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**Author:** Peter O'Dell, KB1N

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• *Basic Amateur Radio*

# Simple Antenna and S-Meter Modification for 2-Meter FM Direction Finding

Enjoy hunting? Want to go after a tame little bunny or a wild turkey? Here are some tools that may help you.

By Peter O'Dell,* KB1N

"Did you see that silly man and woman driving around with the TV antenna on their car? They must have been down to the dump and picked it up. She was driving and he was holding onto the antenna with his arms stuck out the window. You'd think they would freeze to death in this weather. Funny thing is that they just kept driving back and forth. Some people are just plain crazy!" said the clerk to our friend Danny. Danny just smiled and nodded because he knew that the crazy man and woman were actually two rather inept bunny (hidden transmitter) hunters. They had managed to get close to the bunny, but couldn't locate him once they were in his immediate proximity. Of course Danny waited until a large crowd had gathered on the local repeater before telling us what the clerk had said *about my wife and me*. It sure is nice to have friends.

### A Source of Vexation

Bunny hunts or fox hunts are organized events in which one member of the group retires to some out-of-the-way place and periodically transmits a signal. The objective of the other members of the group is to find the bunny as quickly as possible. There are a number of variations on this theme. On the other hand, a wild turkey hunt (well, at least, that's what I call it) occurs when an unknown operator begins transmitting an unidentified signal, intentionally or unintentionally, that causes disruption of service. The objective of the whole group is to find him/her and convince him/her to stop transmitting in such a manner. The generic term for these endeavors is direction finding (DF).

Direction finding is easy for a vhf fm signal; all you need is a map, a compass, a receiver and a directional antenna. If you are a couple of miles from a signal, you should have no trouble getting the general direction of its origin. Move to another location and take a second reading; draw the corresponding lines on your map and, *presto*, you know exactly where the transmitter is located — well, almost.

Most newcomers to DF make the same mistakes that we did. They try to use the same kind of antenna for DF that they use for making distant contacts. The trouble is that the objectives and needs of the two situations are quite different. Typically, a Yagi beam with parasitic reflector and directors will have one main signal lobe, several minor lobes and numerous nulls between the lobes. Hall has recently discussed the interpretation of patterns as presented in *QST*, so that information will not be repeated here.[1] Also, for more detailed information on antenna patterns, consult *The ARRL Antenna Book* (available from ARRL for $5). A pattern with one narrow major lobe is what is needed for making long-distance contacts.

But that is not the most useful pattern for DF operations. Usually, as an operator moves toward the location of the hidden transmitter, the signal strength will increase. Do you know what happens with an antenna/receiver system that determines direction based on the main lobe? Sooner or later the S meter will be fully

*Basic Radio Editor

[1]Notes appear on page 47.

deflected on some or all of the minor lobes as well as the major one. At that point the searchers will probably go back and forth or in circles because the signal will seem to be coming from several different directions at the same time! I speak from experience.

Fig. 1 shows the pattern of an antenna that can be much more useful for DF operations. The antenna has only one lobe in its pattern. Notice that there is only 3 dB difference 90 degrees either side of a bearing of zero degrees. This lobe is virtually useless for direction finding. But take a look at the null. The computer program used to generate plot points for this pattern indicated that the signal level at 180 degrees would be − 120 dB. [This is a somewhat nebulous number arising from rounding in the computer's math operations. The theoretical response is −∞ dB. — Ed.] Ten degrees either side, the signal level rises to −40 dB — a difference of many, many dB! The point is, when the null is pointed at a signal, the operator should notice a *sharp* decrease in the received signal strength. This is a significant advantage for DF. Why? Because the antenna pinpoints a direction based on a *minimum* reading, it will be useful when close to the source. Cardioid is the general name applied to patterns with one very broad lobe and one very sharp null.

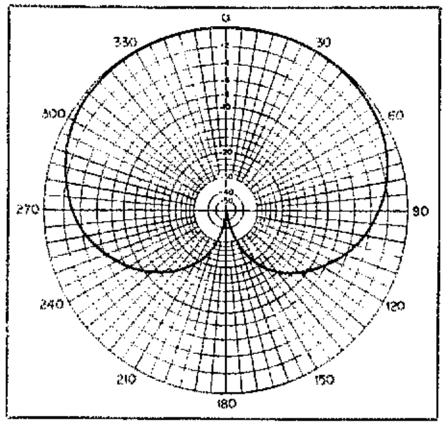



Fig. 1 — This is a cardioid antenna pattern. As the antenna is rotated, an operator would notice little change in the S-meter indication of an incoming signal until the notch was pointed at the signal. Then the S-meter reading should drop dramatically.

## The Antenna

What kind of antenna produces a cardioid? Although there may be any number of different antennas that will produce this type of pattern, the simplest design is depicted in Fig. 2. Two quarter-wavelength vertical elements are spaced one quarter-wavelength apart and are fed 90 degrees out of phase. Each radiator is shown with two radials approximately 5 percent shorter than the radiators.

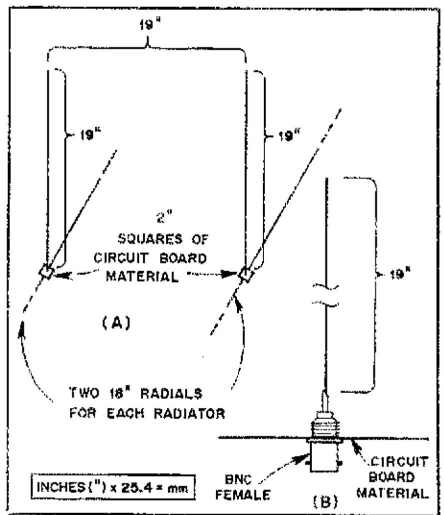



Fig. 2 — At A is a simple configuration that can produce a cardioid pattern. At B is a convenient way of fabricating a sturdy mount for the radiator using BNC connectors.

During the design phase of this project we used the TRS-80 computer to predict the impact on the antenna pattern of "slight" alterations in its size, spacing and phasing of the elements.[2] The results suggest that this system is a little touchy and that the most significant change comes at the null. Very slight alterations in the dimensions caused the notch to become much more shallow and, hence, less useable for DF. Early difficulties in building a working model bore this out.

This means that if you decide to build this antenna, you will find it advantageous to spend a few minutes to "tune it" for the deepest null. If it is built using the techniques I used, then this should prove to be a small task which is well worth the extra effort. Tuning is accomplished by adjusting the length of the vertical radiators, the spacing between them, and if necessary, the lengths of the phasing harness that connects them. Tune for the deepest null on your S-meter using a signal source such as a moderately strong repeater. This should be done outside, away from buildings and large metal objects — I tried tuning in our kitchen and found that reflections off our appliances were producing spurious readings. Beware too of distant water towers, radio towers, and large office or apartment buildings. They can reflect the signal and give false indications.

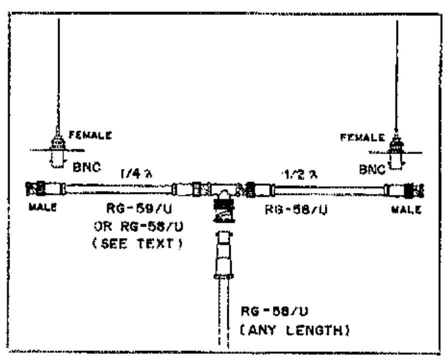



Fig. 3 — The phasing harness for the two verticals that produce a cardioid pattern. The phasing sections must be measured from the center of the T connector to the point that the vertical radiator emerges from shield portion of the upside-down BNC female; i.e., don't forget to take the length of the connectors into account when constructing the harness. If care is taken and coax with polyethelene dielectric is used, you should not have to prune the phasing line. With this phasing system, the null will be in a direction that runs along the boom toward the quarter-wavelength section.

Construction is simple and straightforward. Fig. 2B shows a female BNC connector (Radio Shack 278-105) that has been mounted to a small piece of pc-board material. The BNC connector is held "upside down" and the vertical radiator is soldered to the center solder lug. A 12 in. (300 mm) piece of brass tubing provides a snug fit over the solder lug. A second piece of tubing, slightly smaller in diameter, is telescoped inside the first. The outer tubing is crimped slightly at the top after the inner tubing is installed. This provides positive contact between the two tubes. For 146 MHz the length of the radiators calculates to about 19 in. (480 mm). You should be able to find small brass tubing at a hobby store. If none is available in your area, you might consider brazing rods. I have noticed some available in the hardware sections of discount stores. It will probably be necessary to solder a short piece to the top of these since they come in 18 in. (460 mm) sections. Also, tuning will not be quite as convenient. Two 18 inch (460 mm) radials are added to each element by soldering them to the board. I happened to have two 36 in (920 mm) pieces of heavy brazing rod available so I used them.

## The Phasing Harness

One of the requirements to produce a cardioid pattern is that the two elements be fed 90 degrees out of phase. Why not put a 19-in. (480 mm) quarter-wave section of coax between the two elements? Radio waves travel slower in transmission lines than they do in free space. Each type of transmission line has a characteristic known as the velocity factor. This is a fractional figure that will convert the electrical wavelength in free space to the electrical wavelength in the transmission line. Since it is a fractional value, the equivalent length of transmission line will always be shorter than the free space distance. In other words, an electrical quarter wavelength of transmission line will be shorter than the distance between the two radiators.

There are any number of ways of getting around this problem. One simple solution would be to separate the elements by a quarter wavelength and connect them with a piece of transmission line that is electrically three quarter-wavelengths long (or any other odd multiple of a quarter wavelength). Lewallen has noted that some care must be taken to avoid having unequal currents flowing in the two radiators.[3] He suggests the use of a T connector to split the phasing line as shown in Fig. 3. Unequal currents tend to reduce the depth of the null in the pattern, all other factors being equal.

With no radials or with two radials perpendicular to the vertical element, I found that a quarter-wavelength section made of RG-59/U 75-Ω coax produced a deeper notch than a quarter-wavelength section made of RG-58/U 50-Ω coax. However, with the two radials bent downward somewhat, the RG-58/U section seemed to outperform the RG-59/U. There will probably be enough variation from one antenna to the next that it will be worth your time and effort to try both sections and determine which works best for your antenna. The half-wavelength section can be made from either RG-58 or RG-59 because it should act as a 1-to-1 transformer. The most important thing about the coax is that it be of the highest quality (well shielded and with a polyethelene dielectric). The reason for avoiding foam dielectric is that the velocity factor varies from one roll to the next — some say that it varies from one foot to the next. Of course, it can be used if you have test equipment available that will allow you to determine its electrical length. Assuming that you do not want to or cannot go to that trouble, stay with polyethelene-dielectric coax. In short, stay away from coax that is designed for the CB market or do-it-yourself cable-TV market. (A good choice would be Belden 8240 for the RG-58/U or Belden 8241 for the RG-59/U.)

Both RG-58 and RG-59 with polyethelene dielectric have a velocity factor of 0.66. Therefore, for 146 MHz a quarter wavelength of transmission line will be 19 in. (480 mm) × 0.66 = 12.5 in. (320 mm).

A half-wavelength section will be twice this length of 25 in. (640 mm). One thing that you must take into account is that the transmission line is the total length of the cable *and the connectors.* Depending on the type of construction and the type of connectors that you choose, the actual length of the coax by itself will vary somewhat. You will have to determine that empirically.

In my earliest efforts I used a Y connector that mated with RCA phono plugs because it is widely available and the phono plugs are easy to work with. The results with this system were not satisfactory. The performance seemed to change from day to day and the notch was never as deep as it should have been. Although they are more difficult to find, BNC T connectors will provide superior performance and are well worth the extra effort. If you must make substitutions, I would suggest that you go with the UHF type connectors (mate with PL-259s).

Fig. 4 shows a simple support for the antenna. PVC tubing is used throughout. I bought the cheapest (smallest diameter) that I could find. Additionally, you will need a T fitting, two end caps, and possibly some cement. (I didn't cement mine together because I wanted to have the option of disassembly for transportation.) Cut the PVC for the dimensions shown. You can use a saw or a tubing cutter to cut the PVC. I prefer the tubing cutter because it produces smooth, straight edges and is a lot less messy. Drill a small hole through the pc board near the female BNC of each element assembly. Measure 19 in. (480 mm) along the boom (horizontal) and mark the two end points. Drill a small hole vertically through the boom at each mark. Use a small nut and bolt to attach each element assembly to the boom.

### Tuning

The dimensions given throughout this article are those for approximately 146 MHz. If the signal that you will be hunting will be above that frequency, then the measurements will probably need to be a bit shorter. If you are to operate below that frequency, then they will need to be a little longer. Once you have built the antenna to the rough size, the fun begins. You will need a signal source near the frequency that you will be using for your bunny hunts (turkey hunts). Adjust the length of the radiators and the spacing between them for the deepest null on your S meter. I would make changes in increments of 1/4 in. (6 mm) or less. If you must adjust the phasing line, make sure that the quarter-wavelength section is exactly one-half the length of the half-wavelength section. Keep tuning until you have a satisfactorily deep null on your S meter.

### Adding an S-Meter

You just realized your radio does not have an S meter built into it! What can you do? Adding an S meter is a lot easier and simpler than you might imagine. It seems that most of the hand-held units on the market today do not offer this particular "bell and whistle." I personally think this is unfortunate for the user and rather short-sighted on the part of the manufacturers. Fortunately for you there is only one difficult problem associated with adding an S meter — where to put it. Many of the smaller hand-helds simply do not have enough open space inside to install a meter. The obvious solution is to "outboard" the meter and connect it to the internal circuitry with a pair of wires.

Egads! Wires dangling from my new $300 hand-held! Yich! You can install a jack in the case of your hand-held and use the matching plug to connect the meter when you want it. Such a modification will not harm the appearance or resale value. The components are easy to find (Radio Shack sells a variety of matching plugs and jacks). The meter can be housed in a leatherette film carrier used by photographers to carry extra rolls of 35 mm film. The carriers are available from photography stores and discount stores

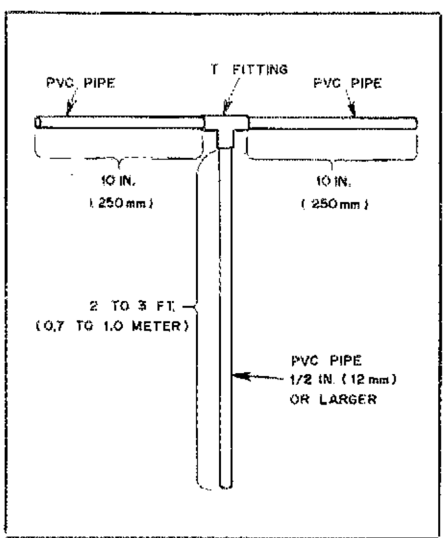
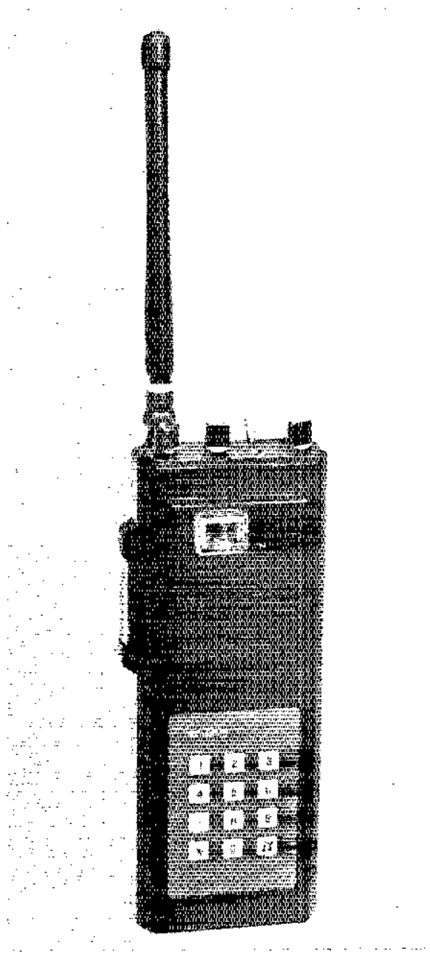



Fig. 4 — A simple mechanical support for the DF antenna made of PVC pipe and fittings.



Heathkit VF-2031 with the S meter added. This hand-held is one of the few currently on the market that has enough room inside for mounting a typically sized S meter.

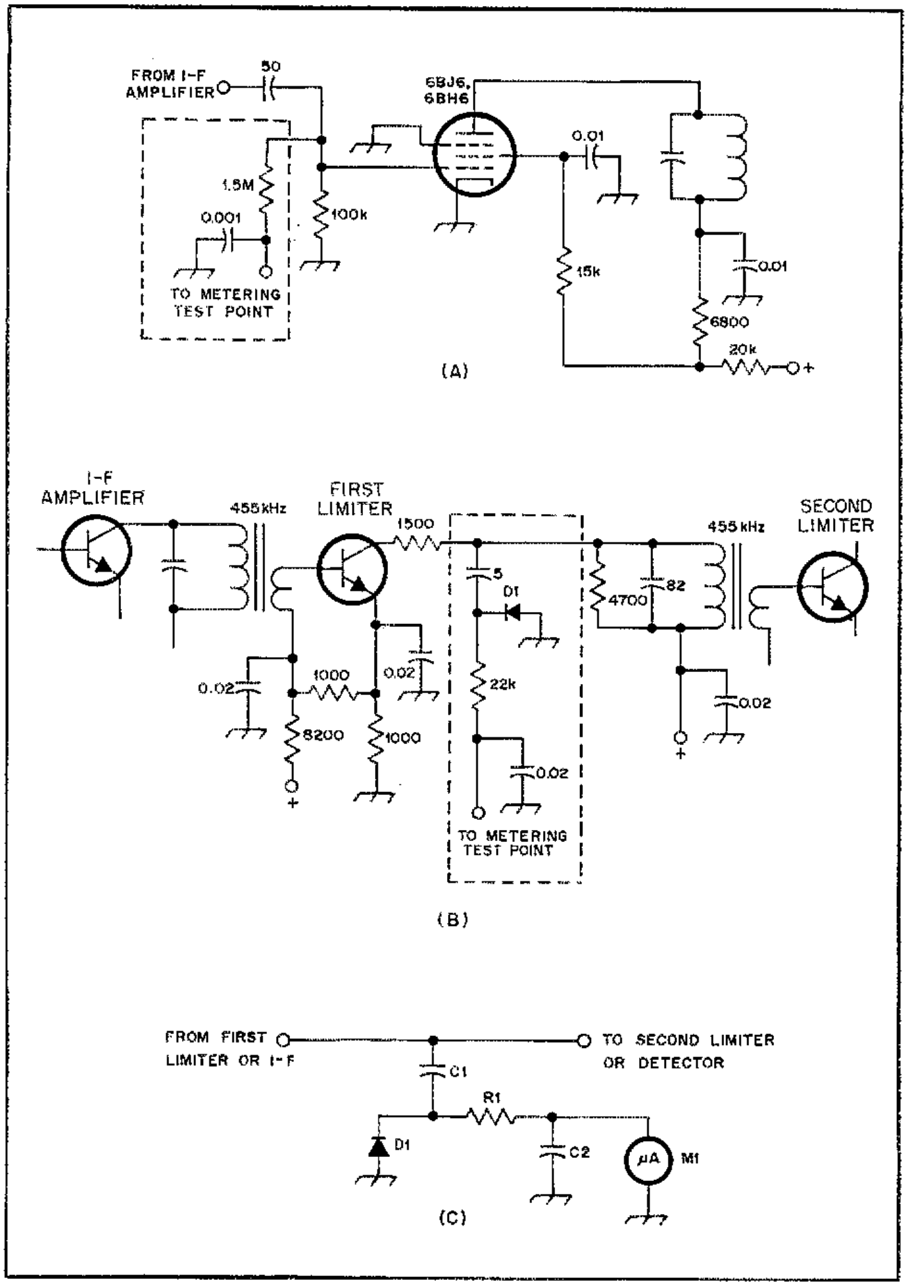



Fig. 5 — At A and B are portions of schematic diagrams of the limiter stages of tube and solid-state receivers, respectively. Many receivers have a test point at this stage for use during front-end alignment. The components associated with the test point are inside the broken lines. If your receiver does not have such a point, you can add the components shown in C. (See text for parts information.)

for less than $2 each. They can be attached to the leather carrying case of your hand-held either with pop rivets or epoxy cement. This very functional modification for your hand-held will not detract from its appearance or resale value (in fact, it will probably boost the resale value slightly).

The detector of an fm receiver detects (decodes) the intelligence from the received signal by demodulating the deviation from the carrier frequency and the rate of change of this deviation. Any amplitude (strength) variations reaching the detector would be detected as noise or distortion of the intelligence in the fm signal. Depending on the design of the receiver, one or usually more stages of high-gain amplification precede the detector. There is an upper limit to the output level from any amplifier, regardless of the level of the input. This characteristic is used by the fm receiver to bring all signals or portions thereof up to the same signal level to minimize noise and distortion in the detected audio. Because these high-gain amplifiers bring the signal up to the upper *limit* of their ability, they are collectively known as the limiter stage(s).

By understanding the above action, you can see it becomes almost trivial to add an S meter to indicate relative signal strength. Fig. 5 (A and B) shows the limiter stages from typical tube and solid-state receivers. Notice that both diagrams have a terminal marked "to metering test point." Typically, a 200-microampere meter will be connected from this point to ground and used to align the front end of the receiver. The stronger the signal reaching the first limiter, the more the meter will be deflected. This is the very action that we are looking for in an S meter! If the schematic diagram of your receiver has such a "test point" indicated, then simply connect your meter here. If not, locate the corresponding point in your receiver and add the circuit that is shown in Fig. 5C. Component values are not critical for the capacitors and diode. Virtually any small-signal diode will be okay for the circuit. C1 and C2 can be any convenient value from 0.001 to 0.05 μF. Determine the value of R1 by substituting a small potentiometer (25 kΩ to 50 kΩ) for the resistor. With the strongest signal available, set the meter for full-scale deflection by adjusting the potentiometer. Once the proper value for full-scale deflection has been determined, remove the potentiometer from the circuit and use an ohmmeter to measure its value. Obtain a quarter-watt fixed value resistor that is close to this resistance and use this resistor for R1. M1 is a surplus S meter that requires up to 350 microamperes for full-scale deflection.

### An Example

Some modern fm receivers have abandoned the use of discrete transistors in favor of monolithic ICs with the limiter stages and the detector all on one chip. One example of this approach is the Heathkit VF-2031 which uses the CA3089 chip. Fig. 6 shows a block diagram of the chip circuitry. Notice that pin 13 (bottom, center) is the output for a tuning-meter circuit. Attached to pin 13 is a resistor and a meter. Like most of the other chips in service, the CA3089 was designed primarily for use in fm broadcast receivers. However, a tuning meter will serve the same function as our S meter. A close look at the service manual of your receiver or the IC manufacturer's specification sheet will probably disclose similar possibilities.

Fig. 7 is a portion of the diagram of the VF-2031, showing the circuitry associated with the CA3089. Notice that pin 13 is already being used to trigger the squelch circuit. But notice also that pin 13 is tied to test point 1 (TP1). Guess what TP1 is used for. That's right — aligning the front end! One unexpected problem cropped up when I discovered that pin 13 never had less than 1.25 V dc on it. Three diodes, D1 through D3, serve the function of providing a constant voltage drop of about

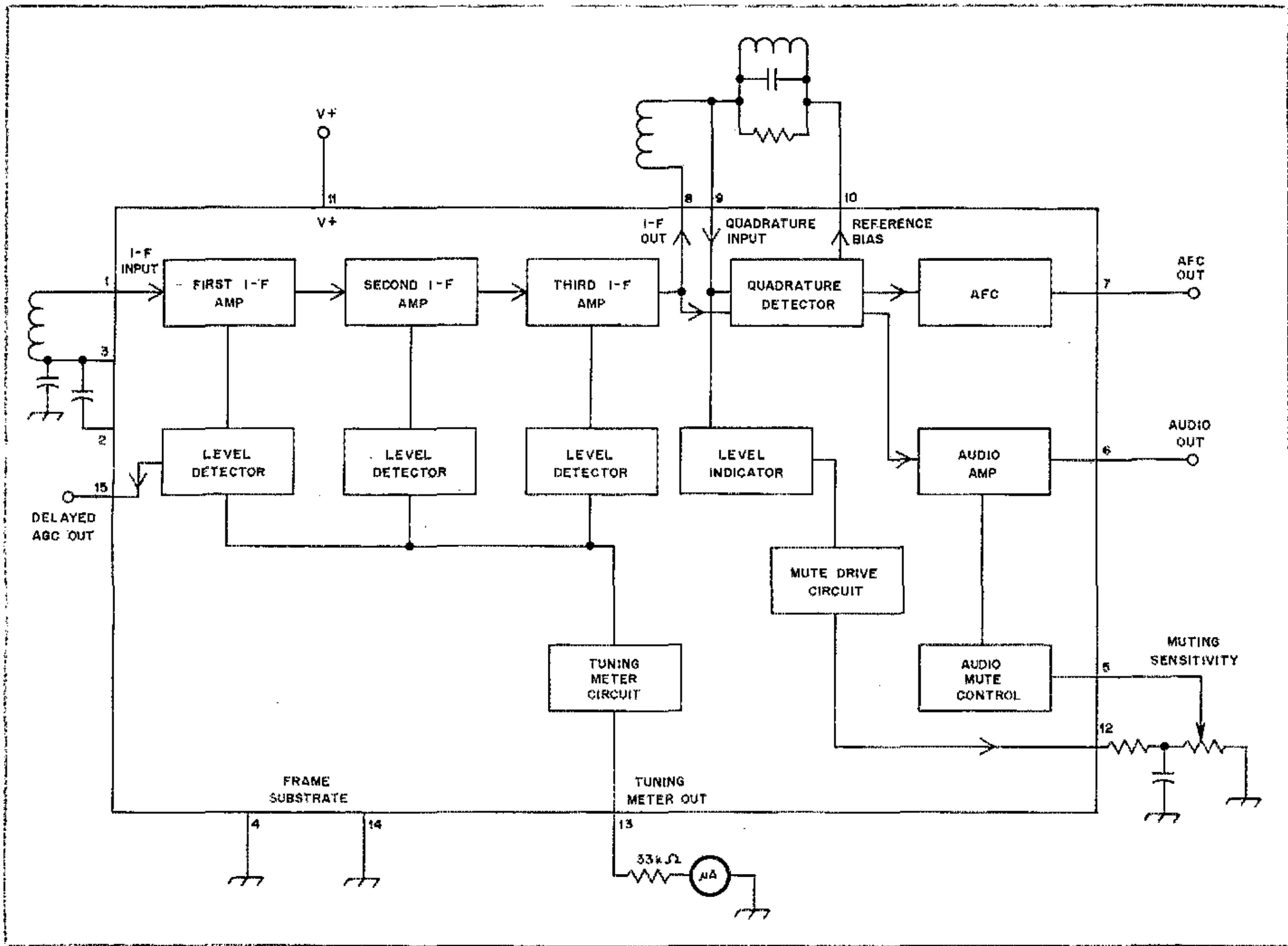



Fig. 6 — Internal block diagram of an RCA CA3089 monolithic limiter/detector IC. Notice that the chip has the circuitry built in for a tuning meter (S meter).

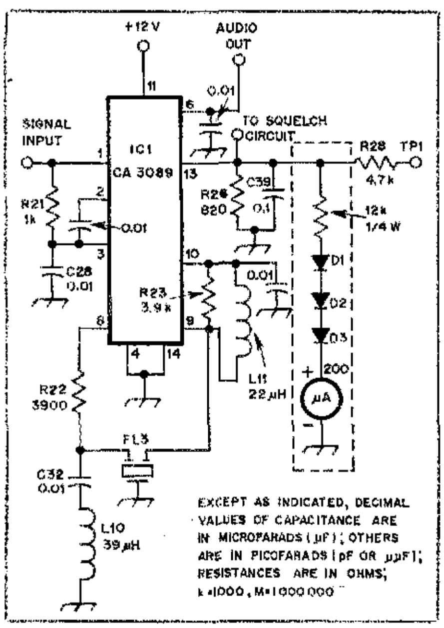



Fig. 7 — Portion of the schematic diagram of the Heathkit VF-2031. The components inside the dotted line were added to provide an S meter.

1.3 V. Without them in the circuit, the meter "idled" at about 1/3 scale when no signal was present. I used the method described earlier to determine the proper value of resistance to produce a full scale meter reading with the maximum voltage present at pin 13. The meter is a surplus unit that was obtained from Poly-Paks.[4]

One of the nicest things about the VF-2031 is the unused space inside which provides ample room for the tinkerer to add any number of options. I drilled a small hole in the front of the case and used a file to enlarge it to the size of the meter housing. I used a small dab of cement to hold the meter in place once I had determined the proper position. The diodes and resistor are encased in heat-shrink tubing and suspended between the meter and the circuit board. It has proved to be a most welcome addition to the transceiver. I suspect that many amateurs would find an S meter a welcome feature on a hand-held.

## Go Get the Bunnies

The best offense is a solid defense! If you have the right tools, bunny hunts are one of the most enjoyable things to do with Amateur Radio on a balmy spring afternoon. And now you have the proper antenna and have added an S meter to your receiver (if it didn't already have one). But more important than just having a good time, you will be preparing a large number of the members of your club to track down the next turkey that takes roost on your repeater. If it is public knowledge that your club can pinpoint a turkey in a matter of minutes, he will probably go gobble somewhere else — turkeys are like that. [QST]

[Note: Next month we will conclude with some useful accessories. In the meantime, go ahead and try the antenna and S-meter combination — you'll like what you find.]

### Notes

[1]Hall, "New Look for QST's Antenna Patterns," *QST*, July 1980, p. 26.
[2]See May, "Antenna Modeling Program for the TRS-80," *QST*, February 1981, p. 15.
[3]Lewallen, "Notes on Phased Verticals," *QST*, August 1979, p. 42.
[4]Poly-Paks part number 92CU5786. This meter or similar available from Poly-Paks, P. O. Box 942, South Lynfield, MA 01940, tel. 617-245-3828.