. A small external sync voltage cannot drive the second circuit without further amplification. For two-tone testing SSB signals, an audio amplifier works well, but for CW, a dc amplifier is better. If your scope has a stable sweep oscillator, this additional circuitry adds little to the effectiveness of monitoring, but it does create a need for feeding power to the adaptor which is otherwise a passive device. For standard linearity patterns, of course, a pair of detectors is needed, but since the regular horizontal and vertical inputs of the scope are used for the test, no power source is needed.

Using the monitor is an easy process. Connected as shown early in the article, the adapted scope will dis-

Parts List

1	Single-pole, 5-position rotary switch	Radio Shack and other sources
1	FT 50-61 ferrite toroidal core #28 enamel wire (28 bifilar turns on core)	Amidon and other sources
2	SO-238 coax sockets	Radio Shack and other sources
2	phono sockets	Radio Shack and other sources
1	1.5k-Ohm, ½-Watt resistor	Radio Shack and other sources
1	40-pF silver mica capacitor	Available from mail-order sources such as Semiconductor Surplus
1	20-pF silver mica capacitor	
1	10-pF silver mica capacitor	
1	5-pF silver mica capacitor	
1	2.5-pF (or two 5-pF in series) silver mica capacitor	Note: disc ceramic capacitors with 350-volt or higher ratings will substitute for the silver micas
1	2¼" × 2¼" × 4" aluminum utility box	Radio Shack and other sources

Total cost: $10, if all parts new; under $5 with surplus and/or used parts.

play CW waveforms, plus two-tone and Christmas-tree SSB patterns. No better observation of CW make-and-break patterns has been invented, and the results of adjustments to component values become immediately apparent. With respect to observation of SSB, the simple adaptor technique might be considered somewhat archaic. A spectrum analyzer will in fact provide more sensitive indications of incorrect linear-amplifier adjustment. However, a spectrum analyzer is an expensive piece of equipment.

The two-tone test provides good indications of improper amplifier adjustment if the operator takes the time to become personally familiar with and sensitive to the meaning of the curves. Handbooks of a few years back provide ample drawings of various conditions of operation and their meaning.

Some recent materials on the subject have bent over backward to discredit our ability to read two-tone envelope patterns effectively. This is true only if we do not thoroughly learn the peculiarities of our equipment. The idiosyncrasies of each amplifier and each scope require that we make extensive on-the-air and dummy-load tests to discover at what point slight flattening of the pattern top, or slight curvature to the pattern sides, means distortion of our voices or adjustments of the drive or loading which are out of spec. We may not be able to match laboratory results, but we can keep our rigs well within FCC regulatory requirements and well within what courtesy to other operators dictates.

Despite the fact that rf adaptors for old audio scopes have been supplanted by more sensitive methods of monitoring, it will be a long time before we can all afford up-to-date test equipment. In the interim, a small investment (maybe $30 to $50 for a used scope and $5 for the monitor) can go a long way toward helping us put out cleaner signals. The tiny monitor box shown here (which might even fit inside some of the large old scope cases) makes the process of monitoring one step easier. I only wonder how small the next monitor design will be. ■