

# Radio Direction\_Finder RDF Projects Joe WB2HOL

Source URL: <http://home.att.net/~jleggio/projects/rdf/rdf.htm>

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## SIMPLE Time-Difference-Of-Arrival RDF

Joe Leggio WB2HOL

This T.D.O.A. RDF set is built into a die-cast Pomona box. I built it in October, 1989. As you can see from the photo, it has held up to lots of abuse as it gets knocked around in my RDF bag.

### How it works

Time Difference of Arrival RDF sets work by switching your receiver between two antennas at a rapid rate. When both antennas are the same distance from the transmitter, the RF phase received by both antennas will be identical. If the two antennas are different distances from the transmitter the RF will have a different phase at each antenna. If we switch between the antennas 500 times a second, this phase change will be detected by an FM receiver as a 500 Hz tone.

By turning the antennas for a null in the tone, your two antennas will be perpendicular to the transmitter. Unfortunately, you can be facing the transmitter or facing away from the transmitter and get a null in the tone. By using a synchronous detector and processing the phase of the tone, it is possible to drive a center scale meter to indicate which direction to turn to face the transmitter.

If you have a null in the tone and turn slightly right, the meter should point to the left and direct you to turn left to face the transmitter. If instead, it points right as you turn right, you need to continue turning right to face the transmitter; you were facing away from it originally. (in other words, you need to turn 180 degrees around)

When you build this unit you must test it with *\*your specific receiver.\** The audio circuits in a receiver sometimes invert the audio phase and if that is the case, the unit will read opposite of the true direction. If this happens to you simply turn the antenna unit around or reverse the connections to the meter.

If you look closely at the center of the antenna boom in the picture below, you will see my markings on the antenna for one of my HTs. (I used abbreviations, but it says "When using the Ten-Tec HT, this side of the boom should be on the bottom and away from the transmitter")



## Circuit Description

This circuit is adapted from an idea which originally was described in QST in an article for a Double Ducky direction finder. It uses a CMOS 4066 as a synchronous detector. I used a CMOS 555 as a square wave oscillator to drive both the antenna switching diodes and the synchronous detector. I also added a stage of audio amplification to help drive a less sensitive meter. This unit was originally designed to be mounted directly on the antenna connector of my HT. This worked fine when I originally built it. Today, I have a Yeasu FT50R. It is smaller than the TDOA unit and has an SMA connector for the antenna. Somehow, I don't think it could support the weight.

Audio is input via a cable connected to the earphone jack of the HT. A small loudspeaker was mounted on the front of the T.D.O.A. RDF unit to allow me to hear the FOX. The loudspeaker is not illustrated in the schematic shown here. The T.D.O.A. RDF unit supplies voltage to the antenna unit through the center conductor of the coax. The voltage alternately causes the diodes connected to the antenna elements to conduct. As the diodes conduct, RF is able to flow from one of the antenna elements to the receiver. The switching rate is set by the .01uf capacitor and the 47k resistor connected to pin 2 of the 555. If you would like a different tone, try adjusting the value of the 47k resistor.

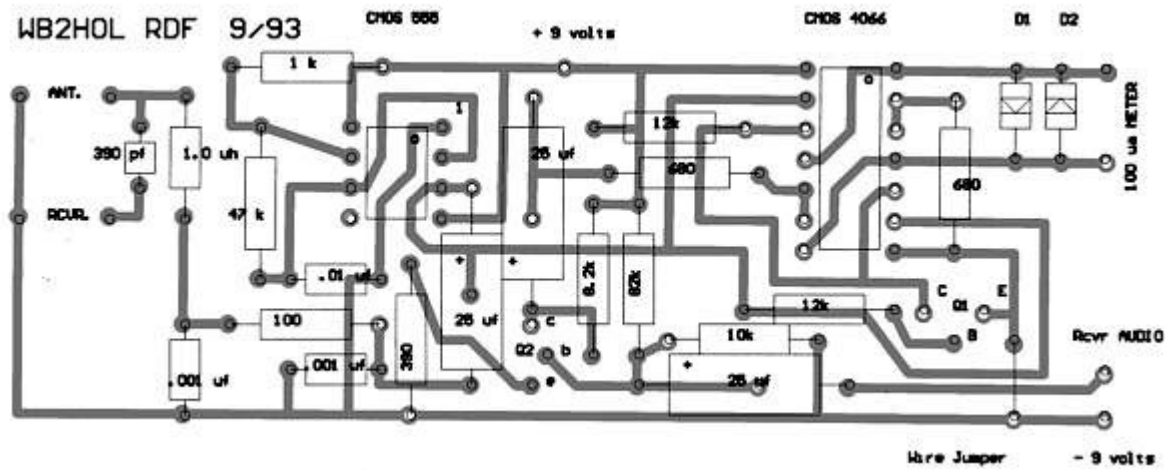
This T.D.O.A. RDF unit uses a center scale meter to indicate which direction to turn in order to face the transmitter. I used a surplus meter movement in my TDOA RDF unit. It was not a center zero meter until I took it apart and moved the mechanical zero adjust lever to make it so. I would guess it was a 100 microamp meter movement originally. I think it was a signal strength meter from an old FM broadcast band receiver. A more sensitive meter would allow you to use less volume. I usually look for a 50 to 200 microamp zero center meter when building one of these units and can usually find a bargain at one of the ham radio flea markets I attend. I never spend more than five dollars for a surplus meter. The meter in this unit cost me about a dollar. I would guess that even a 500 microamp meter could be used. I would be less sensitive and require you to use a bit more volume.

## The Printed Circuit Board

I used rub-on transfers (available from Radio Shack) to lay out the PC board in this unit. It does not have the audio amplifier stage which is present on the PC layout included on this web page. The amplifier is needed when using less sensitive meter movements.

The PC board layout is shown here looking at the bottom of the board as if you had X-ray eyes and could look through the board and see the parts on top. There is one wire jumper. It is at the lower right side of the PC board. The two transistors are 2N3904 or equivalent. The two diodes across the meter movement are 1N914 or equivalent. The three 25uf capacitors each have two different pads available for their leads. If you can obtain parts small enough to fit the set of pads spaced closer together, use them. There is nothing critical about the value of most of the parts. Anything plus or minus 20 percent of the value indicated will work. (don't add 20% to the 555 or the 4066. I doubt \*that\* would work!).

All of the resistors are 1/4 watt. The two diodes on the PC board are connected "back-to-back" The PC layout illustrates how the diodes should be mounted. The electrolytic caps should be rated for at least 10 volts. (assuming you are going to use a 9 volt battery). The 1.0 microhenry coil used to couple the output from the 555 to the antenna was fashioned by winding about 20 turns of number 22 AWG wire on a 3/16 inch drill bit. It was then slid off of the drill and mounted on the PC board.



## The Antenna Unit

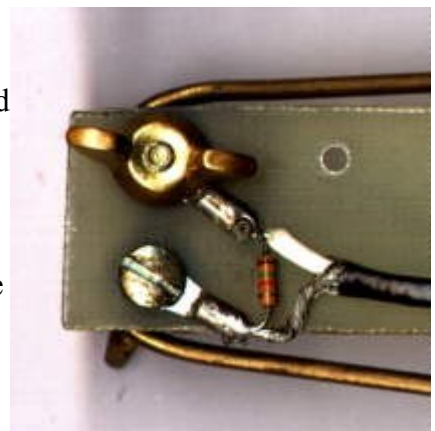
Details of the antenna are shown below. The four antenna elements should be fashioned out of stiff wire or metal rods. One club member recycled a broken TV antenna and used 19 inch segments of its elements. The schematic shows two antennas; you might be wondering why there are four antenna elements. The extra two are connected to the coax shield at the ends of the boom. These form a counterpoise for the two active elements.

The boom of the antenna must be less than 1/2 wavelength long. The longer the boom, ( up to 1/2 wavelength ) the more RF phase difference will be detected. I found that spacing the antennas about 1/4 wavelength apart gave the best results. Further apart resulted in more modulation but at the expense of portability. It also seemed a bit less sensitive to multipath errors when I used the shorter boom. The antenna unit pictured here has a 15 inch long boom.

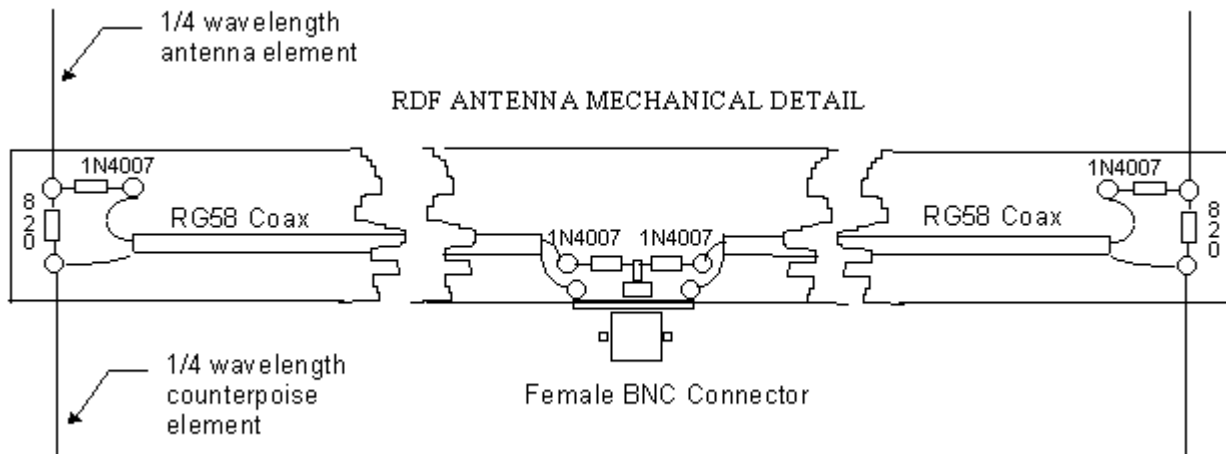
The antenna must be constructed as symmetrical as possible. The lengths of coax from the center BNC connector must be identical. A difference of 1/2 inch will cause an error of several degrees. If you use 1/2 wavelengths of coax you only need one set of diodes where the coax connects to the BNC connector at the center of the boom. If you find it easier to mount a flange style SO-239 connector on the boom instead of a BNC, use it instead. You will then need a cable with an PL-259 at one end and a BNC connector at the other to connect the antenna to the RDF unit.



I have found that by mounting the antenna on a mast so it is up and in the clear will result in the most accurate bearings. (It is then away from reflections from your body and the ground) Whatever you do, make the unit collapsible so it can be



stored when not in use.



It is very important that the diodes on the antenna be connected as shown on the schematic. Most diodes have a band which shows which end is the cathode. The best diodes for use in the antenna are RF PIN diodes. I used 1SS103 PIN diodes I purchased at a flea market. An equivalent diode is the MPN 3404. In a pinch, you can substitute a 1N4007 power diodes. They have a similar internal diode structure to the PIN diodes and will work almost as well. The MPN 3404 is advertised at Dan's small parts

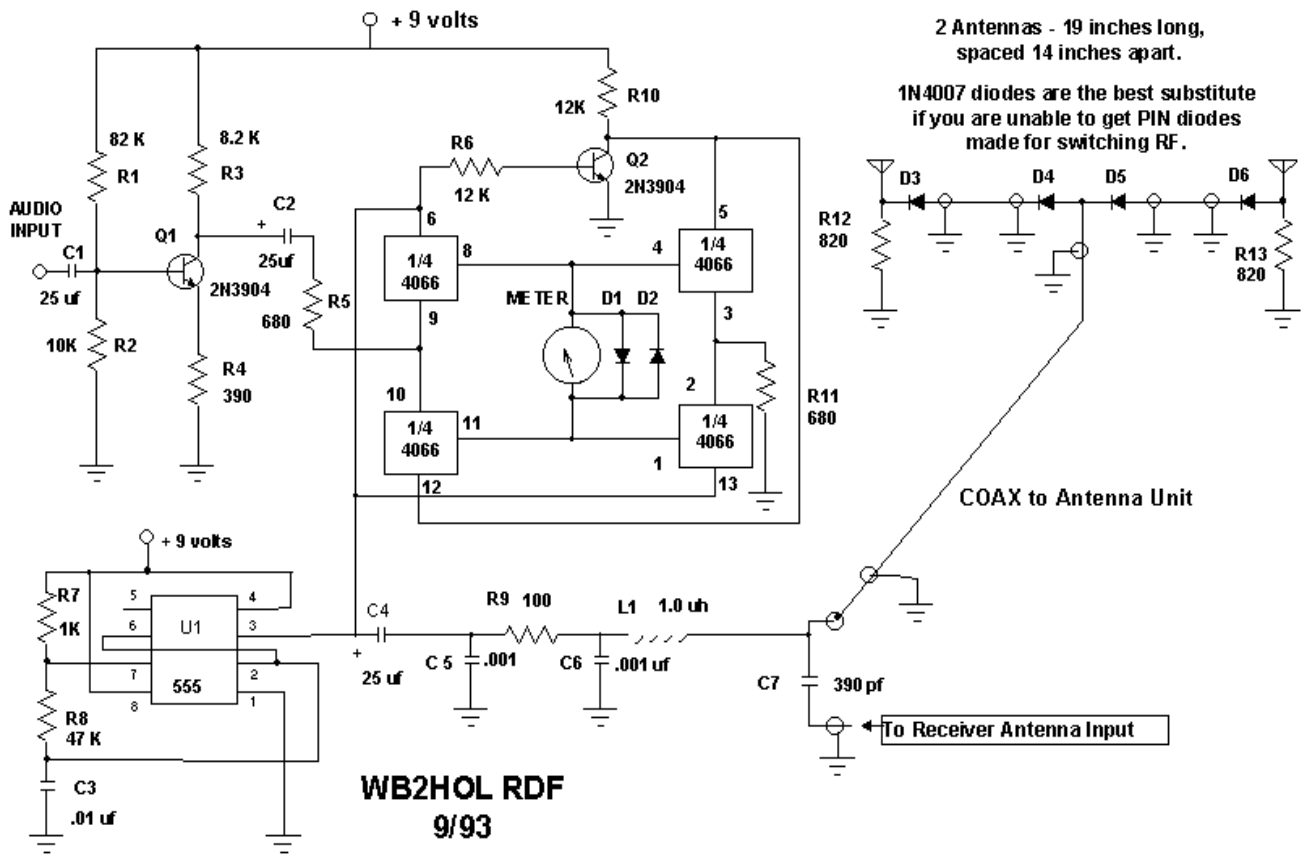
## RDF Antenna Mechanical Details

My antenna unit is designed to fold for storage. Wing nuts are used to secure the elements in position. I used brass brazing rod for the antenna elements on my latest hand-held unit. Earlier units used straightened out coat hanger. On the unit pictured, I used 1/2 wavelength lengths of coax between the center PIN diode and the antenna elements. This allowed me to use only one pair of PIN diodes in the center. I coiled the coax and secured it to the boom mid way between the center BNC connector and the ends. RG-174 coax was used on the unit illustrated here to reduce weight. The resistor in the picture is a 1.5k. The schematic below shows 820 ohms. Remember, in this circuit, few part values are critical.

The antenna boom was made from a piece of scrap glass epoxy circuit board material about 15 inches long and about 1 1/4 inch wide. I peeled the copper from the board, mounted a BNC connector at the center, and used small ring terminals secured by screws as tie points. The PIN diodes are the small rectangular black parts with the red stripe at one end. The picture shows them soldered to the back of a chassis mount BNC connector.

When you build your antenna make sure you mark one side as being the side towards the transmitter. Also mark the TOP. The first time I used this antenna, I started out walking away from the fox instead of towards it because the antenna was being held upside down. (My antenna was visually as well as physically symmetrical) What amazed me was the number of other hunters who followed me thinking I knew where I was going. For the second fox hunt, I had marked the antenna. I won that event using this unit.

### The Schematic



## **555 Time-Difference-Of-Arrival RDF**

by Joe Leggio WB2HOL

This T.D.O.A. RDF set is built on a Radio-Shack experimenters board. It was featured on the cover of the May,June,July 1993 issue of the South Eastern Repeater Association, Inc Repeater Journal.

It uses a single 555 timer wired to produce a square wave output at about 500 Hz. 1N4007 power rectifier diodes were used in place of PIN diodes to switch between two dipole antennas at a 500 Hz rate. If you substitute another lower voltage power rectifier, it will work, just not as well. Of course, if you have RF PIN diodes, use them. (the 1N4007 is the only diode in the 1N400X series to contain a PIN diode structure) Power is supplied by a 9 volt battery.

I mounted the 555 oscillator circuit at the center of a 15 inch long piece of wood which acts as a boom to support two dipoles. The dimensions are not too critical. I used small brass screws as tie points at the ends of the boom and used wing-nuts to allow the dipole elements to fold against the boom when the unit was not in use.

I did not bother to add a power switch. I simply used a rubber band to secure the 9 volt battery to the boom and disconnect the battery from the circuit when I'm not using it.

### **How it works**

Time Difference of Arrival RDF sets work by switching your receiver between two antennas at a rapid rate. When both antennas are the same distance from the transmitter, the RF phase received by both antennas will be identical. If the two antennas are different distances from the transmitter the RF will have a different phase at each antenna. If we switch between the antennas 500 times a second, this phase change will be detected by an FM receiver as a 500 Hz tone.

By turning the antennas for a null in the tone, your two antennas will be perpendicular to the transmitter. Unfortunately, you can be facing the transmitter or facing away from the transmitter and get a null in the tone. This circuit does not give you the ability to know if you are facing the transmitter or facing away from it. You must use triangulation to determine the correct direction. Although I have not tried it, you may also add a switched phasing line to your unit as shown here. This will result in a non-symmetrical receive pattern and allow an indication of which direction to travel.

The best method to tell the front from the back when using a TDOA RDF unit is by using a T.D.O.A. with a synchronous detector and processing the phase of the tone. It is then possible to drive a center scale meter to indicate which direction to turn to face the transmitter.



## The Antenna Unit

Details of the antenna are shown below. The four antenna elements should be fashioned out of stiff wire or metal rods. One club member recycled a broken TV antenna and used 19 inch segments of its elements. The schematic shows two antennas; you might be wondering why there are four antenna elements. The extra two are connected to the coax shield at the ends of the boom. These form a counterpoise for the two active elements. I found that 15 inch lengths of wire "coat-hanger" worked well as antenna elements for the unit pictured here. You can experiment to determine the optimal length and distance between the dipole elements. (until you run out of wire hangers, that is)

The boom of the antenna must be less than  $1/2$  wavelength long. The longer the boom, ( up to  $1/2$  wavelength ) the more RF phase difference will be detected. I found that spacing the antennas about  $1/4$  wavelength apart gave the best results. Further apart resulted in more modulation but at the expense of portability. It also seemed a bit less sensitive to multipath errors when I used the shorter boom. The unit pictured here has a 15 inch long boom.

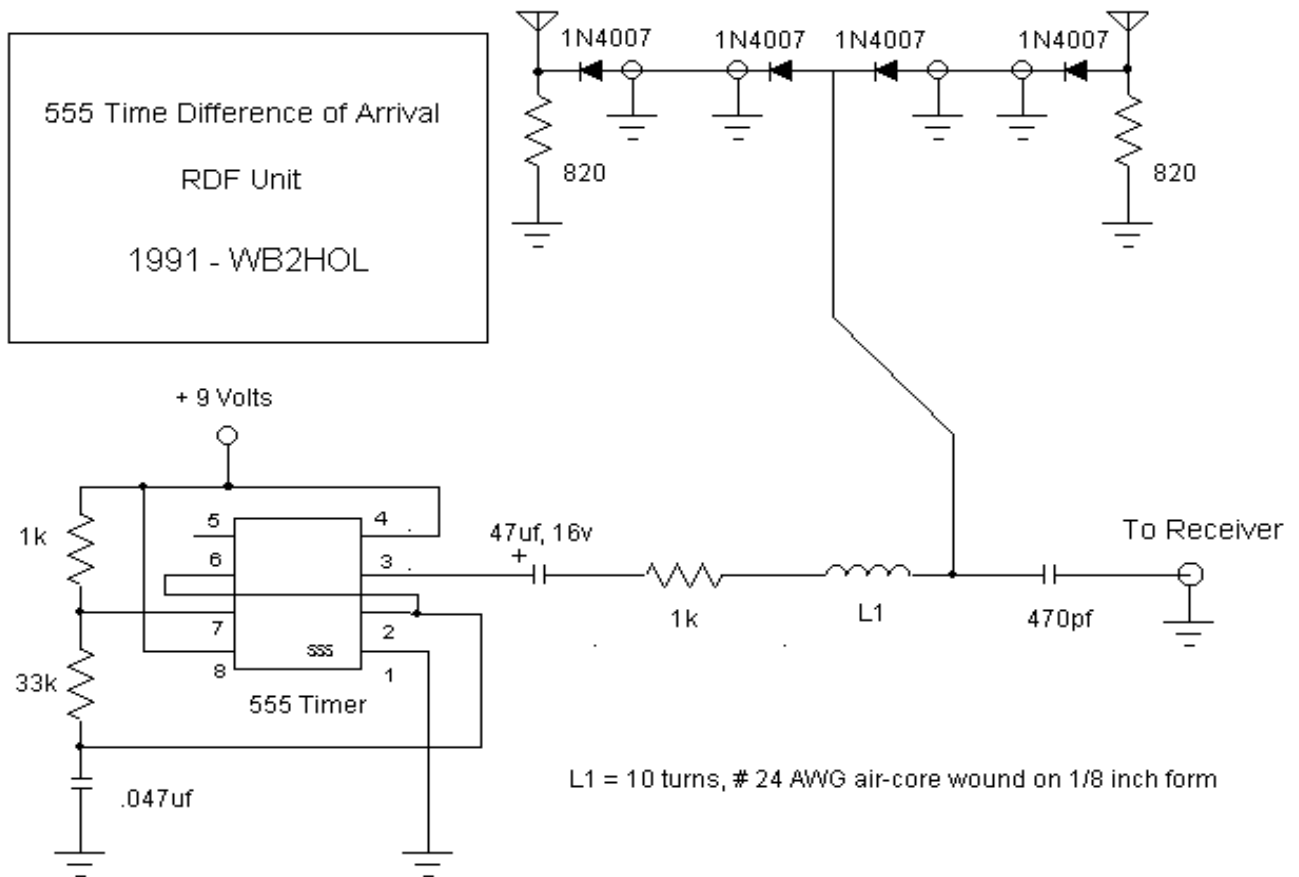
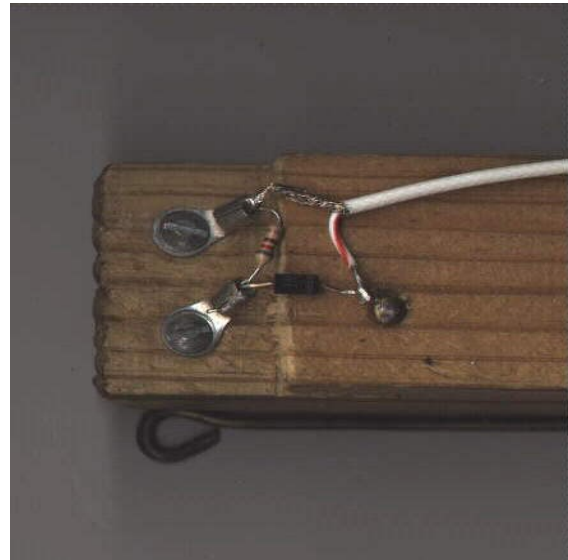
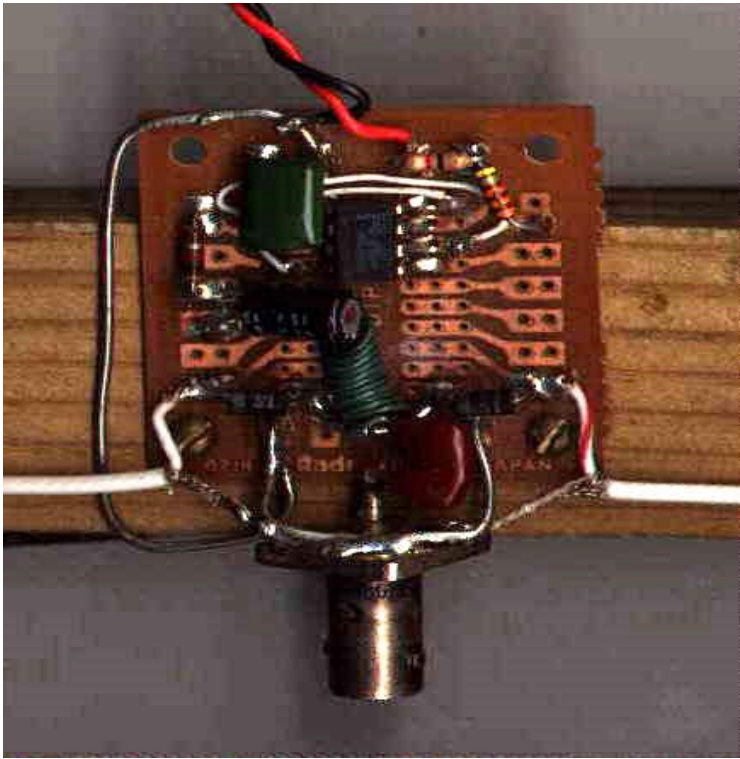
The antenna must be constructed as symmetrical as possible. The lengths of coax from the center circuit board must be identical. A difference of  $1/2$  inch will cause an error of several degrees. Note that the layout of the antenna switching diodes on the experimenters PC board is symmetrical.

I have found that by mounting the antenna on a mast so it is up and in the clear will result in the most accurate bearings.(It is then away from reflections from your body and the ground) Whatever you do, make the unit collapsible so it can be stored when not in use. I used wing-nuts on the antenna elements to allow the unit to fold easily.

It is very important that the diodes on the antenna be connected as shown on the schematic. Most diodes have a band which shows which end is the cathode. The best diodes for use in the antenna are RF PIN diodes. I used 1SS103 PIN diodes I purchased at a flea market. An equivalent diode is the MPN-3404. In a pinch, you can substitute a 1N4007 power diodes. They have a similar internal diode structure to the PIN diodes and will work almost as well. The MPN-3404 is advertised at Dan's small parts







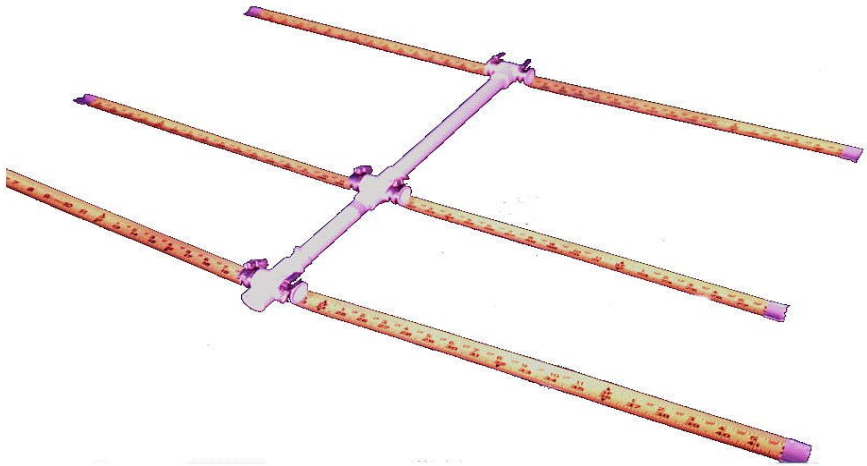
## TAPE MEASURE BEAM OPTIMIZED FOR RADIO DIRECTION FINDING

Joe Leggio WB2HOL

### Description

This antenna evolved during my search for a beam with a really great front-to-back ratio to use in hidden transmitter hunts. This design exhibits a very clean pattern and is perfect for RDF use. It trades a bit of forward gain in exchange for a very deep notch in the pattern toward the rear. (You could optimize the design for more forward gain, but at the expense of a really good notch in the pattern toward the rear.) It is a design that can be constructed using only simple hand tools (no machine shop needed) and still perform well. It has been duplicated several dozen times by other local hams and has been successfully used as a club construction project.

When I designed this antenna I had one basic idea in mind. It had to be easy to get in and out of the car when hunting for a hidden transmitter. This would be accomplished by the use of steel "tape measure" elements. These elements could fold easily when fitting the antenna into my car and yet still be self supporting. I decided to use three elements to keep the boom from getting too long.



Another of my design goals was to use materials that were easy to obtain. I chose to use Schedule-40

PVC pipe and fittings available at my local hardware store for the boom and element supports. These kept the cost for the antenna very low. The element supports consist of PVC crosses and tees.

Since I had never seen any plans for an antenna using elements made from 1 inch wide steel "tape measure," I had to do the design myself. To assist in the design I used a shareware computer aided yagi design program written by Paul McMahon VK3DIP. It allowed me to optimize the antenna for the cleanest pattern combined with the best front-to-back ratio.

Performance Predicted by YAGI-CAD	
GAIN	7.3 dBd
Front-to-Back Ratio	>50 db
3 db Beamwidth	E = 67.5 degrees
3 db Beamwidth	H = 110 degrees

When I first built this beam I found it needed a matching network of some kind to have a low SWR. My first attempt was a Gamma match. This was unwieldy. The driven element could barely handle the weight and the Gamma match itself was not very flexible. The best matching network turned out to be a "hairpin match." This is simply a 5 inch length of wire that is connected across the feed points of the driven element. The antenna has some capacitive reactance without the matching network. The 5 inch length of wire has just enough inductance to cancel the capacitive reactance. This resulted in a better match than anything else I had tried.

The wire I used for the hairpin match was enamel insulated 18 gauge solid. Other hams who have duplicated this beam have used just about anything they had on hand. 14 gauge house wire works well, so does a length of 22 gauge hookup wire. It does not seem to matter if it is stranded or solid, use whatever you have available. This results in a very good match across the two meter band once you have adjusted the distance between the halves of the driven element for minimum SWR. (1 inch apart on my prototype).

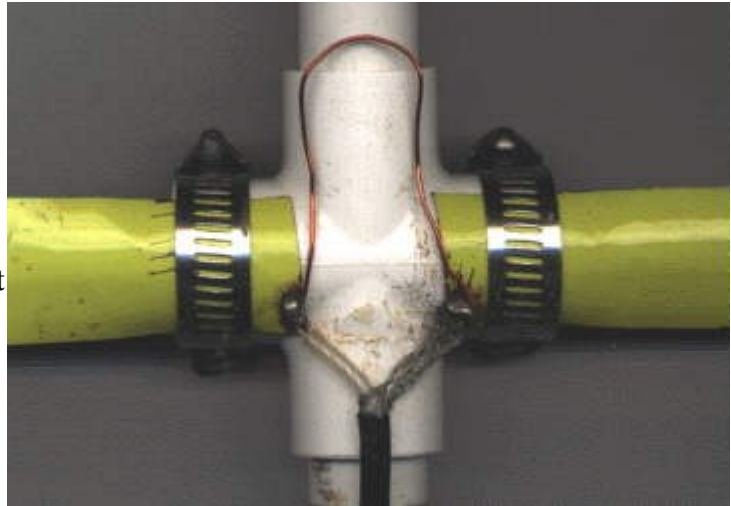
I used a pair of shears to cut the tape measure elements to length. An old pair of scissors will probably do as well. No matter how you cut the elements be very careful. Those edges are very sharp and will inflict a nasty cut if you are careless. Use some sandpaper to remove the really sharp edges and burrs resulting from cutting the elements to size. I put some vinyl electrical tape on the ends of the elements to protect myself from getting cut. I encourage you to do the same. It will probably be best if you round the corners of the elements once you cut them. Wear safety glasses while cutting the elements. Those bits of tape measure can be hazardous.

The RG58 coax feedline is connected directly to the driven element. No matter what method you use to attach the feedline, make sure you scrape or sand the paint off the tape measure element where the feedline is attached. Most tape measures have a very durable paint finish designed to stand up to heavy use. You do not want the paint to insulate your feedline connection.

If you are careful, It is possible to solder the feedline to the element halves. Care must be taken since the steel tape measure does not solder easily and since the PVC supports are easily melted. You might want to tin the tape measure elements before mounting them to the PVC cross.

If you decide not to solder to the tape measure elements, there are two other methods that have been used to attach the feedline. One method employs ring terminals on the end of the feedline. The ring terminals are then secured under self tapping screws which hold the driven element halves. This method does not allow you to tune the antenna by moving the halves of the driven element. 6-32 bolts and nuts could be used if holes are drilled in the elements near the ends. If the bolt heads are placed nearest the PVC fitting, you could secure ring-terminals with nuts and lock washers. Another possibility is to simply slide the ends of the feedline under the driven element hose clamps and tighten the clamps to hold the ends of the coax. I know this is low-tech, but it works just fine.

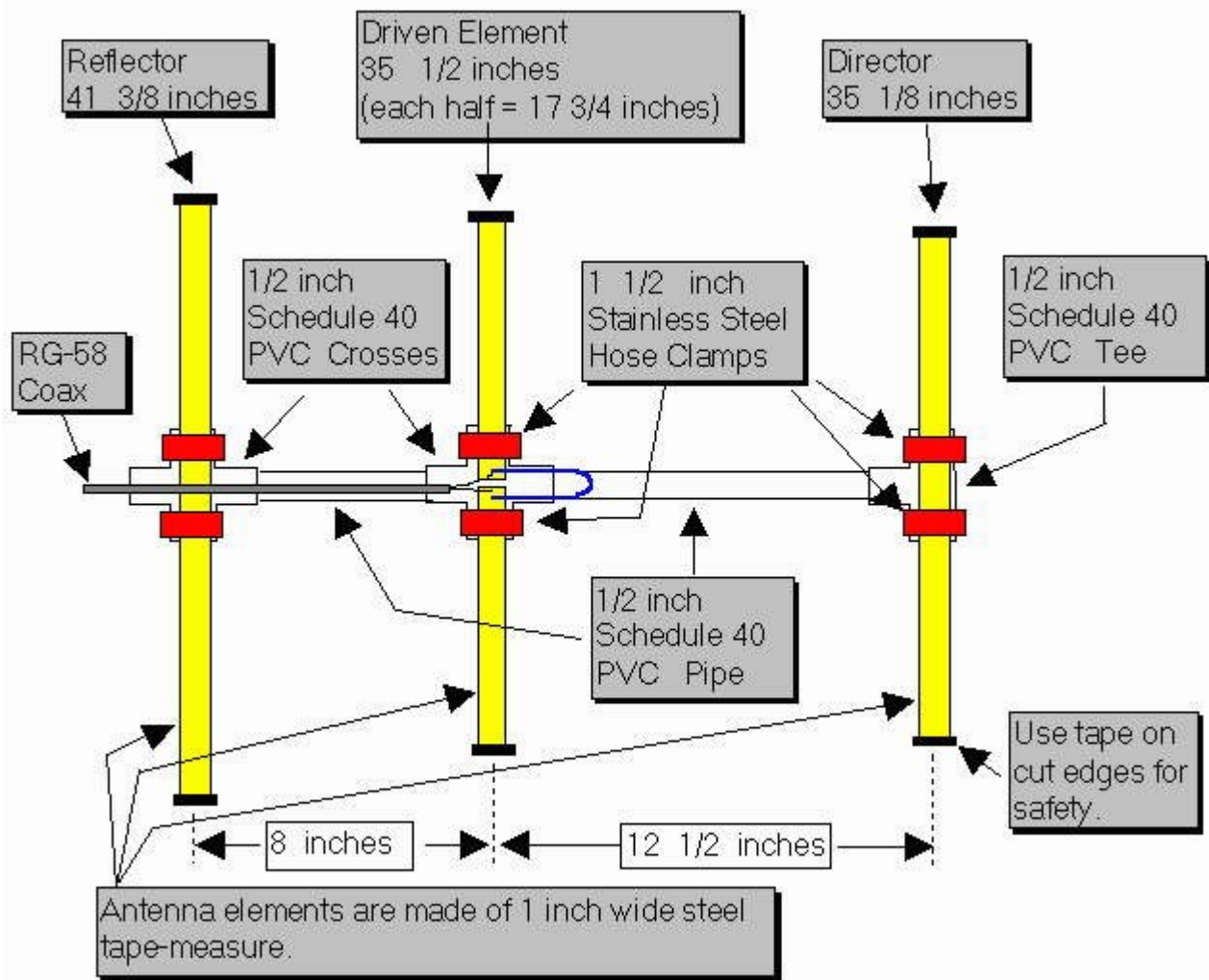
Stainless steel hose clamps are used to attach the driven element halves to the PVC cross which acts as its support. This has the added benefit of allowing you to fine tune your antenna for lowest SWR simply by loosening the hose clamps and sliding the halves of the driven element either closer or further apart. By using the dimensions specified, I found that the SWR was 1:1 at 146.565 Mhz (our Fox-Hunt frequency) when the two elements were spaced approximately 1 inch apart. Figure 1 shows the method used to attach the driven element to the PVC cross.



I used 1 1/2 inch hose clamps to attach all the elements on my prototype beam. Others who have duplicated my design have used self tapping screws to attach the elements to the PVC crosses and tees. Performance is the same using either method. The screws are much less expensive but they do not hold the elements as securely. If you do not use 1/2 inch PVC fittings but instead use 3/4 inch, make sure the hose clamps you buy are large enough to fit.

If you wish a slightly neater looking beam, use the self tapping screws. If you do not mind spending a few more dollars for the hose clamps, use them instead. If I were to build another beam I would use screws for the director and reflector, and hose clamps for the driven element. That would give me the best of both methods.

Rubber faucet washers have been used by some builders between the tape measure element and the PVC fittings on the director and reflector. These allow for the tape to fit the contour of the PVC fitting and will make the antenna look better. Now you know what to do with those washers left over from the assortment you once purchased; You know the ones I mean, the washers that do not fit the faucets you have in your house. If you are an apartment dweller, ask around, these things are stashed in almost every homeowners basement or garage.



## Construction:

Cut a length of tape measure to 41 3/8 inches. It will be the Reflector element. Cut two lengths of tape measure to 17 3/4 inches. These will be used for the Driven element. Cut one length of tape measure to 35 1/8 inches. It will be used for the Director. Once you have cut the tape measure to length, put vinyl tape on the cut ends to protect yourself from the sharp edges. You will want to scrape or sand off the paint from one end of each of the driven element halves so you can make a good electrical connection to the feedline.

If you are planning to solder the feedline to the driven elements it is best to tin the elements first before attaching them to the PVC cross. If you don't, the PVC will melt as you apply heat to the element. It would be a good idea to also take the time to form the wire used for the hairpin match into a "U" shape with the two legs of the "U" about 3/4 inch apart. Tin the ends of the hairpin if you plan on soldering it to the driven element. If you tin 1/4 inch of each end of the hairpin it will leave 4 1/2 inches to shape into the "U".

You will need to cut two lengths of PVC pipe to use as the boom. One should be cut to 11 1/2 inches. It is used to form the boom between the Director and the driven element. The other piece of PVC should be cut to 7 inches. It will be used between the Reflector and the Driven element. Just about any saw will cut through the soft PVC pipe. I used a hacksaw. When we mass produced this antenna as a club project, we marked the pipe and used a portable jig saw to cut the lengths in assembly line fashion. It took longer to measure the pipe than to actually make the cuts. Since the pipe is available in ten foot lengths, you can make a few beams from a single 10 foot length. In any case, you might want to cut a few extras lengths for your friends. They will want to duplicate this once they see your completed antenna.

At this time you can pre-assemble the PVC boom, crosses and tee which will support the tape measure elements. I did not use any cement or glue when I assembled mine. The PVC pipe is secured in the fittings with a friction fit.

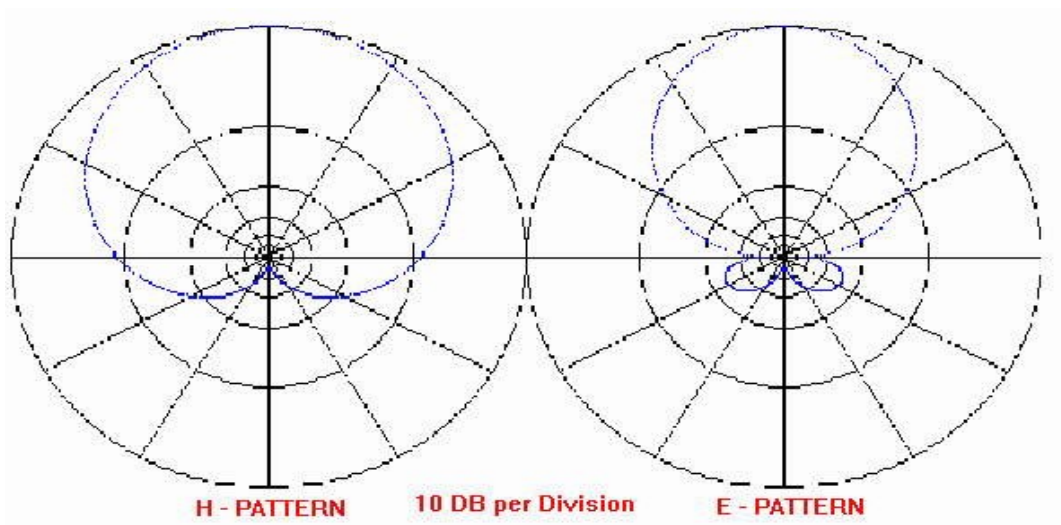
The hose clamps I used are stainless steel and have a worm-drive screw which is used to tighten them. They are about 1/2 inch wide and are adjustable from 11/16 inch to 1 1/2 inch diameter. Attach the tape measure elements to the PVC fittings as shown in the accompanying drawing. It is normal for the Reflector and Director elements to buckle a bit as it is tightened to the PVC Tee and Cross. You can eliminate this buckle if you use the washers and self tapping screws to attach these elements instead of the hose clamps. I do not think the beam will withstand as rough a treatment as when hose clamps are used.

## **How does it perform?**

Once you have completed your beam you probably will be interested to see if it performs as well as the computer predicted. The SWR should be less than 2:1 across the entire two meter band. The front-to-back ratio is predicted to be very good with the antenna exhibiting a very deep notch in its pattern towards the rear. The YagiCad 4.1 program produced these antenna pattern graphs showing the pattern you should expect. If you would like to experiment a bit with this program, the yagi specification file for this tape measure beam is available for download here. Simply download the YAGI-CAD program and put the tape measure beam design file in the same directory. You will then be able to experiment with the design.

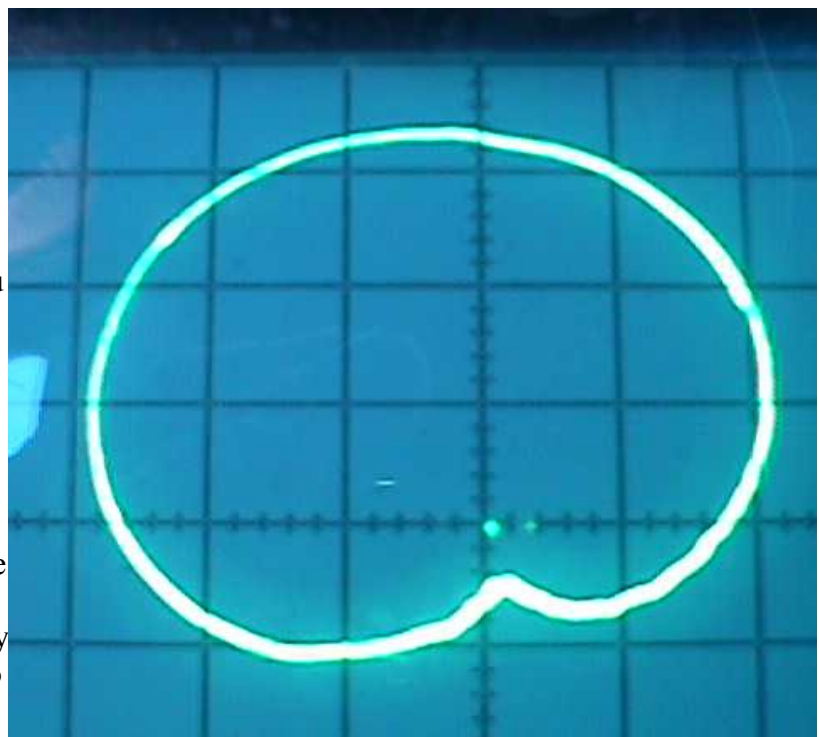
Note: under Windows95, only the first .yag file will show in the OPEN-FILE menu. You can either move all the other .yag files to a sub-directory or re-start the computer in MS-DOS mode. It works fine there. (I really do not know why this occurs but will blame Microsoft)





### How does the tape measure beam "measure up?"

WB4SUV and WA6EZV used a storage scope connected to a copy of this antenna constructed by KC8FQY and provided the following picture of the actual antenna pattern. I am very happy to see that the computer prediction of a clean pattern with a really great front-to-back ratio was accurate. What do you think?

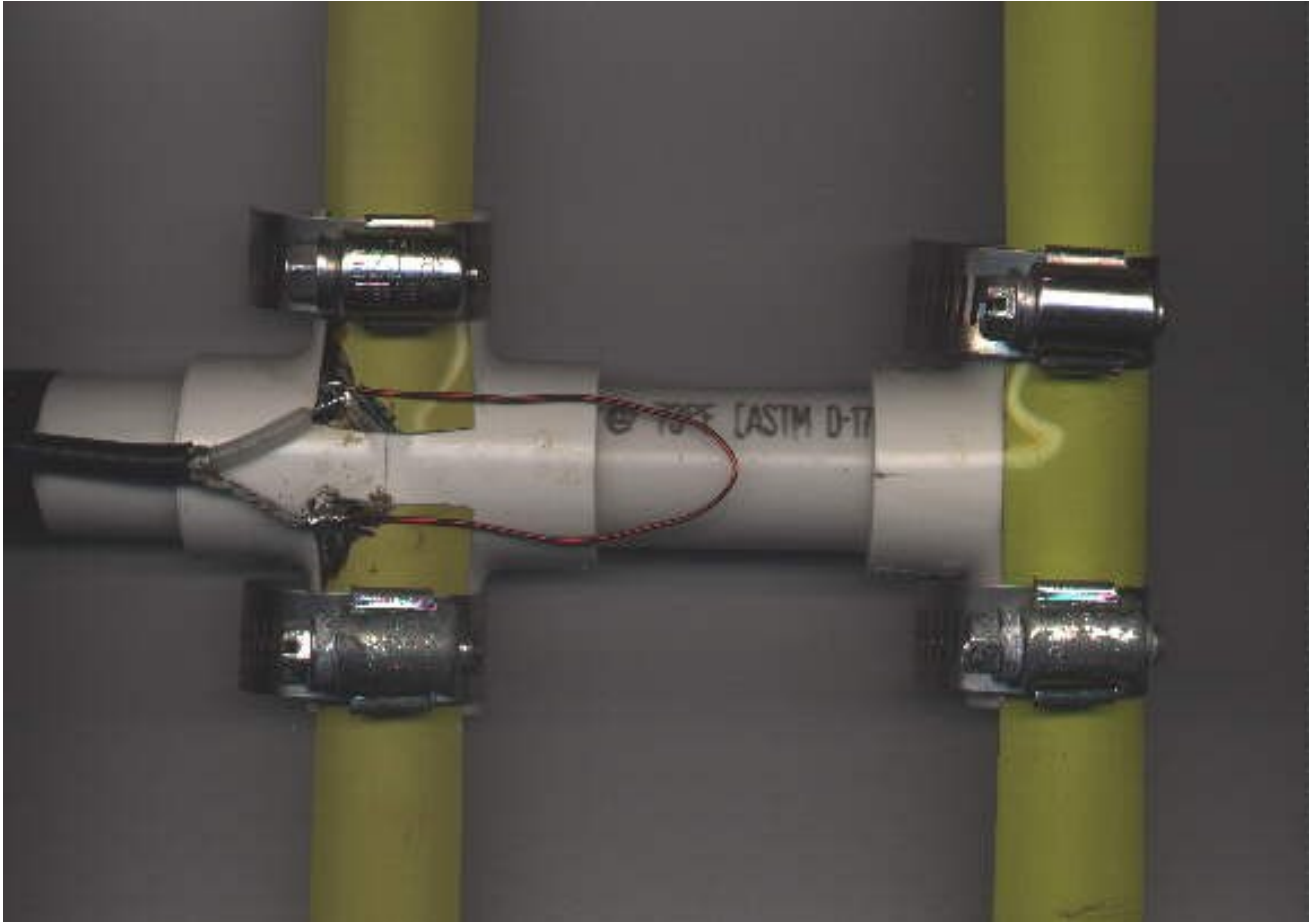


### Summary

This beam has been used on Fox-Hunts, on mountain tops, at local public service events, outdoors, indoors in attics, just about everywhere. The SWR is typically very close to 1:1 once adjusted. Front to back performance is exactly as predicted. The null in the rear of the pattern is perfect for transmitter hunts. When tested using a sensitive field strength meter and a low powered fox transmitter, full scale readings were seen from a distance of ten feet. With the same field strength meter I was able to point the antenna away from the transmitter and move the reflector element to within a few inches of the transmitter antenna and still not see a reading. I don't have the facilities to verify a 50 db notch as predicted by the Yagi-Cad software but It sure seems close. The flexible elements have taken a lot of abuse. My antenna has seen a lot of use and has held up quite well. Best of all, when on a fox-hunt, this beam is a breeze to get in or out of the car.

## RDF2 YAGI WITH TAPE MEASURE ELEMENTS

Joe Leggio WB2HOL



### Description

This antenna is an adaptation of the RDF2 two element, close spaced Yagi antenna described in the May, 1996 issue of 73 Amateur Radio Today Magazine.

The original design, developed by N6WZI and featured in the Homing In column of 73, used 1/4 inch solid aluminum rods for antenna elements. If you don't subscribe to 73, find someone who does and ask to see the original article.

My version of the RDF2 antenna uses 1 inch wide steel "tape measure" elements. This is one antenna you can take into the woods without having to worry about Yagi Eating Trees. The flexible elements also make it very easy to get this antenna in and out of the car.

You do not need a machine shop to build this antenna. You only need common hand tools. It is much easier to construct than the original design and can be assembled in about 30 minutes once you gather the needed parts.

Performance Predicted by ELNEC	
GAIN	4.7 dBi
Front-to-Back Ratio	>8 db
3 db Beamwidth	E = 36 degrees
3 db Beamwidth	H = 70 degrees

N6WZI's original design used a "hairpin" matching network made from a length of TV antenna twinlead. I made a similar "hairpin match" but instead used a 5 inch length of wire connected across the feed points of the driven element. The antenna has some capacitive reactance without the matching network. The 5 inch length of wire has just enough inductance to cancel the capacitive reactance.

The wire I used for the hairpin match was enamel insulated 18 gauge solid. This results in a very good match across the two meter band once you have adjusted the distance between the halves of the driven element for minimum SWR at the desired frequency. (3/16 inch apart on my prototype). Experience has shown that the wire gauge used for the hairpin match is not very critical. Use what you have on hand. 14 gauge house wire works well, probably any insulated wire which will hold its shape will work just fine.

I used a pair of shears to cut the tape measure elements to length. An old pair of scissors will probably do as well. No matter how you cut the elements be very careful. Those edges are very sharp and will inflict a nasty cut if you are careless. Use some sandpaper to remove the really sharp edges and burrs resulting from cutting the elements to size. I put some vinyl electrical tape on the ends of the elements to protect myself from getting cut. I encourage you to do the same. It will probably be best if you round the corners of the elements once you cut them. Wear safety glasses while cutting the elements. Those bits of tape measure can be hazardous.

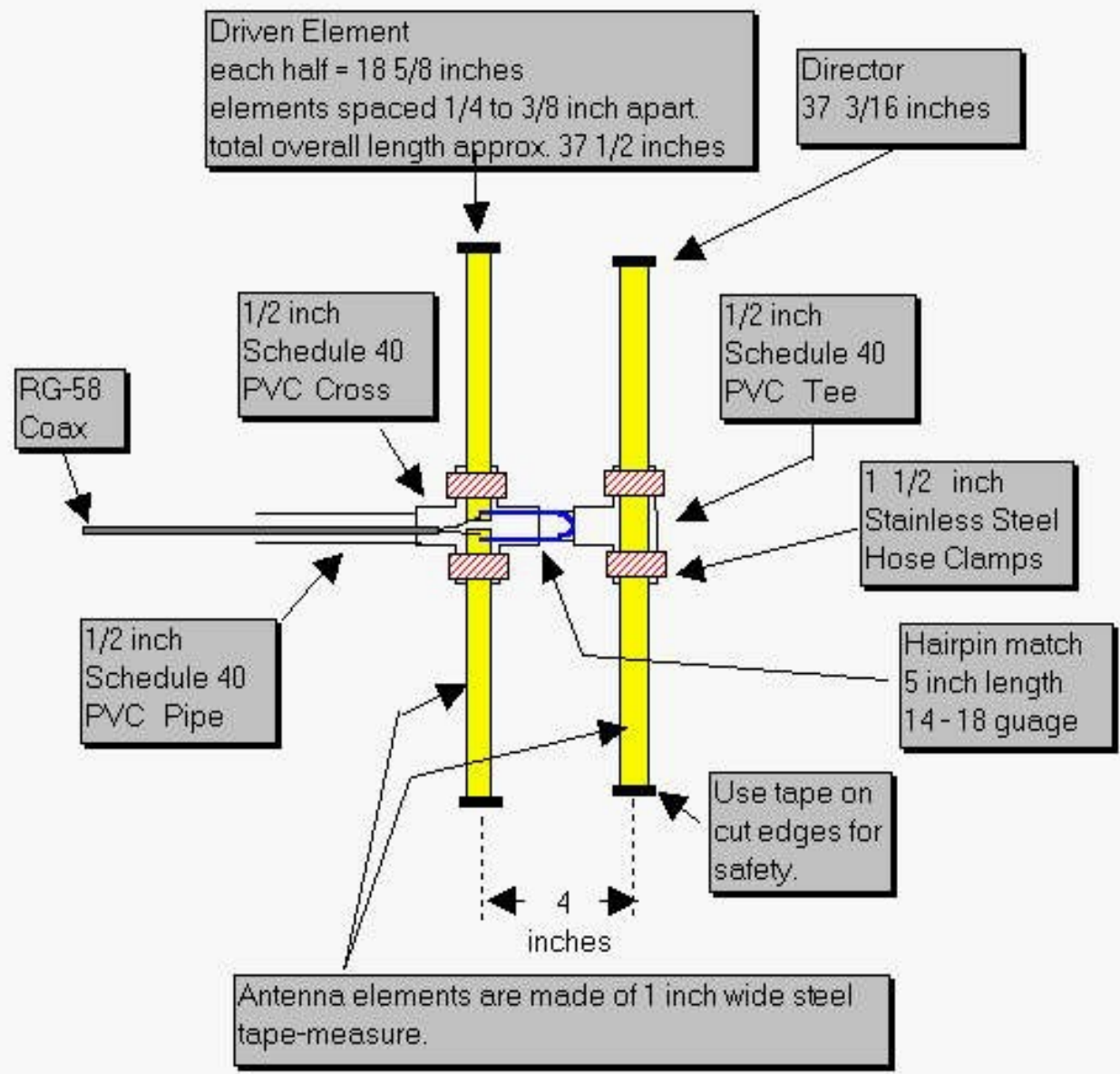
Replacement tape measure blades are available for reasonable prices at larger hardware stores. I found a 30 foot replacement blade at Sears for less than five dollars. If you use a replacement blade, be very careful when removing it from the package. The blade I purchased had a hard plastic cover which, when twisted, allowed access to the end of the replacement tape measure element. When you twist the cover, make sure you keep your fingers away from the "razor sharp" end of the blade. ( I probably could have assembled this antenna in even less time if I didn't have to go upstairs to the medicine chest to get a band-aid. This is experience speaking. The spring steel popped out, inflicting a nasty cut on my thumb. I'll probably heal in a week or so...)

The RG58 coax feedline is connected directly to the driven element. No matter what method you use to attach the feedline, make sure you scrape or sand the paint off the tape measure element where the feedline is attached. Most tape measures have a very durable paint finish designed to stand up to heavy use. You do not want the paint to insulate your feedline connection.

If you are careful, It is possible to solder the feedline to the element halves. Care must be taken since the steel tape measure does not solder easily and since the PVC supports are easily melted. You might want to tin the tape measure elements before mounting them to the PVC cross. I used a bit of rosin flux to help with tinning the element connection points.

## Two Meter Tape-Measure RDF<sup>2</sup> Beam

12/97 WB2HOL - adapted from N6WZI design



Stainless steel hose clamps are used to attach the driven element halves to the PVC cross which acts as its support. This has the added benefit of allowing you to fine tune your antenna for lowest SWR simply by loosening the hose clamps and sliding the halves of the driven element either closer or further apart. By using the dimensions specified, I found that the SWR was 1:1 at 146.565 Mhz (our Fox-Hunt frequency) when the two elements were spaced approximately 3/16 inch apart. Figure 1 shows the method used to attach the driven element to the PVC cross.

I used 1 1/2 inch hose clamps to attach all the elements on my prototype beam. if you do not use 1/2 inch PVC fittings but instead use 3/4 inch, make sure the hose clamps you buy are large enough to fit. Others who have duplicated my design have used self tapping screws to attach the elements to the PVC crosses and tees. Performance is the same using either method. The screws are much less expensive but they do not hold the elements as securely. In addition, the screws do not allow you to tune the antenna by sliding the halves of the driven element closer or further apart.

If you wish a slightly neater looking beam, use the self tapping screws. If you do not mind spending a few more dollars for the hose clamps, use them instead. If I were to build another beam I would use screws for the director, and hose clamps for the driven element. That would give me the best of both methods.

## **Construction:**

Cut two lengths of tape measure to 18 5/8 inches. These will be used for the Driven element. Cut one length of tape measure to 37 3/16 inches. It will be used for the Director. Once you have cut the tape measure to length, put vinyl tape on the cut ends to protect yourself from the sharp edges. You will want to scrape or sand off the paint from one end of each of the driven element halves so you can make a good electrical connection to the feedline.

It is best to tin the elements first before attaching them to the PVC cross. If you don't, the PVC will melt as you apply heat to the element. It would be a good idea to also take the time to form the wire used for the hairpin match into a "U" shape with the two legs of the "U" about 3/4 inch apart. Tin the ends of the hairpin to make it easier when soldering it to the driven element halves. If you tin 1/4 inch of each end of the hairpin it will leave 4 1/2 inches to shape into the "U".

You will need to cut two lengths of PVC pipe. One should be cut to 3 inches. It is used to form the boom between the Director and the driven element. The other piece of PVC should be cut to 6 1/2 inches. It will be used as a handle so you can hold the antenna from the rear. Just about any saw will cut through the soft PVC pipe. I used a hacksaw. Since the pipe is available in ten foot lengths, you can make a few beams from a single 10 foot length. In any case, you might want to cut a few extras lengths for your friends. They will want to duplicate this once they see your completed antenna.

At this time you can pre-assemble the PVC boom, cross and tee which will support the tape measure elements. I did not use any cement or glue when I assembled mine. The PVC pipe is secured in the fittings with a friction fit. When assembled, the cross and tee will be 4 inches from center to center.

The hose clamps I used are stainless steel and have a worm-drive screw which is used to tighten them. They are about 1/2 inch wide and are adjustable from 11/16 inch to 1 1/2 inch diameter. Attach the tape measure elements to the PVC fittings as shown in the accompanying drawing. It is normal for the Director element to buckle a bit as it is tightened to the PVC Tee. You can eliminate this buckle if you use washers and self tapping screws to attach this element instead of the hose clamps but I do not think the beam will withstand as rough a treatment as when hose clamps are used.

## **How does it perform?**

Once you have completed your beam you probably will be interested to see if it performs as well as the computer predicted. My prototype antenna does seem to have a pretty good front-to-back ratio. It is real easy to get a peak on the "S" meter. It does not hear cross polarized signals very well. This is an advantage as most reflections will not have the same polarization as the original transmitter. Gain seems to be between 3 to 5 dB less than the three element RDF beam I designed. This is probably an advantage when close to the transmitter. You will need a bit less attenuation. The short boom and light weight make this antenna attractive if you have to use it for any length of time. It is light enough for youngsters to carry without tiring. As long as you put vinyl tape on the ends of the elements, this antenna is pretty safe to carry. Descriptions of the N6WZI RDF2 Yagi performance when used on a foxhunt may be found at Jim Elmore's site.

## **Drawbacks**

The curved, airfoil shaped, flexible elements will "flutter" and bend when in high wind situations. (Mobile flutter while stationary?) If you need additional support, you can add short lengths of PVC pipe to the TEE and CROSS and then tape the elements to the PVC pipe. I figure 6 to 12 inches of PVC would add lots of strength to the elements. The short boom does result in less gain than a more conventional Yagi. You may need more gain when starting on a foxhunt and still far from the fox transmitter.



## THE FOX - 40 milliwatt transmitter

Joe Leggio WB2HOL

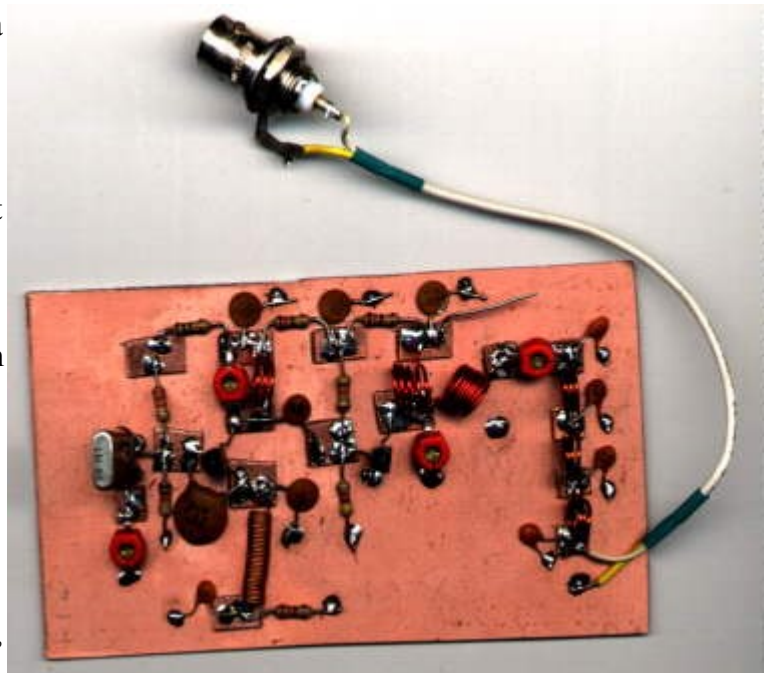
This two transistor 144 MHz transmitter uses a 48 MHz scanner crystal as an oscillator / tripler. A second transistor boosts the power output to 40 milliwatts. A 7-element filter is used to minimize output on the third harmonic. (I did not want it to be easy to RDF this on the 450 MHz third harmonic)

The scanner crystal I used was actually for a receive frequency 10.7 MHz higher than the two meter transmitter output. It was marked 156.21 MHz. (When you subtract the 10.7 MHz IF offset, it resulted in a transmit frequency of 145.51. Since this circuit is not the exact same circuit as the scanner, you may find that the crystal oscillates somewhere close to the marked frequency. The crystal marked as 156.21 MHz I used in this transmitter actually resulted in a signal on 145.53 MHz. )

I did get the salesperson at the local Radio Shack store a bit confused when I asked to look at his box of scanner crystals. The first thing he asked was which service I was trying to listen to... Police, Fire, Ambulance, etc.... When I said that I was looking for something for a homemade project and did not have a specific frequency in mind he understood. I did not try to tell him the crystal was to be used in a transmitter. He probably would have told me that I can't use a "receiver" crystal for a "transmitter."

As I looked at the available crystal selections, I simply took my calculator and subtracted 10.7 MHz from the marked receive frequency. I was lucky; several crystals ended up in places on the two meter band where a fox could transmit without interfering with other users. If you are not lucky, or live in an area where you must put your fox on a specific frequency, you can order a crystal through Radio Shack. Since there are still quite a few crystal controlled scanners out there, the odds are that someone in your town will have something you can use. Be aware, although most scanners use a 10.7 MHz IF, there are some with a 10.8 MHz IF. In that case, you may end up 100 kHz from where you expected.

You will need to wind several coils to build this transmitter. They are all self-supporting air-core coils made from enamel covered wire. If you follow the instructions illustrated here, you should not have any difficulty. The top of my workbench is littered with coils I have wound and tried in various circuits. I specifically avoided tapped coils or multi-winding coils to keep construction as easy as possible.



I use a simple diode detector across a 50-ohm dummy load to measure the power output while tuning up this transmitter. It is reasonably stable. It does not have a tendency to break into spurious oscillations. I did try about 5 or 6 different prototype circuits as I designed this transmitter; many were not stable. Their RF output did not smoothly change as the trimmer capacitors were adjusted but instead jumped as spurious oscillations occurred. I used an oscilloscope to monitor the output waveform and confirm the lack of spurious oscillations. This is not really necessary as you can usually hear the instability if you monitor the output signal with your 2-meter rig.

## Style of PC board construction

I built all of the transmitters using copper clad PC board as a ground plane and 1/4 inch squares of PC board as tie points. The tie points were cemented to the ground plane using "crazy-glue." This technique made constructing the transmitter go very fast. It only took a drop of glue to secure the tie points. The glue set up in seconds. It made it easy to experiment with different circuits. In a pinch, a tie point could be removed or relocated by prying upward on its side with a screwdriver. I built three transmitters using this style of construction in the past month. All have worked exactly as expected. I used a pair of shears to cut a number of 1/4 inch squares of PC board material. I then used a wide file to remove any burrs created by the shear. This allowed the square of PC board material to lay flat against the PC ground plane. (Crazy-glue is not designed to fill voids. It works best when the surfaces to be glued fit together well) Be careful as you work with "crazy-glue." It is very effective at gluing fingers together.

I tried to use parts that could be obtained with little difficulty. You will need to wind several coils. I also kept these as simple as possible. The wire I used was recycled from old transformers.



*Tie-points are made from 1/4 inch squares of PC board material glued with "crazy-glue" to a solid ground plane of PC board.*

## Winding the Coils



*Enamel wire is close-wound on a drill bit to form the coils for this transmitter. It is easier to cut the leads to the coil and strip the enamel from the ends prior to removing the coil from the drillbit used as the form.*

All the coils are wound in a single layer using a drill bit as a winding form. To help you visualize how to form the coils, I have included an illustration showing how the coils are wound..

All of the coils are "close wound" with "air cores." I used a drill bit as a form and then slipped the coil off of the bit after I had cut the free ends to about 1/4 inch. I used a hobby knife to scrape the enamel paint from the ends of the wire before I removed the coil from the drill bit used as a form. This made the coils easy to solder. With any luck, you too will be able to wind your own coils for this project.

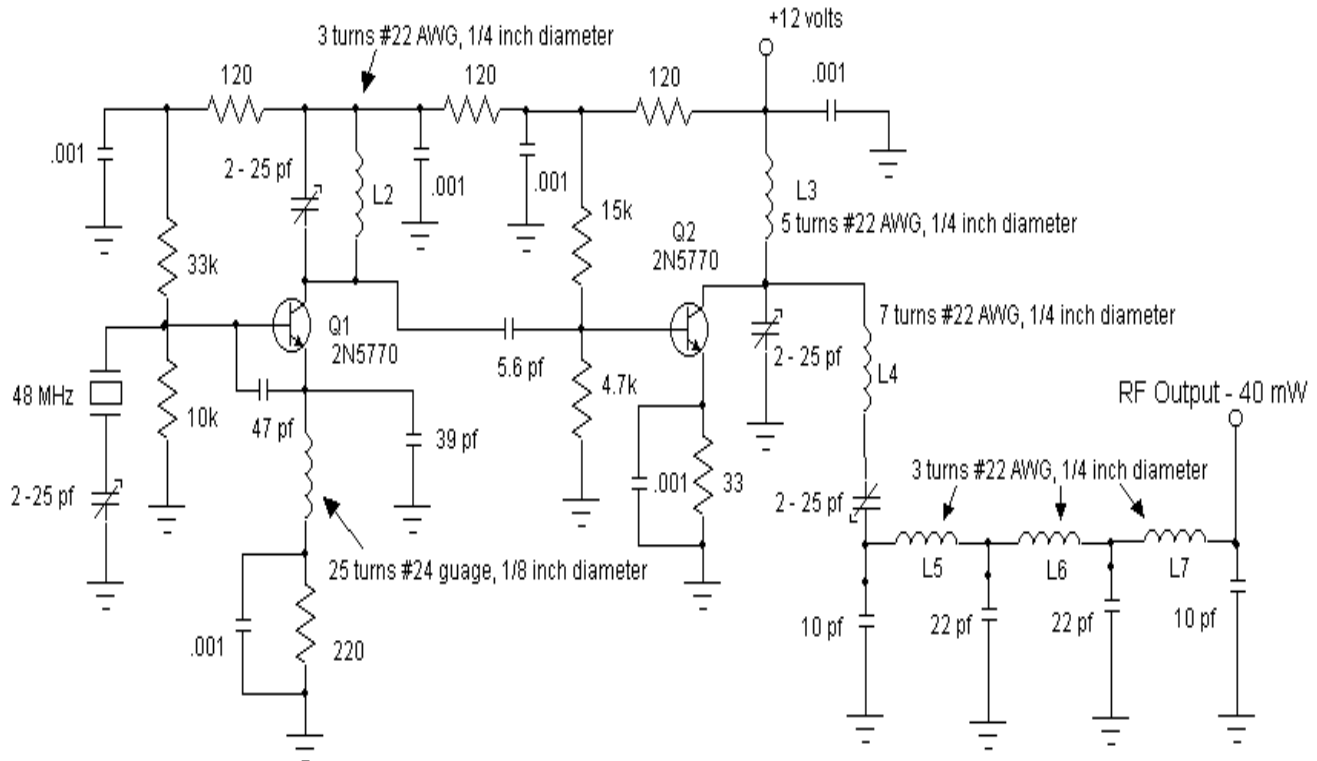
Two different gauges of enamel covered wire are used for the coils in this project. If you have wire reclaimed from an old transformer, or from an old television deflection yoke, you can determine its gauge by winding a single layer on a drill bit. You will be able to fit about 46 turns per inch if the wire is 24 gauge. You will be able to fit about 37 turns per inch if the wire is 22 gauge. If you can't find an old transformer with the correct gauge wire to recycle, the best places I have found to buy enamel covered wire are shops which specialize in rewinding electric motors. In a pinch, if you live in the USA, Radio Shack sells "magnet wire" in both 24 and 22 gauge. You will only need a few feet of each gauge wire for this project.

I used the same transistor for both the oscillator and the amplifier stage. It is important that the transistors you use in your transmitter have sufficient gain at 2 meters. The 2N5770 is one of many I could have used. Please note: a 2N3904 would probably work fine as the oscillator (at 48 MHz), it would not work well as the amplifier as it does not work well at 144 MHz.

The tune-up of this transmitter is easy. Simply adjust each of the trimmer capacitors for maximum RF output to the antenna. (The trimmer in series with the crystal is the only exception, it is used to trim the transmitter frequency, use a frequency counter to adjust it)

I packaged one version of this transmitter in a very well shielded cast aluminum box and powered it with a 9 volt battery. The output power was reduced at the lower voltage to about 25 milliwatts. Even at that power level, it can be heard for miles. As an experiment, I tried voltages as low as 5 volts. The power output was down to below 10 milliwatts but the transmitter stayed on the air! This design works well even as the battery gets weak.

### Schematic

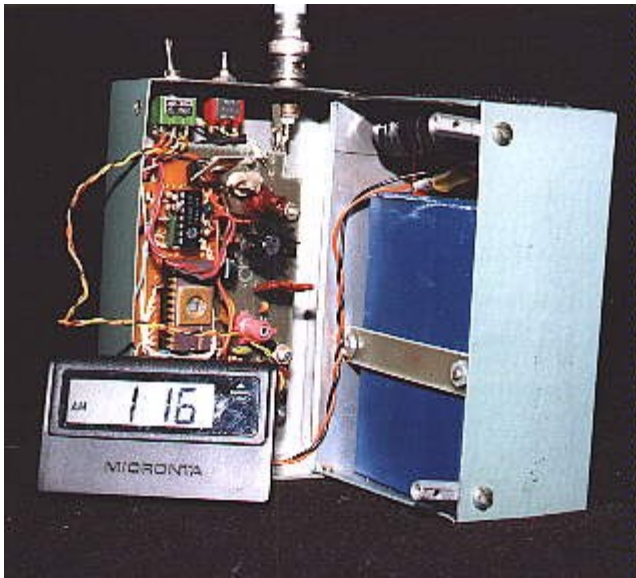


**2 Meter - 40 mW FOX TRANSMITTER - 4/98 WB2HOL**

## THE FOX - 250mw transmitter with TIMER

Joe Leggio WB2HOL

This FOX transmitter is equipped with a timer. It can be set to start transmitting up to 24 hours later.



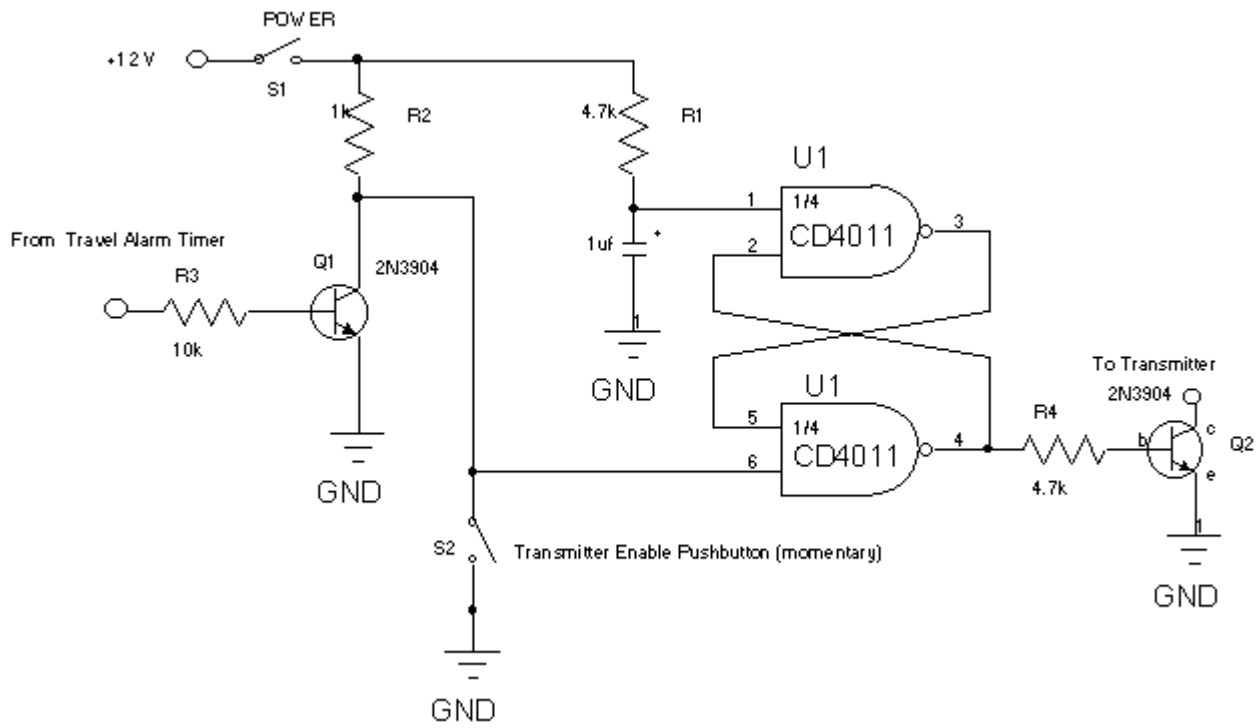
The timer consists of a Radio Shack travel alarm. I disconnected the piezo-ceramic beeper and used the signal to set a flip-flop built from a CMOS 4011. The output of the flip flop is connected to a switching transistor which supplies voltage to the CW ID. I used an R/C combination on the flip/flop so it would be reset when first powered up. A push button is provided so the flip/flop can be set manually (turning on the transmitter)

The transmitter consists of three stages: a 45 MHz oscillator, a tripler, and a "power" amplifier. I know the heat sink on the final is a bit of overkill at 250 milliwatts output. I used a 6 volt gell cell for power. This thing can go for days.

The CW ID consists of a CMOS 4011 clock and a CMOS 4020 binary counter connected to a 2k EPROM. One bit on the EPROM is used for the CW ID, a second is used to control the switching transistor which supplies power to the transmitter oscillator. It is set up to transmit once every few minutes and stay on the air for about one minute.

Normally, the travel alarm timer is attached to the outside of the 3x5 file card box with velcro. This makes it easy to change the clock battery when needed.

A word of advice. Do not try to take a device like this through the security gate at an airport. It looks too much like something you would see in a "Die Hard" movie. Please make sure it is plainly labeled as an Amateur Radio Transmitter Location Device (or some other official title) and put your name and address on it in case it is discovered by someone not familiar with fox hunting. They \*might\* think the FOX looks suspicious and call officials to investigate. (You might want to notify officials in advance about your FOX-HUNT. We usually do just to eliminate problems when neighbors call in reporting \*strange\* people in the neighborhood)

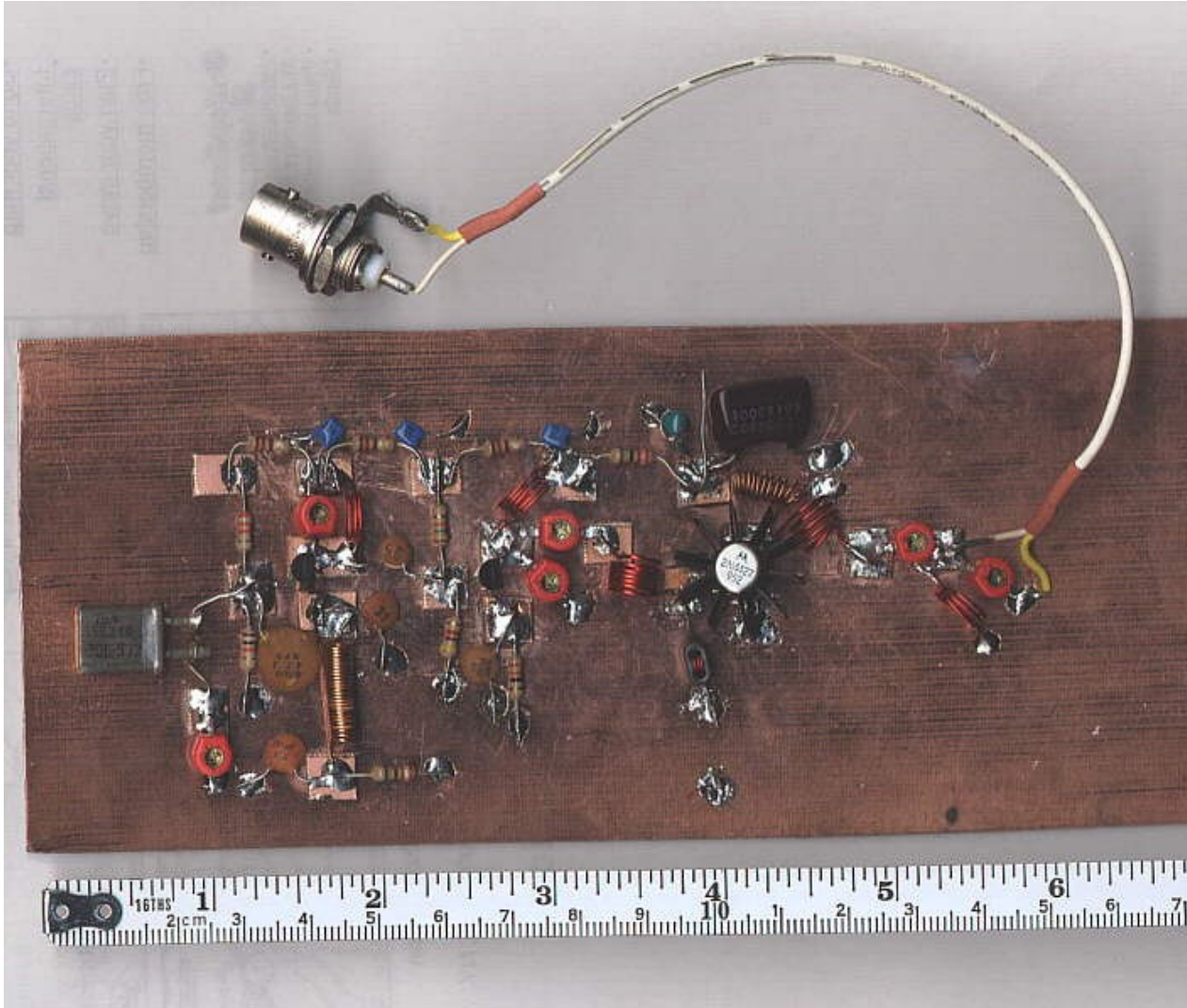




## THE FOX750 - 750 milliwatt transmitter

Joe Leggio WB2HOL

This three transistor 144 MHz transmitter uses a 48 MHz scanner crystal as an oscillator / tripler. A second transistor boosts the signal to 40 milliwatts, a third amplifies the power output to 750 milliwatts.



The scanner crystal I used was actually for a receive frequency 10.7 MHz higher than the two meter transmitter output. It was marked 156.21 MHz. (When you subtract the 10.7 MHz IF offset, it resulted in a transmit frequency of 145.51. Since this circuit is not the exact same circuit as the scanner, you may find that the crystal oscillates somewhere close to the marked frequency. The crystal marked as 156.21 MHz I used in this transmitter actually resulted in a signal on 145.53 MHz. )

I did get the salesperson at the local Radio Shack store a bit confused when I asked to look at his box of scanner crystals. The first thing he asked was which service I was trying to listen to... Police, Fire, Ambulance, etc.... When I said that I was looking for something for a homemade project and did not have a specific frequency in mind he understood. I did not try to tell him the crystal was to be used in a transmitter. He probably would have told me that I can't use a "receiver" crystal for a "transmitter."

As I looked at the available crystal selections, I simply took my calculator and subtracted 10.7 MHz from the marked receive frequency. I was lucky; several crystals ended up in places on the two meter band where a fox could transmit without interfering with other users. If you are not lucky, or live in an area where you must put your fox on a specific frequency, you can order a crystal through Radio Shack. Since there are still quite a few crystal controlled scanners out there, the odds are that someone in your town will have something you can use. Be aware, although most scanners use a 10.7 MHz IF, there are some with a 10.8 MHz IF. In that case, you may end up 100 kHz from where you expected.

You will need to wind several coils to build this transmitter. They are all self-supporting air-core coils made from enamel covered wire. If you follow the instructions illustrated here, you should not have any difficulty. The top of my workbench is littered with coils I have wound and tried in various circuits. I specifically avoided tapped coils or multi-winding coils to keep construction as easy as possible.

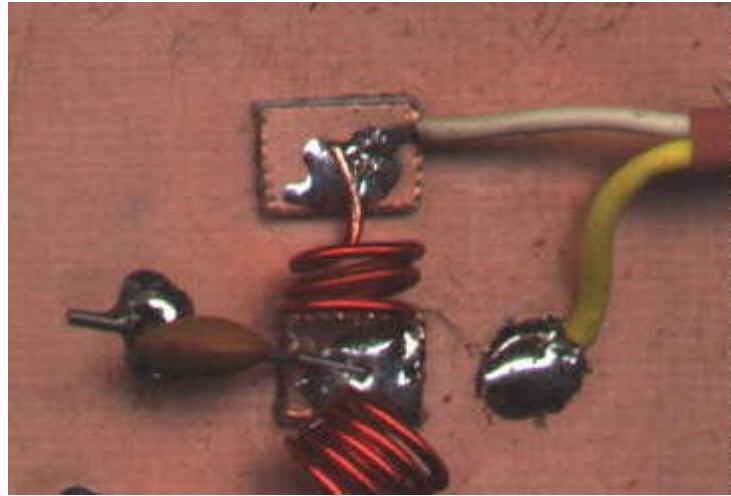
I use a simple diode detector across a 50-ohm dummy load to measure the power output while tuning up this transmitter. I did try about 5 or 6 different prototype circuits as I designed this transmitter; many were not stable. Their RF output did not smoothly change as the trimmer capacitors were adjusted but instead jumped as spurious oscillations occurred. This design is reasonably stable. It does not have a tendency to break into spurious oscillations. I used an oscilloscope to monitor the output waveform and confirm the lack of spurious oscillations. This is not really necessary as you can usually hear the instability if you monitor the output signal with your 2-meter rig.

## Style of PC board construction

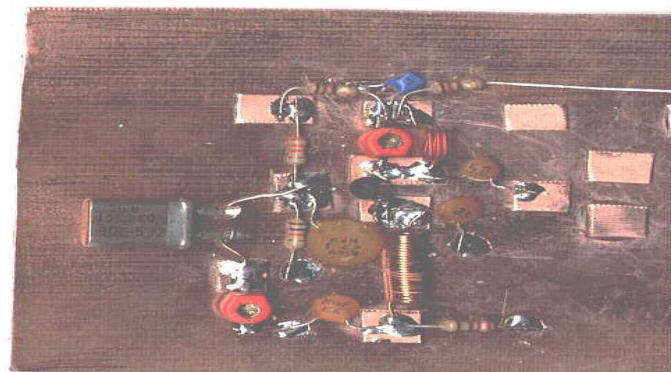
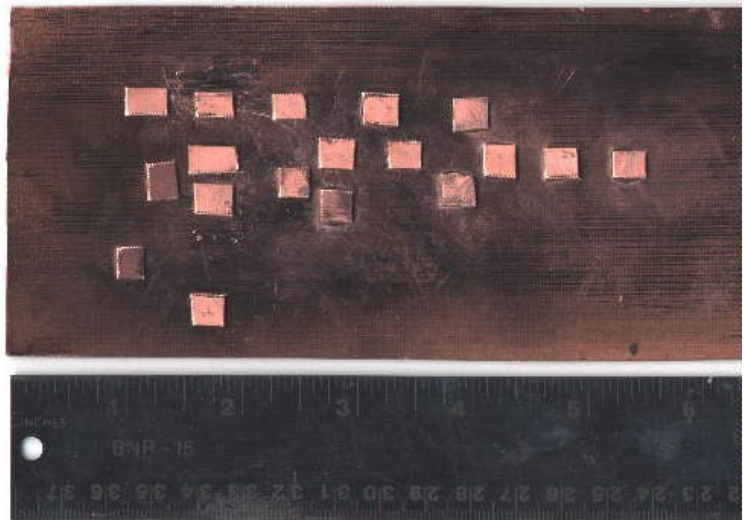
I built all of the transmitters using copper clad PC board as a ground plane and 1/4 inch squares of PC board as tie points. The tie points were cemented to the ground plane using "crazy-glue." This technique made constructing the transmitter go very fast. It only took a drop of glue to secure the tie points. The glue set up in seconds. It made it easy to experiment with different circuits. In a pinch, a tie point could be removed or relocated by prying upward on its side with a screwdriver. I built three transmitters using this style of construction in the past month. All have worked exactly as expected. I used a pair of shears to cut a number of 1/4 inch squares of PC board material. I then used a wide file to remove any burrs created by the shear. This allowed the square of PC board material to lay flat against the PC ground plane. (Crazy-glue is not designed to fill voids. It works best when the surfaces to be glued fit together well) Be careful as you work with "crazy-glue." It is very effective at gluing fingers together.

As I had already constructed several low power versions of this transmitter, I first glued squares of PC board material for the first two stages to the PC board ground plane. I then proceeded to add the components. I saved the output stage for last as I had not yet decided upon the interstage and output coupling circuit design. The design I finally used was a combination of several from the ARRL handbook. I tried to use parts that could be obtained with little difficulty.

Construction is under way. The oscillator stage was constructed first and tested before proceeding.



*Tie-points are made from 1/4 inch squares of PC board material glued with "crazy-glue" to a solid ground plane of PC board.*





## Winding Coils

You will need to wind several coils. I kept these as simple as possible. The wire I used was recycled from old transformers. All the coils are wound in a single layer using a drill bit as a winding form. To help you



*Enamel wire is close-wound on a drill bit to form the coils for this transmitter. It is easier to cut the leads to the coil and strip the enamel from the ends prior to removing the coil from the drillbit used as the form. Winding the Coils*

visualize how to form the coils, I have included an illustration showing how the coils are wound..

All of the coils are "close wound" with "air cores." I used a drill bit as a form and then slipped the coil off of the bit after I had cut the free ends to about 1/4 inch. I used a hobby knife to scrape the enamel paint from the ends of the wire before I removed the coil from the drill bit used as a form. This made the coils easy to solder. With any luck, you too will be able to wind your own coils for this project.

Two different gauges of enamel covered wire are used for the coils in this project. If you have wire reclaimed from an old transformer, or from an old television deflection yoke, you can determine its gauge by winding a single layer on a drill bit. You will be able to fit about 46 turns per inch if the wire is 24 gauge. You will be able to fit about 37 turns per inch if the wire is 22 gauge. If you can't find an old transformer with the correct gauge wire to recycle, the best places I have found to buy enamel covered wire are shops which specialize in rewinding electric motors. In a pinch, if you live in the USA, Radio Shack sells "magnet wire" in both 24 and 22 gauge. You will only need a few feet of each gauge wire for this project.

I used the same transistor for both the oscillator and the amplifier stage. It is important that the transistors you use in your transmitter have sufficient gain at 2 meters. The 2N5770 is one of many I could have used. Please note: a 2N3904 would probably work fine as the oscillator (at 48 MHz), it would not work well as the amplifier as it does not work well at 144 MHz.

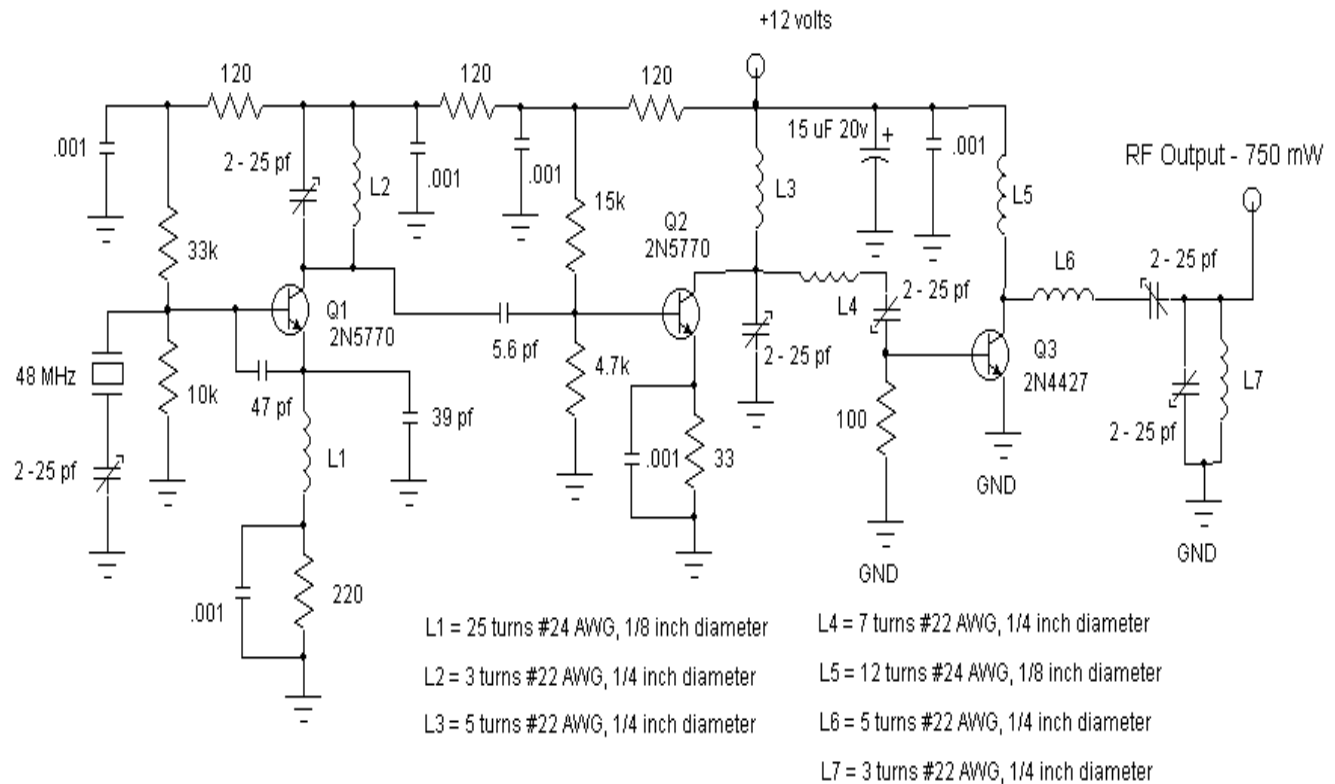
You will need to use a heat-sink on the output transistor. I used a small press-on style. I gets warm to the touch after transmitting for a few minutes. If it gets very hot, you probably have something mis-tuned or the circuit is oscillating on it own. If you follow the layout shown, you probably will not have any difficulty. If you try a different layout, be sure to keep the input and output coils of the various stages away from each other. It is too easy to create an accidental feedback path. If this occurs, the transmitter will be very unstable and almost impossible to tame. If you are experienced with VHF design, you may want to try winding the coils in toriod coil forms. Because toriods are self-shielding, you may be able to try other layouts without as much concern towards stability. Obviously, if you do this, you will have to determine the number of turns needed for the toriods. A grid dip meter would be helpful in that case.

When building the output stage, I realized that I needed to bend the base lead of the output transistor between the emitter and collector in order to install it properly. Although it did not affect performance, it did make soldering the transistor to the PC board pads a bit more difficult. If I build another version of this transmitter, I will lay out the board a bit differently so the transistor will fit better to the pads.

The tune-up of this transmitter is easy. Simply adjust each of the trimmer capacitors for maximum RF output to the antenna. (The trimmer in series with the crystal is the only exception, it is used to trim the transmitter frequency, use a frequency counter to adjust it)

Power output was between 750 milliwatts and 900 milliwatts. I will probably add a three terminal voltage regulator so I can vary the output power for any specific hunt. As an experiment, I tried voltages as low as 5 volts. The power output was down to 100 milliwatts but the transmitter stayed on the air! This design works well even as the battery gets weak.

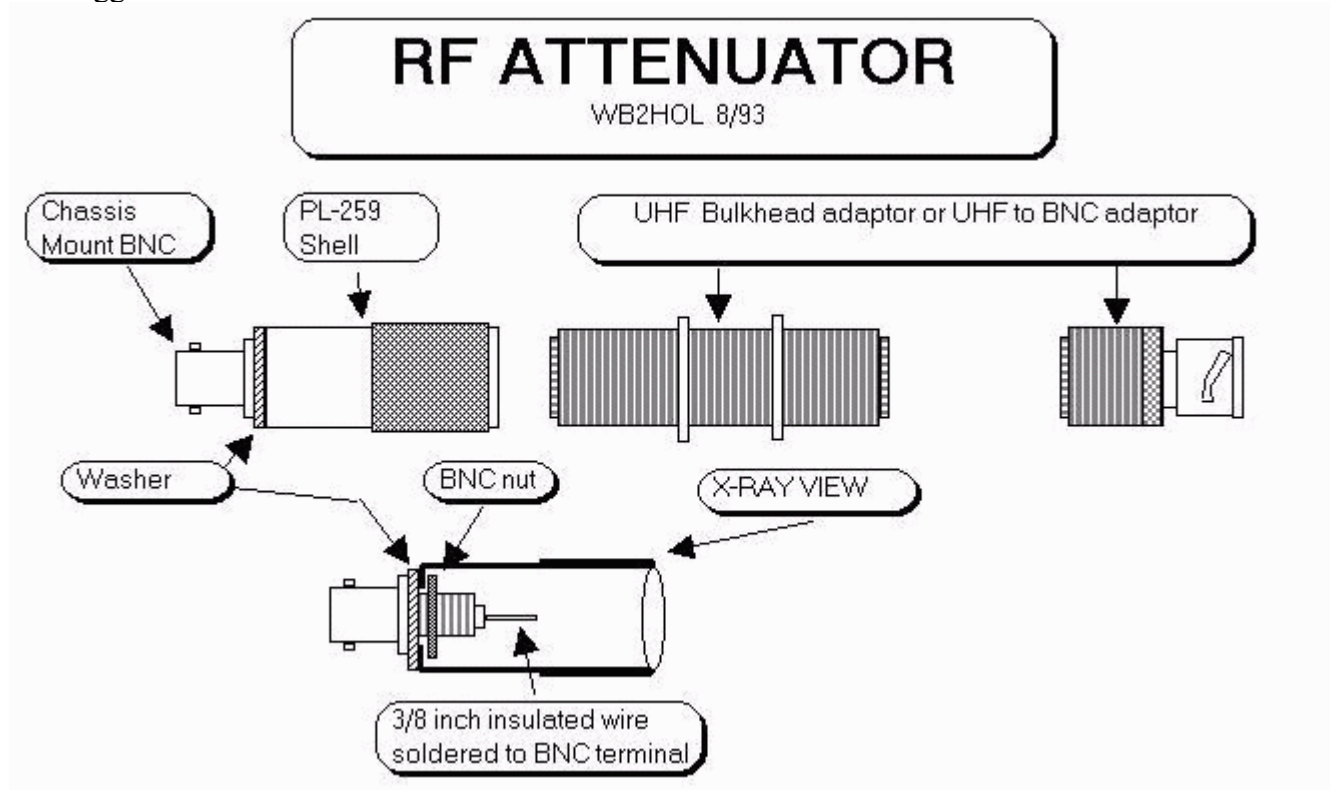
### Schematic



**2 Meter - 750 mW FOX TRANSMITTER - 4/98 WB2HOL**

## SIMPLE ADJUSTABLE PASSIVE ATTENUATOR

Joe Leggio WB2HOL



This adjustable passive attenuator works as a "waveguide beyond cutoff." It can be constructed in about ten minutes from parts available locally.

This attenuator was the result of a search for an inexpensive attenuator which could be used on an HT to help beginners equip themselves for a hidden transmitter hunt. The 3/8 inch piece of wire will extend into the center conductor of the bulkhead adaptor forming a small capacitor. The coupling between the two conductors will vary as the PL-259 shell is turned further onto the bulkhead adaptor.

If you are able to find a BNC to UHF adaptor with a long threaded portion, you may use it instead of the bulkhead adaptor.

The maximum attenuation available depends upon the length of the wire soldered to the chassis mount BNC connector. A service monitor measured a loss of up to 36 dB. With the cost so low and construction so simple, many hams have made several with different length wires.

Although 36 dB may sound like a lot of attenuation it will not be sufficient when on most transmitter hunts. This passive attenuator project is aimed at the beginner who is armed with only an HT and is attempting to use the "body-fade" method of Radio Direction Finding. The passive attenuator can be put in-line with the existing rubber-duck antenna and adjusted so the signal no longer is full scale on the S-meter.



Tuning off frequency by 5 or 10 kc, listening for the third harmonic, using a foil wrapped tube as an RF shield around the HT, or even wrapping aluminum foil directly around the HT are all methods which will help to some degree. One or more of these techniques will reduce the signal to where a "S" meter reading peak (or null) gives you a clue to the direction where the transmitter might be found. (If you do wrap aluminum foil around your HT, put some tape over any exposed battery charging contacts. Otherwise, the foil may get a bit warm as it rapidly discharges the battery)

When closer to the fox, more signal will enter the HT through the case than through the antenna. At this point, other methods must be used to locate the fox transmitter. The most effective attenuator in most cases is an "active attenuator." They can offer over 100 dB of attenuation. Plans for one are available here.

## Construction Details

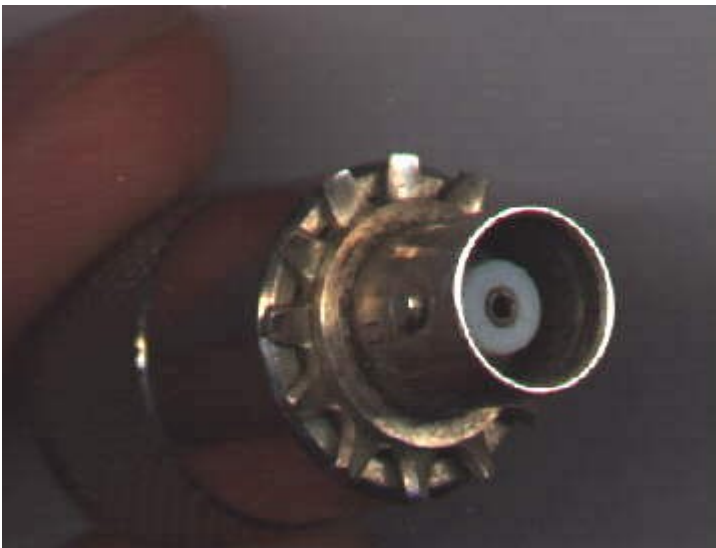
This BNC to UHF adapter has a raised knurled portion of the barrel which prevents the PL-259 shell from being tightened completely. (The BNC and insulated wire do not "bottom out" when tightened all the way) You can file that section of the adaptor down and enjoy more range in available attenuation.



Looking in at insulated wire I soldered the wire to the BNC before mounting it in the PL-259 shell. I used a length of wire clipped from a 2 watt resistor. (Use any stiff wire) I then forced a small length of insulation stripped from another piece of wire onto it. By using this method, the insulation does not melt during assembly.



I used a "star" washer. It was just the right size. The washer prevents the BNC connector from falling through the PL-259 shell. The hardest part of the construction is tightening the nut on the BNC connector. I usually wedge a screwdriver in the shell to hold the nut and tighten the BNC from the outside.



## ACTIVE ATTENUATOR

Joe Leggio WB2HOL

### How it works

This active attenuator works as a simple mixer. A signal from a 1 MHz oscillator is mixed with the received signal in a 1N914 diode. The 1000 ohm potentiometer adjusts the level of the local oscillator fed to the mixer diode.

It is possible to get over 100 db attenuation using this device. This circuit is a variation of one first described in the November, 1992 issue of QST. That circuit was designed by PA0ZR. It used a L/C tuned 500 KHz oscillator.

I used a 1 MHz crystal oscillator and it made construction even simpler than the original unit.

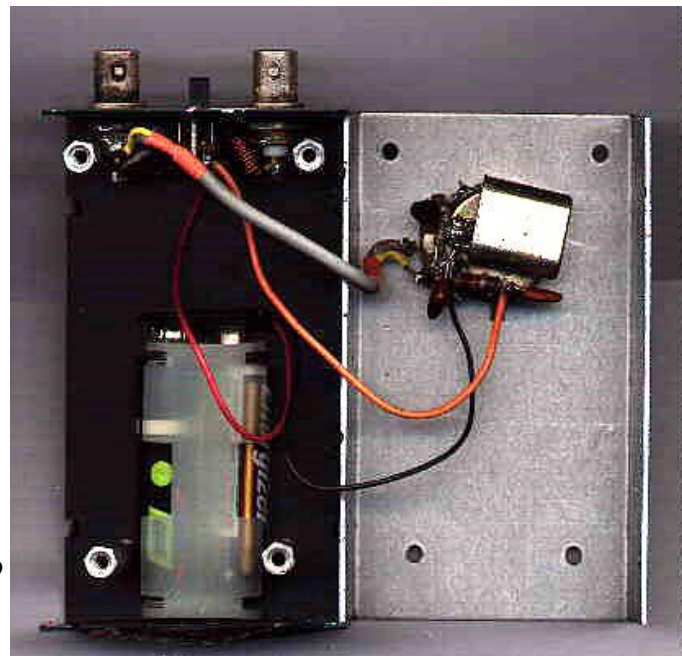
This attenuator is used by tuning the receiver 1 MHz above or below the frequency of the transmitter. By adjusting the oscillator level fed to the mixer diode, the signal output to the receiver will be attenuated.

Note: You may also tune your receiver 2 MHz above or below the frequency of the transmitter and get even more attenuation. (thanks to VE3EFY for this tip)

### Technical Hints

If you find that this circuit does not oscillate with your crystal you might need to add a small capacitor (anything from 5pf to 25pf) from the gate of the FET to ground. It may also help to reduce the 150pf capacitor connected from the drain to ground to 100pf.

These two capacitors, along with the crystal, provide a 360 degree phase shift from the drain to the gate of the FET. The circuit pictured in the schematic below is a Pierce oscillator and relies upon the gate-to-source capacitance of the FET to form part of its phase shift network. If there is not sufficient stray capacitance to ground from the gate of the FET, you may need to add the additional capacitor. VE3EFY reported that his oscillator would not function below 4.5 volts. He used a 9 volt battery to power his unit. The battery should last a long time, he measured the current drain to be 1.8 mA.



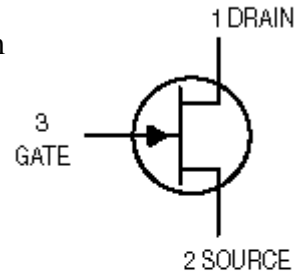
### Construction

I built this unit "dead-bug" style. Most of the components were mounted and supported by their own leads on the back of the 1000 ohm potentiometer. The RF Choke connected between the output connector and ground was made by winding about 20 turns of 22 guage wire on a 1/8 inch drill bit. The coil was then slid off of the form and wired in place. If you want to use a commercially available coil, a value of 3.3uh should work just fine. That was the value specified in the original article.

I mounted the 150pf capacitor, the 1N914 diode, and the RF Choke on the inside panel of the attenuator box between the two BNC connectors. I also mounted a slide switch between the BNC connectors so I could conserve the batteries when the unit was not being used on a hunt.

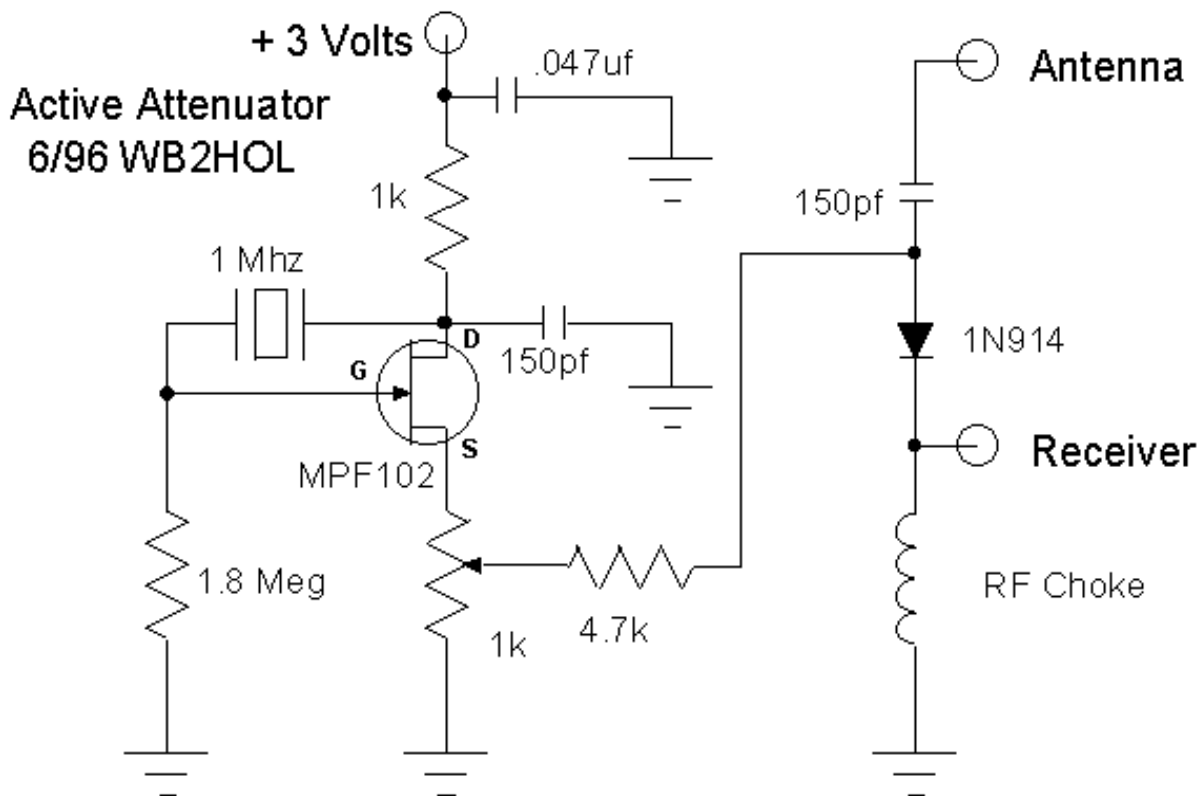
Note: The MPF-102 Field Effect Transistor has an unusual pin-out compared to general purpose transistors. The GATE is not the lead in the center. The pin-out for the MOTOROLA MPF-102 is illustrated below. (The Radio-Shack MPF-102 I used had the same pin-out)

### MOTOROLA MPF102



CASE 29-04, STYLE 5  
TO-92 (TO-226AA)

### The Schematic

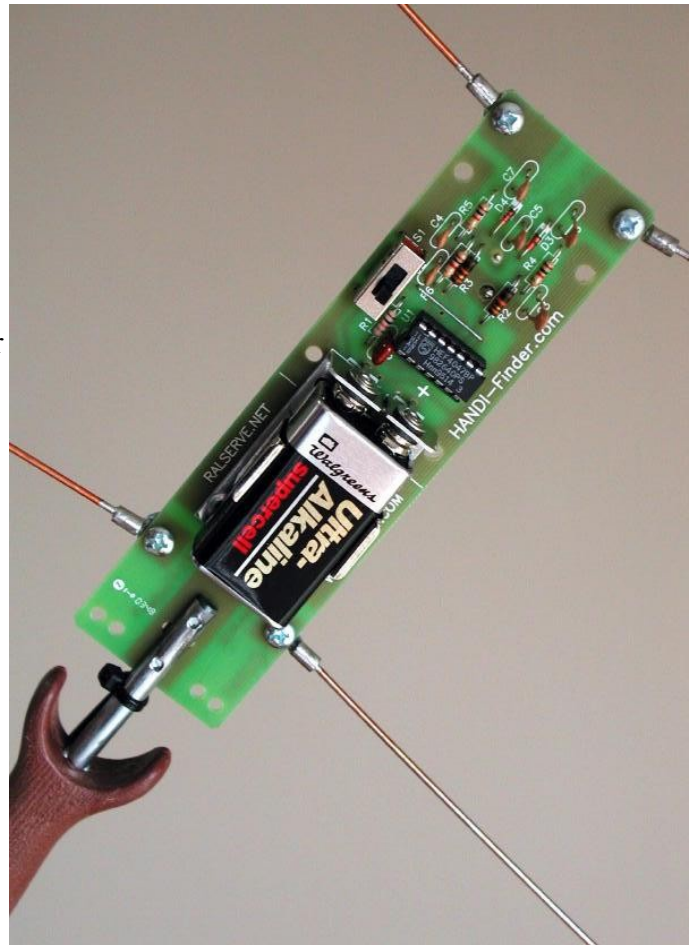


## The HANDI-Finder®

The HANDI-Finder® is a HANdheld DIrection Finder which can be used to localize both AM and FM carrier-based sources using a single connection to the antenna input of an FM receiver tuned to the frequency of interest in the range of 45 to 450 MHz. It has been designed for bare-bone functionality as well as low power consumption, simplicity, and economy!

Because it is both an easy-to-build kit for the beginner and a convenient basis for further experimentation by those with more experience, it makes a great club project! Overall, it is a quick, inexpensive way to implement the concept of direction finding, and provides something relatively compact to keep readily available for locating sources of interference.

Except for adding a handle, fabrication is minimal. Two open-loop antennas are made from coat hanger wire bent into halves of a "bow-tie" shape and mounted directly to the circuit board, as illustrated in the "layout" drawing.



The coax download is connected to an FM receiver and detects the carrier regardless of whether the transmission mode is AM or FM. The unit is switched on (UP) and rotated for a null in the audio tone that it adds to the audio coming out the receiver. The signal direction is perpendicular to the plane of the antennas. There is 180-degree ambiguity, but this is not a problem in actual use because multiple "bearings" must be taken anyway in order to establish a "fix" on the location. Once close in, the operator works toward the general sense of the direction, and again the ambiguity is not a problem.

The 3-position switch is moved DOWN to stop the tone but still keeps the antenna activated for monitoring and standby purposes, --or it is moved to the CENTER position to shut off the unit. Refer to the extensive discussion in the manual which describes construction variations, and the concepts behind the design.

"Build the HANDI-Finder" appeared as an article in QST Magazine, May, 1993. All the information in that article and much more is included here! By clicking on the appropriate boxes in this web page, all the drawings and text that come with the kit can be printed out or downloaded from PDF files.

may be obtained by contacting:

Northern Ohio Amateur Radio Development

P. O. Box 271  
Brunswick, OH 44212-0271 USA  
Tel: 330-225-7373



## **The HANDI-Finder® Experimenter's Kit**

by Bob Leskovec, K8DTS

6th Edition,

The HANDI-Finder® is a HANdheld DIrection Finder which can be used to localize both AM and FM sources using only a single connection to the antenna input of a VHF-FM receiver tuned to the frequency of interest.

The basic HANDI-Finder® when equipped with open-loop wire antennas and a short handle, stores flat and ready-for-use in a briefcase. It works well with just an HT (handy-talky).

The HANDI-Finder® has been designed for low power consumption, simplicity, and economy. The goal was to provide an easy-to-build kit for the beginner and a basis for further experimentation by those with more experience. Overall, it is a quick, inexpensive way to introduce users of FM communications equipment to the principle of direction finding and give them something with which they can help locate sources of malicious interference.

A HANDI-Finder® Experimenter's Kit has been put together to conveniently supply the essential parts necessary to build the control circuit powered by an on-board 9V battery. The user provides the coax, cable connector, and appropriate antennas. By using two open loop antennas made out of coat-hanger wire, the unit can be put into immediate use!

An equally valuable part of the kit is this instruction manual which describes variations in antennas, general construction and detailed discussions of the circuit and components, to encourage experimentation and ideas for improvements.

The HANDI-Finder® first came together in October of 1986, and continued to evolve. A write-up later appeared in May, 1993 QST Magazine, entitled "Build the HANDI-Finder".

### **TECHNICAL OVERVIEW:**

The electronic circuit is based on a design credited to Tom Feierabend SO/CM 03N18 circa 1979 which appeared in a manual published in May, 1980 by Van Field, DCP XVIII, entitled "VHF Radio Direction Finding Manual for Coast Guard Auxiliary Use".

A similar circuit, referred to as the "Double-Ducky" direction finder (DDDF) designed by David Geiser, WA2ANU, is described in July, 1981 QST and reprinted in the 1983 ARRL Antenna Handbook.

The USCG AUX-03N18 version uses an LM555 driving two successive stages of 7404 TTL to provide complementary buffered outputs. Since TTL requires a 5-volt power supply, yet another IC, a 7805 or 78L05 is needed, to regulate the stated 6-30 volt input range.

One problem is that the LM555 does not easily put out a symmetrical square waveform, which is useful in this application. The antenna assembly consists of two vertical ½-wave dipoles (37" long) mounted 8" apart on a boom. This assembly is rather bulky and quite a bit of mechanical fabrication is required.



The QST circuit uses only one IC, the LM567 Phase-Locked-Loop Tone Decoder. This is a complex chip that contains an oscillator and other circuitry, including an output circuit which does put out a symmetrical square wave. However it does not have simultaneous complementary outputs. In the DDDF the single output is connected to the diode switches through a non-polar capacitor, and some adjustment is required to achieve the proper switching level. Data sheet specifications show that the LM567C typically draws 12mA. The antenna assembly consists of two “rubber duckies” mounted 10” apart on a 4.25” X 18.5” ground-plane. While the ground plane requires much less work to fabricate than the USCG-AUX circuit, two “rubber duckies” must be obtained.

The HANDI-Finder® is a good example of integrated simplicity, wherein one simplification contributes to another.

First, it uses a single CD4047B CMOS IC, which contains both an oscillator and a divider flip-flop to automatically provide complementary symmetrical square wave outputs without special adjustments. Only a single resistor and capacitor are needed to set the frequency. While many have not heard of this IC, it continues to be available from standard suppliers like Digi-Key, Mouser, and Jameco.

Second, very little current is used to bias the switching diodes so the total current draw is only 1.7mA at 9V. Good service can therefore be provided by a common alkaline “transistor radio battery” and there is no need for wiring to an external source such as a 12V vehicular supply. This, in turn, eliminates the need for noise filtering. The operation of the circuit is not dependent on battery voltage, so a regulator is not required. Supply voltage for the CD4047 can be anywhere from 3-18 volts. Finally, since all the parts, including the battery are mounted on a single circuit board, the board is designed to also serve as the mounting base for the two open-loop antenna elements easily made out of bent wire. Thus, there are no ground-plane or vertical dipole elements to make, nor “rubber duckies” to buy, and no case to drill, until later if you really want to!

## HOW IT WORKS:

All three circuits described above are based on the same principle. An electronic switch alternately connects two antennas to the coax cable download going to the antenna input of an FM radio receiver tuned to the frequency of interest. First one antenna is connected, then the other, etc., back and forth with equal intervals. This is done at an audio rate, well within the audio bandpass of the receiver, and usually in the range of 400 to 1500 Hz. A good frequency is 1000Hz.

Of the two antennas, if one is slightly closer to the source, it receives the wave front slightly earlier in time (phase) than the other. There is a phase difference in the signal received by one antenna compared to the other. Since the receiver is being switched between the two antennas, the switching action imposes phase modulation on the incoming signal. This is detected in the FM receiver and is heard at the audio output as a tone equal to the switching frequency. The amplitude of the audio signal corresponds to the deviation, which depends on the physical separation of the two antenna elements, up to  $\frac{1}{2}$  wavelength. In other words, if the antennas are farther apart the circuit will impose a higher percentage of modulation or a larger deviation, producing a louder tone, but the modulating frequency will stay the same.

If the antenna is rotated so that the plane of the two elements is perpendicular or broadside to the direction of the signal, both elements receive the signal at the same time (phase) and there is no longer a difference in phase. Hence, the audio tone disappears. This is perceived as a rather sharp null in the audio as the antenna array is rotated into position perpendicular to the direction of the signal.

This type of direction finder has the disadvantage that it exhibits 180-degree ambiguity. However, it has several advantages:

- 1) It works on a nulling principle rather than a peaking principle. The null is sharp and much easier to detect than the peak from a directional or beam antenna.
- 2) When you null the superimposed audio, you are not nulling the carrier. This is unlike a conventional loop antenna or cardioid array, which nulls out the carrier. The problem with carrier-null, is that as you get closer to the null, the signal you are trying to hear in order to null out, is getting harder to hear! Also, when you null the superimposed audio, you can still hear the audio coming from the source.
- 3) Since audio is being nulled, the operator does not have to watch a field-strength meter. He only needs to listen, which is something he can do while driving, riding a bike or walking.
- 4) Since this method uses phase information, it works well with strong signals, so no attenuator is required. (By comparison, the signal from directional gain antennas must be progressively attenuated to keep the receiver RF within the range of the S-meter.)

## REFERENCE INFORMATION:

The HANDI-Finder® is an evolving project which underwent several changes (hopefully for the better) during the early stages. However, the basic circuit remains essentially the same. This manual might be supplied to help you work on an earlier unit, as far back as 1986. If you have a model that does not correspond to the pictorial description in this document, you should be able to identify the components with only minimal tracing of the etched circuit pattern.

Your unit may also have component values that differ from the schematic. If you did not buy a kit, you may have obtained the circuit board and documentation from separate sources that copy and distribute such things and try to make them “public domain”.

The circuit board versions are identified by a prefix letter “A”, a 6-digit date code (YYMMDD), and an optional suffix. (The suffix, if present, indicates very minor changes.) As of this writing, the numbers used are: A861003, A860102, A870122, A890422, A01110, and A031123.

In general, if the board has a date code earlier than the documentation, the component values in the documentation take precedence, provided the integrated circuit type is pin-compatible. If the board has a date code later than the documentation, and/or a different IC pinout, you would do well to send a self-addressed-stamped-envelope (SASE) to the distributor for an update of the layout and parts list. Of course, be sure to furnish the number on your board, so you will be sent the correct information. Please indicate whether the RALTEC® or other trademark is present and we will help you figure it out. Try contacting the author at [ral@ralserve.net](mailto:ral@ralserve.net). (If you have trouble, you can also find the author’s current snail mail and e-mail addresses through the internet Ham-Call database.) For information, try the website [handi-finder.com](http://handi-finder.com).

## **CHECKING THE COMPONENTS**

If you received this instruction manual as part of a packaged kit along with the circuit board and loose components, unpack all the parts and check the quantities and values against the Component Parts List before you do anything else because some parts have the same value but different mounting positions and lead lengths. Before proceeding with actual construction, it is suggested that you read this manual to see if there are any changes you would rather incorporate right away. Then proceed with “ASSEMBLING THE KIT” which is located at the end of this discussion.

### **NO PILOT LIGHT:**

Considering that a small transistor radio draws about 10mA, it can be seen that the battery will last quite a while if the user remembers to turn it off. Unfortunately a pilot light would be self-defeating, since it would draw 5-10 times the current of the circuit itself!

How many times have you forgotten to turn off your HT? After a while you finally learn to double check. With the HANDI-Finder® it should even be a little easier, because you will probably be disconnecting it from your radio or otherwise storing it at the end of a “DF’ing” session. That action should help remind you to check that the switch is off. Better yet, remove the battery. That’s why we have included a top grade battery holder in the bare board version.

### **ON-OFF SWITCH STATUS INDICATOR:**

For models prior to A890422, here are a couple of things to help you tell OFF from ON in the absence of a pilot light. First, the “ON is UP” convention has been followed. This is fairly commonplace on most equipment. Second, you can make a “passive” indicator by using a dot of bright paint, for example, typewriter correction fluid such as “whiteout”. Push the slider to the ON position, then paint a small dot on the lower part of the slider that is now exposed. Let the paint dry thoroughly so it doesn’t rub off. When you slide the switch to OFF, the painted part should be hidden; when ON, it should be visible. On Model A890422 and later the switch has 3-positions: OFF is in the center, UP is for DF’ing, and DOWN is for straight receiving or Standby. (Notice the design date is embedded in this code as YYMMDD.)

### **ON-OFF SWITCH MECHANICAL VARIATION:**

There are a couple of subminiature slide switches available from “experimenter” sources such as Mouser and Digi-Key, but they differ slightly in the spacing and style of the connector pins. Circuit boards A861003 and A860102 used the CW Industries switch available from Digi-Key as SW103-ND.

Starting with circuit board A870122, the switch pads were made larger and the spacing changed to use the Mouser 10SM007 or 10SP001. The larger pads allow larger holes to be drilled to allow for the wider flat pins. If the switch you have does not go right in, do not force it. Study the problem and carefully enlarge the holes only where necessary. A small modeling file is handy for this purpose. Don’t make the holes any larger than necessary, or you will have trouble bridging the gap and getting a good flow joint when soldering. When you do solder it into position, use ample solder and heat it enough so the solder surrounding each terminal flows evenly into a nice even form similar to an “Indian tepee.” A890422 and later use a DP3T switch with 6 pins, which will not fit the previous models, but that gave the ability to add the “standby” position which is very useful.

**BATTERY HOLDER:**

The 9-volt battery holder is fastened at one end by soldering the two terminal tabs that pass through the board. The other end of the frame can best be fastened by using 1/8" diameter "pop-rivets", but you may alternatively try hot-melt glue, epoxy, small screws, etc. However, make sure that whatever you use won't protrude and prevent the battery from seating in the clip.

**QUICK HANDLE:**

The bottom area of the circuit board contains an area where the handle is attached. The unit can be mounted on either a short handle or directly to a mast, whatever you desire. To get going quickly, take any convenient piece of wood or metal, lay the end against the board, mark the holes, drill them through the handle, and attach with screws. If you use a round handle, you will either have to make a flat cutout along one side, or cut a slot in the end so that the board can slide in. A round handle is best. The most utilitarian handle is described next.

**PAINT-ROLLER HANDLE:**

Find an inexpensive paint roller, but one with a handle which is threaded for an extension pole. (Home supply stores sell them typically for \$1.39). Study how the handle is attached and determine the best way to remove it or otherwise adapt it so the HANDI-Finder® can be mounted on it.

Most of the handles available these days are plastic, force-fit directly to the metal roller rod. Use a hacksaw and cut off the roller assembly rod so that about 3" of rod is left protruding from the handle. File the rod enough to have a flat area, center punch, then drill two #6 holes to match up with the circuit board, and attach. The flat side should of course go against the board.

Next, shop around for your choice of a wood or metal paint roller extension pole, preferably the type which is made of 3 sections which screw together. You will thus have a very flexible system. You can use the unit with just the handle alone, or screw on up to three lengths of additional "mast". You may even wish to obtain a second extension to have more lengths available. Be aware that some extension handles have different threads in the sections than they have at the roller end. In any event, the pieces are easily stored when disassembled.

**UTILITY-DUSTER HANDLE:**

There is a homemaker's utility duster on the market called a WEBSTER® which can be found for as little as \$4 in discount stores. Unfortunately, only a small percentage of stores seem to stock it. However, this is an amazing value for our purposes because it contains not only a 6-inch detachable handle, but includes a removable, telescoping, extension pole!

The dusting head consists of an 8-inch diameter half-spherical array of bristles embedded in the end of the short handle. This end is easily sawed off to allow for the HANDI-Finder®. The extension pole is about 36" in the collapsed position and 60" when extended.

**HANDLE, CAUTIONARY NOTE:**

Mount the handle against the component side and put the screws through with the heads on the solder side, to keep a low profile for the coax cable which will come down the solder side

The HANDI-Finder® works best when the first  $\frac{1}{4}$  wavelength of coaxial cable downlead to the receiver is kept vertical or parallel to the center line of the circuit board. (Measure the  $\frac{1}{4}$ -wave from the bottom antenna terminal.) If it waves around, it can throw off the bearing. Therefore, when using the unit with a short handle, make sure to hold it straight and high so that the cable hangs straight down. When using the unit with a long handle it is preferable to attach the coax to the mast for the first  $\frac{1}{4}$  wavelength. Use tape, nylon cable ties, etc.

### **RESISTORS vs. INDUCTORS:**

The HANDI-Finder® was designed mainly out of the need to inexpensively provide Radio Amateurs with something they could use to help locate interference on the 2-meter repeaters. But the unit operates over a much wider range of frequencies because the chokes “traditionally” used in such RF circuits have been replaced by resistors.

Inductors are usually used to feed direct current into some point in a circuit where it is desired to allow an alternating current signal to pass without attenuation. At radio frequencies these are called “RF chokes”. Circuits which operate in the 150MHz range, for example, usually use small coils with a value of 1.0 to 1.2 microHenries. Using the expression  $X_c = 2(3.14)fL$ , where “f” is the frequency in MHz and L is the inductance in microHenries, the corresponding reactance works out to about 1000 Ohms. At  $\frac{1}{3}$  the frequency, or 50 Mhz, this same inductor would have a reactance of only 333 Ohms. At UHF this inductance would mathematically exhibit a proportionately higher reactance, but other difficulties arise. Certain assumptions about the construction of the coil are no longer valid and the math becomes more complicated. Factors like the “capacitance between turns” and the length of the connecting leads can no longer be ignored. At some frequencies the coil looks like a high impedance, but at others it may look like a short circuit!

Thus, the frequency band over which the circuit can operate is limited by the chokes. Different sets have to be installed to operate over different ranges of frequencies. Normally it is necessary to use chokes because they have a comparatively low resistance at d.c. so there won't be any significant voltage drop. The key word here is “significant”.

In this circuit, the switching diodes are biased by current. As long as enough current is supplied to do the job, it doesn't matter if a little voltage drop occurs across the connecting element. The chokes can simply be replaced by 1000 Ohm resistors. The currents are so small that the voltage drop is negligible. Further, for all the complications involved with determining how chokes will act at different frequencies, it is no less risky, and a great deal easier, to assume that a resistor will exhibit the same resistance over a much wider frequency range.

In this circuit R4, R5, and R6 would have “traditionally” been specified as 1.0uH chokes for operation in the 150 MHz region. As you can see, by using 1K resistors, operation at 150 MHz should not be affected, and operation over a wider range of frequencies should now be possible. The value of the resistors is not that critical. Values in the range of 1K-1.3K will do, but make them all the same value. Using carbon-film resistors, we also get some useful inductance, but since the resistance is high and distributed with resistance, these are inherently free of self resonance, and broadband because they are low Q.

However, if you wish to experiment with inductors, you can either make them or buy them. According to the USCG AUX article, you can make these with one layer of #28 close wound on a 1 Meg ½-watt carbon composition resistor. Actually there is nothing magical about the 1 Meg value, it is the physical size and shape that is more important. The intention is that the resistance be at least a factor of 100 times greater than the inductive reactance. Therefore any value above 100k is acceptable.

Mouser Electronics has a line of good quality subminiature RF chokes that are quite reasonably priced, roughly \$.23 each. Consult their catalog for the “43LQ” series. The 1uH value is part number 43LQ106. Keep in mind they probably will not fit on the HANDI-Finder circuit board supplied with the kit.

## **WIDEBAND OPERATION:**

The HANDI-Finder® should work over a wider range when resistors are used in place of inductors, but there will still be problems with resonances (series LC) and anti-resonances (parallel LC) for any given set of antennas. However, ignoring those effects, let us discuss the effect of antenna spacing. Remember, you want the vertical members of the two antennas as far apart as practical to get maximum modulation.

This will make it easier to tune for a null.

For a given set of antennas, the upper frequency limit should be that which corresponds to a ½ wavelength equal to the widest spacing of the vertical members.

If the usual wavelength formula is multiplied by 12 inches/ft, a new “constant” factor is obtained: dividing 5616 by the frequency in MHz will give the ½ wavelength in inches. For the open-loop antennas you will be instructed to make elsewhere in this manual, the spacing between opposing vertical sections is typically 17.5 inches. Turning our formula around, and dividing 5616 by 17.5 gives 321 MHz, which is also the frequency at which maximum deviation would be available. Some have reported operation to include the 70cm Ham Band.

Moving to 1/10 that frequency or 32 MHz, only 1/10 the modulation would be available, but the units should still function. So it would appear that operation over a 10:1 range might be possible.

## **COUPLING CAPACITORS:**

At the lowest limit, it is important that the coupling capacitors have a reactance of 50 Ohms or less so as not to attenuate the signal by more than 3dB. If we choose that limit to be 27MHz the value of capacitance having 50-Ohm reactance is 117pF. Values of .001uF, or 1000pf will be one tenth that or 5 Ohms, and work just fine.

## **SCREW TERMINALS:**

Antenna connections to the board are made using screw terminals. On early units, these are formed by installing a clip-type “tinnerman nut” which is slipped onto the circuit board edge at each designated point, and then threading in a 6-32 x 3/8” or ½” binder head machine screw. Only four are needed for any given configuration. Later units use regular hex nuts, serrated lock washers, and flat washers against the board to keep the lock washers from tearing up the copper foil.

When fastening small diameter or stranded wires to these, it is suggested that you first install crimp-on spade lugs or ring lugs on the end of the wire. If you must wrap the wire around the screw, do it under a washer and wrap it in the direction that the screw tightens (clockwise).

**BE CAREFUL NOT TO OVERTIGHTEN.** If you experiment a lot, the tinnerman nuts will strip and wear out. If you need to have things very tight, you can use 6-32 screws with regular hex nuts. However, do not put serrated lock washers against the surface of the board since they really dig in and cause problems. It is better to use a slightly longer screw with flat washers to protect the surfaces. If you are tempted to just solder directly to the board, don't do it! The heavy heat may cause the foil to delaminate. Further, if the antennas are bumped, the foil may be pulled off the board. If you want to have some sort of "rounded off" nut on the thread end, inquire about "acorn nuts" in the screw specialty section of most hardware stores.

## **ANTENNAS:**

The HANDI-Finder® is quite versatile in the way it can be used with different kinds of antennas. First of all, you can get it running immediately without extensive fabrication because two simple wire antennas can be attached directly at the circuit board. For 150 MHz, take two EQUAL lengths of stiff wire about 19 to 20 inches long and bend each one into a neat square "U" shape. The bottom of the "U" should be about 6". Form the ends into a hook and fasten them to the screw terminals on the circuit board. Looking at the component side of the board, you will see there are three terminals along the left side and three along the right side. Fasten one end of one antenna to the very top terminal on the right side. Fasten the other end of that same antenna to very bottom terminal on the same side. Then repeat this procedure for the left side.

Note that the bottom terminals are merely mounting points. They are electrically isolated. On some board designs there are circuit pads to allow installation of a grounding jumper. **DO NOT INSTALL THIS JUMPER!** It is desired that the antennas be open loops. If you ground the bottom of the loop, you will create a closed loop that will cause a carrier null in the direction of the signal. This is not desirable. On later circuit boards provisions for grounding was eliminated to avoid confusion.

The wire you use should be thick enough to provide desired rigidity, but thin enough to allow fastening under the screw terminals. If it is too thick, you might be better to first solder on some spade lugs or similar terminations. Of course, it helps if the wire is a good conductor, but steel coat-hanger wire or welding rod will work satisfactorily. A better choice would be brass rod or brazing rod, between 1/16" to 3/32" thick. If you wish, you can make the loops even larger.

Note the **ACTIVE ELEMENT** of each antenna in this application is the vertical part of the open loop supported in space by the horizontal part. A greater separation of the vertical elements will produce a larger deviation and more audio. However, the longer a vertical element is, the more signal it will receive, provided there isn't some gross impedance mismatch. This shows up as more carrier, better quieting, or a stronger S-meter reading. Of course, when that vertical section is maintained in space by an unshielded horizontal section, determining the resonance or tuning gets very complicated. Also consider that the horizontal part does receive some signal, and this degrades the intended signal. Therefore, larger loops may work worse. Feel free to experiment; that is the whole object of this project!



Alternatively, the circuit board is designed to accommodate connections by coax cable to other kinds of antenna arrays. Just below the top antenna mounting screw on each side, is a ground screw. This is not used with the open loop antennas, but is used for the coax shield. Thus, if you do wish to make a “Double-Ducky” direction finder as described in the ARRL Antenna Handbook, you can connect the two equal-length coax cables to the HANDI-Finder® circuit board. Similarly, you can fabricate the dual half-wave vertical dipole array described in the Coast Guard Auxiliary Manual and run it with the HANDI-Finder® board.

One suggestion for a more extravagant system is to position two multi-element Yagi antennas with vertical orientation at opposite ends of a horizontal boom. Support the boom at its center on a vertical mast so that it can be rotated. Use equal lengths of coax from each beam and connect them to the HANDI-Finder® board which should be mounted in a protective enclosure at the center of the boom. The beams will give greater forward gain and reduce the 180-degree ambiguity. It is just a little hard to use with the mobile!

Since the antennas have no path to ground, there is no need for DC blocking capacitors. On A890422, the positions of C6 and C7 are jumpered out with board foils. If an application is encountered which requires DC blocking, slit each foil at each end carefully with a sharp hobby knife, then heat the center section with a soldering iron and peel it off the board with the knife. Holes are provided to install the capacitors. Refer to parts list. Later boards don't have this connection, and come with capacitors. Check the board. If you don't have the capacitors, then be sure to insert some jumpers.

## **NO ENCLOSURE**

As you can now appreciate from these discussions, there are many ways you may end up using the circuit board and enclose it accordingly.

In its simplest “quick & dirty” constructed form, the unit can be put to immediate use. The long narrow profile was purposely selected to minimize wind resistance for the benefit of a vehicle operator who may be trying to hold on to the unit mounted on a narrow mast protruding through the drivers window.

You will discover that an enclosure will only increase the drag and may not be worth the effort! With only minimal care, these units have rattled around in many trunks and back seats without anything getting shorted out. The battery in one of the demo lasted over three years, even though it had been left “ON” for several weekends during that time!

However, you might want to consider that numerous sharp edges from component leads could snag cloth upholstery, or scratch leather and vinyl.

Where you really need to, the circuit board can be mounted to surfaces on standoffs using 6-32 screws through existing holes.

## **MOUNTING IN AN ENCLOSURE:**

Model A890422 and later are designed so that it can be more easily modified to fit into a case. This is somewhat irreversible since it requires that the bottom part of the board be cut off, unless you can find a really long, flat plastic case. Some have come and gone off the market, so there is no particular model case that can be recommended. It is strongly suggested that the circuit be completely built up on the existing board and thoroughly checked out. After you are familiar with the unit's operation, you may NOT wish to put it in a case.

## **TRYING IT OUT:**

It is best to start off with a "test" situation where you know the location of the source, and experiment with "getting a feel" for the null. The null itself is fairly sharp, but it does not always manifest itself as a total null in the audio tone. Sometimes, you will observe instead, a jump in tone one octave up or down. (Refer to the ARRL Antenna Handbook article for more discussion.)

At other times, you may hear a "buzz" or a fast "twiddle". This is usually due to multipath, so moving just a few feet may help clear up the null. Also, if there is a strong transmitter in the area, such as a 1kw paging system, 3 or 4 MHz away, you may experience more "de-sense" than normal when the HANDI-Finder® is switched on in the DF-ing mode. The sharp edges of the diode switching waveform cause it to be rich in harmonics, all of which modulate that strong RF source and cause it to broaden its normal spectrum at the input of your receiver. (These are the same problems that bother the more complex "DOPSCANS" that switch 4 or 8 antennas.)

Using the unit with a synthesized scanner or one of the new extended-coverage HT's will not only allow you to work in the Ham bands, but other frequencies as well. The prototypes were tried over the range of 49 MHz to 450 MHz and worked well even though the 450 MHz test was well above the suspected 1/2-wave limit frequency of 321 MHz calculated previously. As you get considerably above or below the 150 MHz design frequency you may find that your unit has a "null" point which is no longer perpendicular to the plane of the circuit board. However this also sometimes occurs due to multi-path in high reflection areas, especially indoors. (Don't try to do anything meaningful indoors!) In any event, don't jump to conclusions. Take several measurements at different locations a few feet apart, and consider your findings carefully before deciding whether the problem is due to the location or a characteristic of the way you have set up your particular unit.

When driving through neighborhoods it is interesting to scan the bands and see what sort of frequencies are in use. For example, one of our experimenters found several homes with 49 MHz "baby monitor" intercoms. You may also hear cordless phones near that frequency.

Another application is to drive around and look for Cable-TV leakage on 145.250 MHz. You will quite easily pinpoint hotspots on poles and at the lawn boxes used for underground installations.

Perhaps you can promote some Ham Radio good will by helping local law enforcement officials find mobiles with "stuck mikes." Such a "free" service can help educate personnel about Amateur Radio and keep you from getting "pulled over" when you are out hunting.

If you are an avid radio-controlled model airplane enthusiast, and have had a plane get away from you and get lost in the woods, this could save you time. Put a low-power transmitter and "crash switch" in your plane. Then if it gets away or crashes in the woods, you can track it down!

Some areas have rather extensive park reserves or other situations where naturalists “tag” wild animals with radio transmitters to track their migration.

They are quite interested in reports on these animals, and will give out the frequencies to individuals with a genuine interest in helping. Invite your local naturalist to speak to your club and demonstrate how you can help. But keep in mind they DO NOT put radio collars on deer and turkey just to make it easy for game hunters to track and kill them!

## **CHECKING DIRECTION CALIBRATION:**

A round handle is best, because it allows a calibration mark at any angle. You would do well to try your unit outdoors in an open field by walking in a circle around a central source. A person keying an HT held up at arm’s reach is easiest, but caution him to hold still. The null should always occur perpendicular to the plane of the antennas, but your radio or other factors may be introducing phase shift. If the error is totally consistent as you walk around the circle, then you will want to mark the true direction on the handle.

If such is the case, expect this calibration to change at different RF frequencies, or if you change the CD4047 oscillator frequency. If the error is not consistent, and changes as you walk around the source, you are experiencing (multi-path) reflections from the surroundings. Try reducing the power of the source. For example, if a 100 mW HT is too strong, remove the antenna and substitute a 51 Ohm, 2 watt carbon resistor. If you still get erratic readings you will have to go to another location.

Once you have established the calibration mark, fasten the cable along the side of the handle or mast so it runs over the mark. That way you can feel it in the dark. Now you are ready to do some serious DF-ing or Fox Hunting.

Notes:

1. The abbreviation “uF” is used throughout this text to denote “micro-Farads”.
2. Bob Leskovec, K8DTS, has been licensed since 1957 and promises not to change his call letters so you can always locate his mailing address via the Ham database!
3. A less detailed description of this project appeared as “Build the HANDI-Finder!” QST Magazine, May, 1993.
4. HANDI-Finder® and RALTEC® are Registered Trademarks.

The HANDI-Finder® Experimenter’s Kit

ASSEMBLING THE KIT: (Please read the whole manual before assembling)

- 1) Check the circuit board and make sure all the holes are drilled and it is otherwise finished and ready to accept the parts.
- 2) Having read the discussions about the ON/OFF switch, locate that item and make sure that the type you have does indeed fit the hole pattern on the circuit board. Do not install it yet.
- 3) Locate the integrated circuit socket, carefully straighten the pins, and insert it onto the component side of the board with the proper orientation. You may have to study the IC socket to determine how its design denotes the position of pin 1. Some sockets have a beveled corner at pin 1. Others have an indentation at the end between pins 1 & 14, some are not clear!

Note, for packing purposes, the IC may have been installed in the socket. It is NOT necessary to remove it, unless you can see it has been inserted in the socket incorrectly. The IC will incur much less handling and there will be less chance of damaging it if you just leave it in place when you solder the socket onto the board. Make sure the socket is properly oriented and seated flat against the board when you do the final soldering.

4) In the following order, mount the diodes, resistors, and capacitors, starting with the smallest parts first. If you have only one capacitor with long leads, SAVE that, and use the precut ones first. There is one location that needs the capacitor to be formed with longer leads.

5) Examine the ON/OFF switch and make sure that the terminals are clean and not tarnished, before soldering. If needed, carefully scrape them with a small hobby blade. Then mount the switch and solder it in position. The 6-pin switch also requires that the two diagonal frame tabs be soldered as well. NOTE: if you later use a solvent to remove flux from the board, be especially careful not to get any into the switch. Some literally melt. Some have four frame mounting pins. Carefully clip off only the two diagonal pins that prevent insertion.

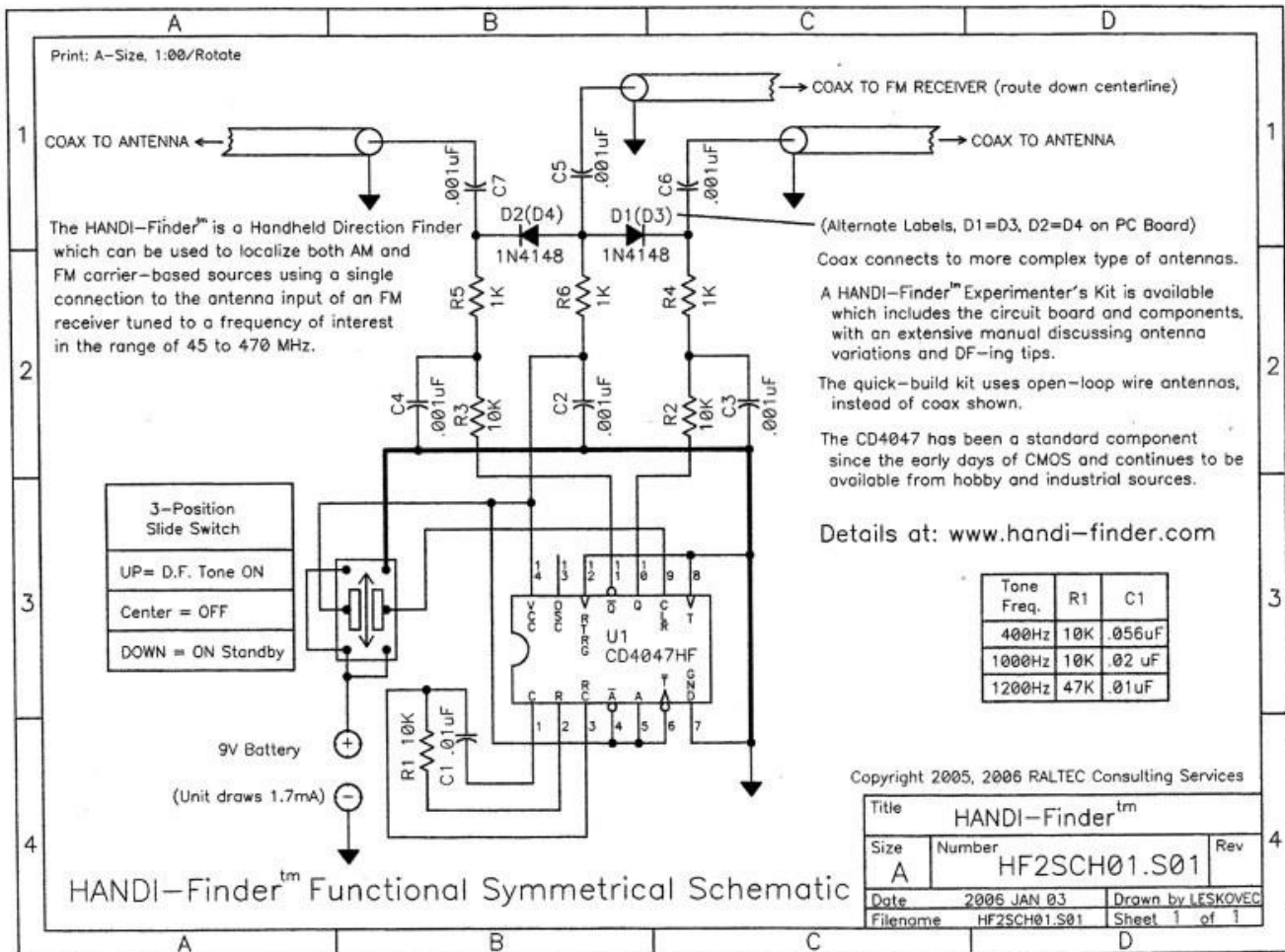
6) Refer back to the discussion about the battery holder and mount that item.

7) Prepare the end of a length of RG-58/U or the miniature RG-174/U and attach it to the board. Note that the hole for the shield should be 1/8" so that the shield can fit through. The excess braid is cut off so that only about 3/16" lies flat against the circuit foil where it is soldered down. Install a nylon cable tie through the holes provided in the circuit board. Pull it tight so that it anchors the coax securely against the board to prevent flexing at the cable end. This is known as a "strain relief." Clip off the excess. Depending on what type of handle you use, you will need to figure out how to route the coax so that it crosses to the center and comes down the handle equidistant from the two antennas for best symmetry. Later circuit board layouts have the coax routed down the centerline in the solder side of the board on the side opposite where the handles should be attached.

8) Slide on "tinnerman" nuts (if such nuts have been supplied) at the four points used to attach the open loop antennas. These are the two top-most and two bottom-most locations.

9) Fashion two open-loop antennas according to the instructions described previously and attach them to the board using the 6-32 x 1/2" screw hardware. That's it! Refer to the section "TRYING IT OUT".

The manual includes discussions of several other options and variations in the way the unit can be wired.



## Sense The Right Way To Go With The HANDI-Finder®

by Joe Moell KØOV  
ARRL Technical Advisor

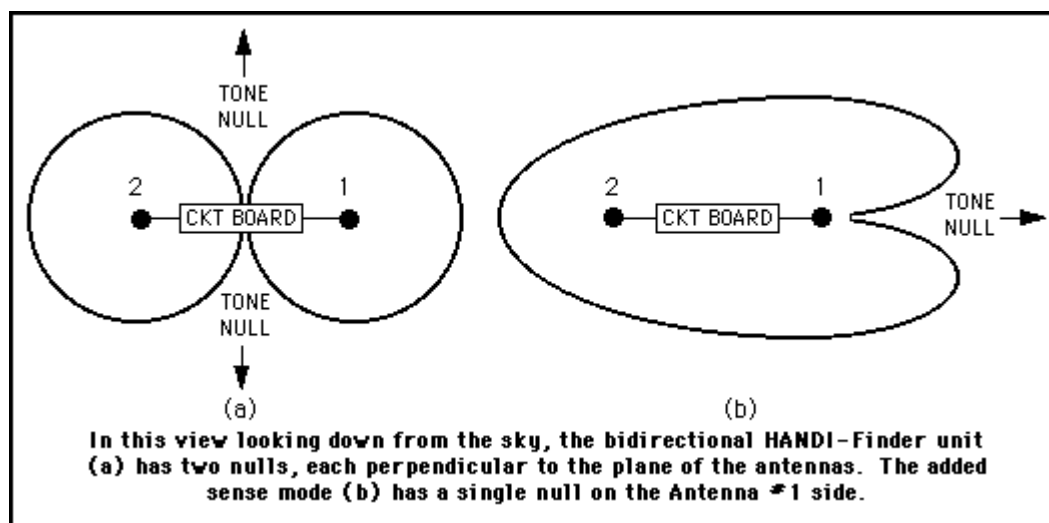
The following was submitted to the Technical Correspondence column in QST Magazine for October 1993 in response to the HANDI-Finder construction project in a previous QST issue. The original HANDI-Finder was created by Bob Leskovec K8DTS. It is documented at the HANDI-Finder Web site. A kit of parts is sold by the North Olmsted Amateur Radio Depot. "Clones" of the bow-tie bidirectional HANDI-Finder are being or have been offered for sale by some other companies and individuals. The KØOV unidirectional pattern modification and antenna improvements described below are applicable to all of these bow-tie sets.

Hats off to QST for its recent promotion of foxhunting and radio direction finding (RDF) activities. Simple RDF gear in the hands of a large number of hams will provide important preparedness for emergency searches and malicious interference location.

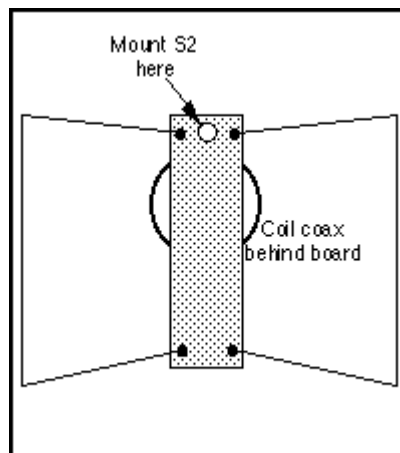
The HANDI-Finder® by K8DTS[1] holds promise for this purpose, but its bidirectional peaks and nulls limit it to short range "sniffing" in situations where time-to-locate is of little concern. Its 180-degree ambiguity makes it unsuitable for long-range or high-speed work.

If you were shopping for a compass to use on a hike, what would you think of one with an indicator that points either north or south, with no way of determining which? You probably wouldn't buy it, even if it was priced much lower than other compasses in the store. It's the same way with foxhunt equipment.

A bidirectional RDF set such as the basic HANDI-Finder presents a 50-50 chance of leading you away from the fox instead of toward it. So it's worthwhile only for occasions when boundaries are small, such as on-foot foxhunts in a small park. Fortunately, it's a simple matter to incorporate a second mode into your HANDI-Finder to resolve the ambiguity.



## Add a Sense Mode



By adding time delay to the signal from one of the two HANDI-Finder antennas, the peak/null tone pattern of the unit is modified. If you add just the right amount of delay, the pattern changes from bidirectional (figure-8) with nulls perpendicular to the antenna plane to cardioid (heart-shaped) with a single null off one end.

This two-pattern technique forms the basis of the Handy Tracker, a RDF unit that I designed in 1989.[2] The cardioid pattern concept came from an unpublished 1980 project by Russ Andrews K6BMG. The Handy Tracker sense mode scheme can be applied to the K8DTS HANDI-Finder with the simple addition of a switch and a length of coaxial cable to provide delay.

As K8DTS points out, the bidirectional HANDI-Finder indication is independent of frequency. This is not true of the added sense mode. A delay line of a given length produces a precise cardioid pattern at only one frequency. A useful pattern is obtained over a frequency range of several per cent, however, so one delay line will provide ambiguity resolution over one full VHF amateur band.

## Modification Details

The modification adds a DPDT micro-mini toggle switch without center-off (Radio Shack 275-626) and a precisely trimmed coax delay line. Mount the switch in the etch-free area of the circuit board between the two antennas.

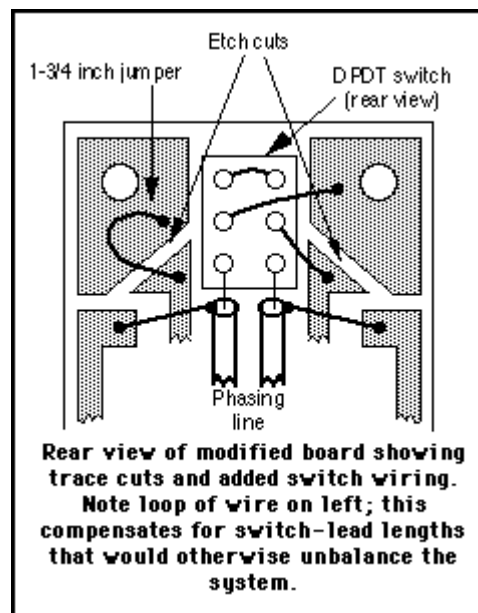
On the rear side, cut the traces where C6 and C7 connect to the antenna terminals per the drawing. On the Antenna #2 side, wire the antenna connection through the switch per the schematic. On the Antenna #1 side, install an unshielded wire jumper 1-3/4 inches long, to compensate for the added switch wiring on the Antenna #2 side. This jumper is important, since one inch of difference in feed length to one antenna will cause 6.5 degrees bearing error in the figure-8 mode.

Cut the delay line according to the following formula:

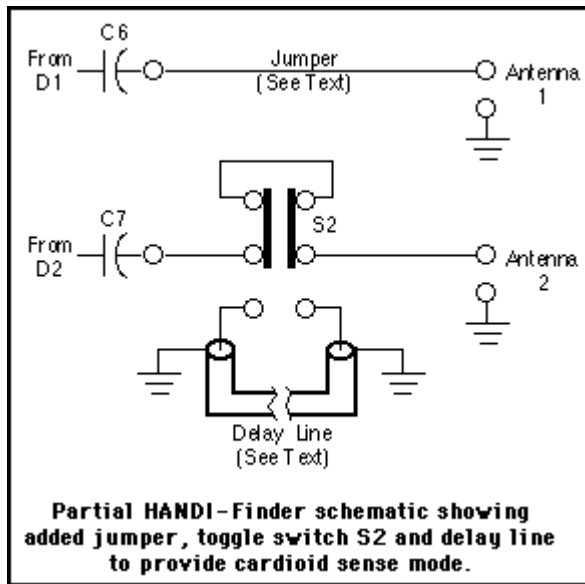
$$l = (11808 - df)v/f$$

where  $l$  = length of coax in inches,  $v$  = velocity factor of coax as a fraction,  $f$  = frequency in MHz, and  $d$  = spacing between the vertical antennas in inches. For example, assume we are adding the sense mode to a HANDI-Finder with "bow tie" open loop antennas for two meters. The vertical sections of the two loops are 15 inches apart. We are using RG-174 coax, which has velocity factor of 65.9 per cent. Computed for the center of the band (146 MHz), delay line length is

$$(11808 - (15)(146))(0.659)/146 = 43.4 \text{ inches.}$$







Coil up the coax and lace it to the board. Miniature coax such as RG-174 is best for the delay line because it makes a compact coil. Whatever coax you use, make sure to determine its characteristic velocity factor. It is different for foam and non-foam type cables.

Because of environmental multipath and stray coupling, a perfect cardioid tone pattern may not be achieved. The end null may not be complete or there may be a double null on one end. This doesn't matter, because the purpose of the sense mode is merely to determine which of the two figure-8 nulls to follow. There is plenty of peak/null amplitude difference for that.

Getting RDF bearings with the modified HANDI-Finder is a simple two-step process. In a clear location, with S2 set for normal (bidirectional) mode, listen for the tone

nulls in the receiver to obtain a line of bearing as described by K8DTS. Next, switch S2 to the cardioid pattern mode and turn the unit 90 degrees so that one end points along your line of bearing. Note the tone level. Rotate the unit 180 degrees and note the tone level again. It should be distinctly different. The lower amplitude tone will occur when Antenna #1 is closest to the signal source. To help you remember, mark the peak/null directions on the board.

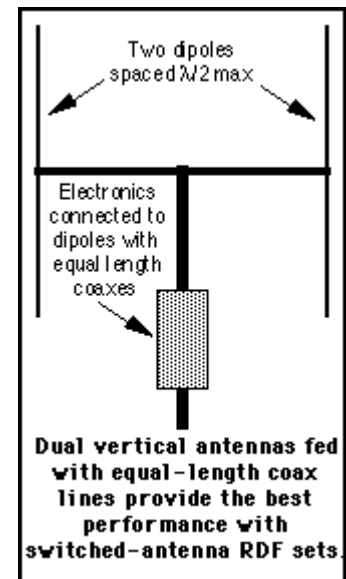
## Other Observations

In the K8DTS QST article photo, the receiver feedline passes over the open end of one antenna loop. This unbalances the antenna pair and can cause major bearing errors on two meters and above. The coax should be routed away from the loop.

The horizontal sections of the bow tie antennas severely degrade RDF performance. Properly spaced coax-fed vertical dipoles are far better for serious use with this type of RDF set. Such an antenna set is easy to make with inexpensive whip antennas and PVC plumbing parts.

The two antennas should be spaced as widely as possible for maximum audible df tone, but spacing must not exceed one half free-space wavelength at the receiving frequency. Approximately 24 inch spacing is practical for both two meters and 125 cm. Coax cables from the HANDI-Finder board to each of the two vertical dipoles must be exactly equal in length.

Wide antenna spacing gives better performance, but it may increase the received tone deviation to the point that the receiver "squelsches out." If this occurs, reduce the tone oscillator frequency to 400 Hz or lower by increasing the value of R1 and/or C1.

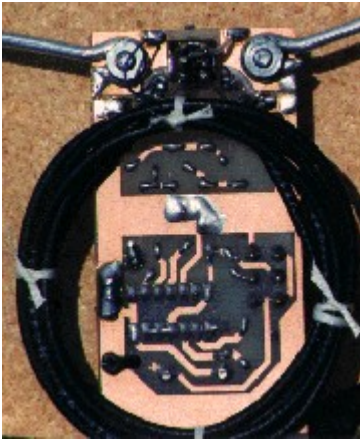


## Footnotes:

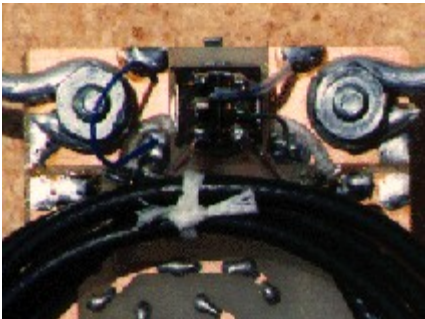
[1] Leskovec, "Build the HANDI-Finder!" QST, May 1993, pp 35-38.

[2] Moell, "Homing In," 73 Amateur Radio, September 1989, pp 58-59 and November 1989, pp 52-53.

The spelling and form of HANDI-Finder constitutes a trademark registered to K8DTS.



The added coax delay line is tied to the rear of the circuit board.



Close-up of top area of board, showing added DPST switch and wire jumper to provide equal signal paths in bidirectional mode.

# Frequently Asked Questions and Answers About T-hunting and RDF

by Joe Moell KØOV

Over 98% of reader response to my articles is via e-mail. The 80-20 rule (or is it 90-10?) definitely applies, because the vast majority of questions are the same. Here they are, along with the answers. Now maybe I can spend more time building and T-hunting!

- Part 1 - Questions about Dopplers (scroll down)
  - Part 2 - Questions about Other RDF Equipment
  - Part 3 - Questions About Transmitters and and Covert Tracking
  - Part 4 - Miscellaneous Questions
- 

## Part 1 - Questions About Dopplers

Q: What is a Doppler? What is a Roanoke Doppler?

A: Nineteenth Century physicist Christian Doppler is credited with creating equations that describe the apparent frequency shifts that result from the relative motion of the sender and receiver of a wave. The Doppler principle is now used for many applications, including dating the universe and catching highway speeders. In radio direction finding, a simulated rotating antenna can be used to determine the direction of an incoming signal using this principle.

When transmitter hunters speak of Dopplers, they usually mean a device with an electronically rotating array of 3 to 8 vertically oriented whips or dipoles and a circular display of 8 to 50 light-emitting diodes. These Doppler add-ons work with VHF and UHF narrowband FM receivers. There are other RDF devices with similar antenna sets and displays that are used with AM receivers (e.g Watson-Watt), but these are not Doppler sets.

The Roanoke Doppler was first published in my book "TRANSMITTER HUNTING---Radio Direction Finding Simplified" (THRDFS), along with an extensive writeup of the theory of operation. The Roanoke Doppler has become the most popular Doppler RDF home construction project. Originated by Chuck Tavaris N4FQ, then improved and documented by Joe Moell KØOV and Thomas Curlee WB6UZZ, the design was named by KØOV to honor the transmitter hunters of Roanoke, Virginia, where N4FQ tested his prototype. This Homing In site is the official support site of the Roanoke Doppler project:

- Three suppliers of circuit boards and parts for the Roanoke Doppler are listed on the Hardware Sources page.
- Updates to the THRDFS documentation of the Roanoke Doppler are in the THRDFS Update page.
- An improved multiband antenna switcher is fully described in the Wide-Range Antenna Array page.

There are other home-construction Doppler projects, but only the ones built from the design in THRDFS and this Web site are Roanoke Dopplers.

Q: I can't locate any 75492 ICs for the Roanoke Doppler display. What shall I do?

A: An improved 16-LED display circuit is in the THRDFS Update page at this site. The 75492 ICs have been eliminated. If you already have a circuit board for this project, you can still use it.

Q: The WA2EBY Doppler circuit in a recent ham magazine looks very much like the Roanoke Doppler. Is it an improvement?

A: That author has utilized many of the design attributes of the Roanoke Doppler, but his unit has no new functions or operating features.

Q: The WA2EBY article states that ECG-555 PIN diodes give poor UHF performance and that ordinary 1N4148 diodes are just as good for a Doppler antenna. Is that true?

A: First, The ECG-555 is an older PIN diode, with unspecified RF series resistance. Newer PIN diode types listed on the Hardware Sources page of this site should perform better. Second, the switcher circuit of the WA2EBY Doppler is not optimized for PIN diodes. For best isolation, RF diodes should be reverse-biased when OFF, not just at zero DC current. That's because the series capacitance of PIN diodes drops dramatically as OFF (reverse) bias goes from 0 to 4 volts. (Examples: HP 5082-3080 goes from 1.1 to 0.4 pF. MPN3404 goes from 2.5 to 1.4 pF.) The lower the capacitance, the less RF gets through (better isolation). The Wide-Range Roanoke Antenna at this Homing In site reverse-biases the OFF diodes, which is an important reason why it performs better than the original Roanoke antenna. The WA2EBY Doppler circuit does not reverse-bias the OFF diodes. I believe that the results of the WA2EBY's loss/isolation tests would have been quite different if it did.

I discuss PIN versus switching/rectifier diodes for Dopplers on page 128 of THRDFS. PIN diodes provide significantly less insertion loss when ON, if biased properly, meaning that a PIN switcher will generally have less loss. More importantly, stray RF rectification is much less likely with PINs. I encountered significant cross-modulation problems using a Doppler with non-PINs, especially when driving near strong RF sources. WA2EBY did not test for cross-modulation when he evaluated diodes. I would welcome input from anyone who has done such tests.

Q: Will the Roanoke Doppler find aircraft Emergency Locator Transmitters (ELTs)?

A: The Roanoke and other ring-antenna Doppler RDF sets can readily track signals in the 120 and 240 MHz aircraft bands, provided that a suitable receiver is used. The Doppler modulation produced by switched whips in a Doppler array is FM, not AM. Therefore, the receiver must have an FM detector to properly process it. I use a venerable Regency MX-7000 scanner for this purpose. Just tune it to the proper frequency (121.5 or 243.0 MHz for ELTs, 121.6 MHz for tests) and set the receiver to the Narrowband FM mode.

The new Wide-Range Antenna Array should be used with the Roanoke Doppler processor for greatest sensitivity and best rejection of multipath distortion. Whips for 121.5 MHz should be 22 inches long, spaced in a square pattern 21 inches on each side. Whip lengths and spacings should be halved for 243.0 MHz operation. The Doppler is intended for vehicle or fixed station use only, not for on-foot operation.

Some high-end scanning receivers (including Icom R1, R10, R100, R7100-2, AOR AR-3000A, AR-8000, Radio Shack Pro-60 and others) can be operated in the Narrowband FM mode on 121.5 MHz. Specification changes may occur, so check to be sure before purchasing. Another idea for experimenters is to install crystals for 121.5 and 121.6 into an old crystal-controlled FM scanner. Everybody wants synthesized scanners nowadays, so "rockbound" sets are cheap and plentiful at swap meets and yard sales. Retune the RF stages as necessary for best sensitivity, because these sets were usually designed for receiving 146 MHz and up.

While a Doppler may be useful in some ELT tracking situations (such as a false alarms from aircraft on an airport runway), it is not a universal tool. ELT signals from actual crashes are usually very weak and of mixed wave polarization. Experienced Civil Air Patrol (CAP) volunteers in my area prefer cubical quads and phased arrays (such as the L-Per) instead of a Doppler when in such weak-signal situations. The photo shows a dual frequency (121.5 and 243.0 MHz) stiff-wire quad built by Bob Miller N6ZHZ, Commander of Brackett Composite Squadron 64 in La Verne, California. He says, "With the quad, I am able to pick up a 243 MHz ELT two to five miles before the L-Per's antenna will hear it. When there are two or three ELTs chirping simultaneously in hangers at an airport, I use a high-gain quad to track one at a time, listening to the differences in tone sweep rate of each one."



An RF attenuator should be used with an RDF quad to allow S-meter bearing readout and to help determine how close you are to the ELT. Plans for suitable quads are in THRDFS. For more on CAP and tales of searches for ELTs, see Homing In for April 1994.

Q: Can I use the Roanoke (or other) Doppler on the 10-meter ham band and/or the 11-meter Citizens Band?

A: It could be done if:

- The receiver is in FM detection mode (not SSB or AM)
- Switcher inductors and capacitors are optimized for this frequency range
- Antennas are 8-foot whips in a square pattern 8 feet by 8 feet

Of course this is not practical on a car, but could be considered for a fixed installation. Remember, Dopplers need carrier-type signals, so you can track amplitude-modulated signals (in FM mode) but not SSB signals. I have experimented with the Roanoke Doppler on 6 meter (50 MHz) FM signals, using resonant whips spaced in a four-foot square. They fit on the roof of the van, but there wasn't enough ground plane area around the whips, and the whips were so tall that they waved around too much while driving. Compared to baseline two-meter performance, this didn't work very well, especially in motion.

Q: I'm thinking of mounting a Doppler RDF antenna on top of my home ham station tower. Any suggestions?

A: One problem with remote operation of the array will be rf losses in the coax. You will probably not have problems with long control lines, although some added protection from lightning-induced transients is in order. For tower mounting, I recommend using four vertical dipoles (which would look like the marine DF antenna photo in THRDFS) instead of whips on a ground plane. This will give better performance by minimizing mutual coupling between the whips.

Q: OK, how about putting the Doppler at our mountaintop repeater site to find jammers on the input?

A: There are many pitfalls in the way of remote mountaintop RDF systems. I get letters regularly from hams who tell me about the wonderful linked RDF systems at repeater sites that they'll be putting on line "real soon now." I encourage them to send me all the details of their results, with photos, so I can tell the world via Homing In. Then I never hear from them again.

You'll probably discover, as they do, that you won't be able to successfully operate a Doppler DF at your repeater site. Here's why:

1. The commutating antenna system, "moving" at an audio rate, will induce the annoying Doppler tone into your repeater receiver and probably into most other receivers at the site, even those on widely different frequencies. This will occur even if you use a separate receiver for the Doppler antenna. Note that this phenomenon is not caused by digital switching noise in the commutating antenna. It is a parasitic RF effect and can occur even if no digital switching noise exists.
2. The cross-modulation products caused by strong signals from your repeater transmitter and other VHF/UHF transmitters at the site into the switched antenna system will make the Doppler insensitive and prone to unreliable indications.

Fast-switched dual-antenna RDF sets such as TDOA's will probably have similar problems. You might consider a slowly rotating beam with some sort of direction indication through the repeater---this was done by the Happy Flyers organization many years ago.

I know of only one successful remote repeater-connected RDF system now in operation, and it is not a Doppler. (If you know of others, please enlighten me.) This system uses a phased array which is switched very slowly (every second or so) to avoid the problems mentioned above. That slow switching is OK in the user's application, because it is intended to track continuously-transmitting ELTs, not ham-band kerchunkers.

So if you want to use Dopplers for remote RDF, put them at sites that are not associated with repeaters or other VHF/UHF radio systems.

Q: I have read several articles on 2-meter Dopplers and they all specify different antenna element spacings. What is the best?

A: No matter how many whips or vertical dipole elements in a Doppler array, the adjacent elements must not be more than  $1/2$  free-space wavelength apart, to avoid ambiguous bearings due to phase steps of greater than 180 degrees. Furthermore, adjacent element spacings of greater than  $1/4$  wavelength will produce phase steps of more than 90 degrees, lowering the level of the recovered audio tone and worsening the signal-to-noise ratio. With that in mind, an optimum adjacent-whip spacing for a 4-whip mobile array for VHF or UHF is slightly less than  $1/4$  wavelength at the highest frequency to be used. Plans for the 4-whip Roanoke Doppler in THRDFS call for 18-inch whip-to-whip spacing, which is 0.22 wavelength.

The array doesn't have to be this big, but don't make it too small, either. Deviation of the recovered Doppler tone is a function of antenna size and speed of rotation, as given by the formula on page 121 of THRDFS. This works out to about 0.5 KHz deviation for the Roanoke Doppler 2-meter antenna, which is a good value. A super-small array such as the 0.07 wavelength-on-a-side mentioned in the Dick Smith literature won't work well, because the recovered Doppler tone out of the receiver would be only 0.1 KHz. It could be readily overpowered by modulation audio and noise.



If you use a mag-mount implementation, remember to place the whips in a perfect square pattern. Measure spacing carefully or make a template. A slightly rectangular or trapezoidal pattern will introduce significant bearing errors at some angles.

Q: What about the spacing if I use more than four whips?

A: Going to 6, 8, 12 or more whips, as provided for in some Doppler sets, provides little improvement if the array size (radius of rotation) is the same as for 4 whips. The Doppler tone deviation is unchanged, though there are fewer high-order harmonics in the recovered audio. (That's unimportant if a very narrow passband filter is used, as in the Roanoke Doppler). Furthermore, the closer element spacing of a same-size-more-whips array increases inter-whip RF coupling, which degrades performance in multipath.

To fully realize the advantages of more whips, the array size must be increased. Consider a two-meter 8-whip array in an octagon pattern of 18 inches per side (i.e. the same adjacent whip spacing as the Roanoke Doppler). Radius of rotation is more than double that of the 4-whip Roanoke, giving over 1 KHz Doppler tone deviation at the same rotation rate. The array aperture is more than doubled, which improves performance in multipath.

However, an array with a diameter of almost 4-1/2 feet won't fit on most vehicles, especially when you remember that you would need 7-1/2 feet total diameter to provide ground plane under the whips. A similar size (in wavelengths) array for the 70 cm band (450 MHz) would be only 2-1/2 feet diameter, which is practical.

Q: Why doesn't the Roanoke Doppler use RF preamps and/or "soft switching" in the antenna system to give more sensitivity and less noise?

A: Questions like this indicate three assumptions:

- Assumption #1: Soft switching eliminates noise
- Assumption #2: Monolithic amps provide increased system sensitivity
- Assumption #3: A Doppler with switched preamps provides the same directional performance as one using PIN diodes.

I disagree with all three assumptions. Here's why:

1. Any Doppler antenna commutation, whether "hard" or "soft," produces additional spectral components in the RF signal to the receiver. It is true that rectangular-wave switching can create some broadband noise, but if the noise is really bad in your system, it's probably because the diodes are biased or driven improperly. Wide-bandwidth receivers such as scanners and handi-talkies are much more susceptible to this problem than mobile radios with good input RF filtering (such as helical resonators). You may find that changing your receiver or adding a helical filter between antenna and receiver improves the performance of your Doppler markedly.

2. Monolithic preamps have gain, which can overcome the small amount of loss in the coax from antenna to receiver. But they usually have a poor noise figure, much worse than most receivers. RF gain ahead of the receiver will worsen any receiver overload and cross-modulation problems. Strong signals can also overload the preamps, distorting the incoming signal phase and degrading the bearing accuracy. (Long-time T-hunter Mike Musick NØQBF has observed this even on signals from one or two miles away!) So unless you are using a very insensitive receiver, antenna preamps will probably do more harm than good. In addition, some Doppler sets hard-switch the preamp supply voltages. This causes the same broadband noise problems in a wideband receiver that improperly biasing the PIN diodes does.
3. As I explained in detail in my Homing In of April 1995 and August 2003, the impedance match (or mismatch) presented to switched-off whips in a Doppler array determines the multipath performance of the system. Preamps usually "look like" 50 ohms, which is undesirable in this application.

In summary, I believe that a properly designed PIN-diode switcher (with correct ON and OFF biasing), when used with a sensitive narrow-range receiver, gives as good or better overall Doppler performance (in both sensitivity and multipath accuracy) than any preamp-based design does, whether hard or soft-switched.

Q: Our club wants to set up some RDF sites to automatically find jammers and display their locations on the Internet. How do we do it?

A: First, understand that you won't be able to use such a system to positively identify RF coming from a specific house or apartment at a distance. Let's say you set up a RDF system with three sites to cover a typical urban area of 20 X 20 miles. For good coverage of the area, the sites will have to be on the perimeter. Assume that you can find enough quiet sites and link them. Now assume that the jammer is right in the middle of the triangle of sites (best case). The intersection of your bearings and their uncertainties will create a polygon with an area of about 4 square miles! That certainly won't be good enough evidence for the FCC. There are about 10 hams per square mile in my city, probably the same as where you live. So you'll still have to do plenty of close-in DFing to verify the actual perpetrator's site and get eyewitness evidence.

Why the large polygon? Because the inherent uncertainty of a bearing from a typical VHF 4-whip Doppler in an urban environment is about +/- 5 degrees, even if you have 10-bit readout precision. Sometimes, the bearing error is even greater, especially at fixed sites. (See Chapter 18 of THRDFS.)

This is not intended to discourage you, just to add a healthy dose of reality. If you want to link up RDF stations, consider using APRS, which allows packet interconnection of a limitless number, both fixed and mobile, close-in or far away, each one displaying their own and everyone else's bearings. Bearings and station locations can be input to APRS either manually or automatically, so even base stations with beams can help out. For more info, see my Homing In columns in 73 Magazine for October 1994, January 1995, and February 1995.

Q: How can I interface my Doppler to APRS?

A: Any of the popular homebrew or kit-built Doppler RDF sets with 8, 16, or 32 LED indicators can be connected to computers using a circuit developed by Robert Swain N7LUE. This includes the popular Roanoke Doppler and the DoppleScAnt from QST in the 70's. Robert's circuit takes the binary information from the LED drivers and outputs a serial RS232 data stream of ASCII characters representing directions. For details, see Doppler-to-APRS interface at this Web site and Homing In for August 1995. A microcontroller-based serial interface that outputs in "Agrelo" format is described on the Web pages of Bob Simmons WB6EYV. He also sells the PicoDopp, a Doppler add-on that includes serial interface, in semi-kit form.

Some sets made by Doppler Systems Incorporated feature RS232 serial output consisting of 3-digit numerical readout of bearing in degrees. Doppler Systems sets in the 3000, 4000, and 5000 series can also be used with N7LUE's interface.

The MicroFinder Doppler set by AHHA! Solutions has serial output of bearing information in "Agrelo" format.

Q: Why are there only 16 LEDs on the Roanoke Doppler?

A: The Roanoke Doppler was designed for the best combination of simplicity and performance. A 16 LED display is usually quite adequate for tracking signals when mobile in urban areas. It gives a rapid indication of which way to drive when time is of essence. I still use my 16-LED unit on the local hunts with good results. When I need higher accuracy for triangulation, I switch to a beam.

Finer resolution is possible with some circuit changes. Tom Curlee WB6UZZ has designed a version with digital readout to the nearest degree. But the basic bearing accuracy of VHF Dopplers on vehicles is typically +/- 5 degrees, so such a display gives a false sense of accuracy. And all these improvements require more complexity. That means more parts to find and greater cost. We have found that most hams want maximum simplicity in projects they have to build themselves. (On the other hand, when they buy a ready-to-use piece of gear, they want maximum bells and whistles.)

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## Part 2 - Questions About Other RDF Equipment

Q: Can you help me get my (choose one) Agrelo, Ramsey, Dick Smith, or "bow-tie" RDF equipment (not in THRDFS) to work?

A: Mail about these units is so frequent that I have posted details at this site.

- Agrelo DFjr Doppler
- Ramsey SlyFox and Foxhound
- Dick Smith Doppler
- "Bow-tie" sets by K8DTS and others

Q: I can't get my Shrunken Quad to work. What's wrong?

A: Most likely you are using the wrong piston trimmers, but it could also be an improperly built balun. Go to More on the Shrunken Quad to find out.

Q: Are there any updates/corrections to \_\_\_\_\_ (fill in your favorite project in TRANSMITTER HUNTING---Radio Direction Finding Simplified)?

A: Click [here](#) to get the latest updates to THRDFS.

Q: Where can I find boards/kits/parts for your projects?

A: I try to locate inexpensive sources for uncommon parts and include them in all my project articles. For updates and additional parts/boards info, jump to the [Hardware Resources](#) page at this site.

### Part 3 - Questions About Transmitters and Covert Tracking



Q: My club wants to start transmitter hunting but first we need a hidden transmitter. What is available?

A: No problem! The transmitting part of T-hunting is easy if you give it a little thought. Keep in mind that no transmitting setup is perfect for all hiding situations. Hiders use a wide variety of equipment, with power output and antenna type depending on the distance to the start point and the level of intended difficulty. You need to determine, for instance, whether you want to do short range on-foot hunting, longer range hunting on bicycles, or still longer range mobile hunts.

For your first mobile hunts, just have someone stay with the transmitter and key it up at appropriate intervals. The hider can read into the mike from a book, or from the club newsletter, or just make comments and urge the hunters on, as NØQEC and KBØIEK of the Lincoln (Nebraska) Amateur Radio Club are doing in the photo at left.

After a few hunts, you may want to put together an unattended transmitting setup, so the hider doesn't have to stay with the rig. For starters, connect your two-meter hand-held or mobile transceiver to a tape recorder playing an endless loop answering machine cassette with an appropriate message and ID. Some hiders like to use a dual-band hand-held and activate it on the subband from another transmitter. Later on, after you gain some experience and have a better idea what suits your needs, consider a dedicated home-built or commercial "foxbox" with tones and a cycling timer for hiding. See the [Hardware Resources](#) page at this site for transmitter controller ideas.



For short-range on-foot hunts in parks, consider complete mini-transmitters like the SquawkBox by Bob Simmons WB6EYV (photo at right). It records and sends short voice messages at adjustable periodic intervals.

More about transmitting gear for on-foot hunts can be found in the [Equipment Ideas for Radio-Orienteering](#) page of this site. And of course there is a complete chapter of clever transmitter hiding ideas in THRDFS.

Q: I need a miniature transmitter to put on my prized possession (sports car, TV set, motorcycle, coonhound) to find it after it wanders away or is stolen/abducted. What is available?

A: Yes, I have actually had inquiries about tracking devices for each of the above examples, and many more! Unfortunately, it is still true that you get what you pay for, and no matter what you pay, there's no assurance of success.

In the under-\$40 category are "experimenter" micro-transmitters such as the TT7-K "Tracking Transmitter Homing Beacon" sold by Amazing Devices. Several miniature transmitter models are available from ElectroKits. These "bugs" typically use the 88-108 MHz FM broadcast band, where low-power unlicensed transmitters are permitted by FCC Part 15. Manufacturers sometimes claim range of three miles or more for these FM micro-transmitters. But that range assumes high-gain antennas on both transmitter and receiver. A practical antenna on a stealth radio tag will seldom be large and efficient enough for that. Furthermore, if one were to actually achieve three-mile range with such a transmitter, that fact would demonstrate that the field strength is in excess of that allowed by FCC Part 15 rules for unlicensed devices in the USA. In other words, it would be illegal operation of a radio transmitter in the eyes of the law.

Some of these experimenter FM-band transmitters use simple L-C tuning, so the transmitter tends shift frequency due to temperature changes, battery voltage droop or proximity to other objects. Furthermore, the FM broadcast band is not suitable for covert operations, as the tag can be tuned in on every home and car radio within range. Usable tracking range is severely limited by interference from powerful broadcast stations. The high level of audio FM deviation ( $\pm 75$  KHz) used by transmitters and receivers in the FM broadcast band is not compatible with narrowband Doppler RDF techniques. Have I convinced you that this is not a good option for most applications?



Also available for about \$40 are micro VHF transmitters for the two-meter ham radio band, such as the MR6 Model Rocket Tracking Transmitter Kit by Ramsey Electronics. A similar postage-stamp sized transmitter project was detailed in *Homing In* for May and September 1993 (photo at left). At about 10 milliwatts, such transmitters are perfect for short-range ham radio transmitter hunts (see previous question). But two-meter frequencies may be used only by licensed ham radio operators, with proper transmitter identification, in accordance with FCC regulations. Plenty of ham radio T-hunters are ready and eager to track down intruders on these frequencies, and they won't be amused if they discover that a non-ham is using their spectrum space to keep track of his cat. There are restrictions and license requirements for the use of other VHF and UHF frequencies at these power levels as well.

A much better choice would be the tiny transmitters and tracking receivers made specifically for tracking mammals, reptiles, birds, fish and even insects. See my RDF links page for commercial suppliers of transmitters and receivers that are popular with two market groups: wildlife researchers and the owners of prize hounds. A good example is Communications Specialists of Orange, California, which sells waterproof tracking transmitters that are about the size of a stack of six quarters (photo at right). They may operate unlicensed under FCC Part 15 rules and are powered by a lithium-ion "coin-cell" battery that lasts about a month. Com-Spec is expanding the market for these radio tags by selling them as the LoCATor Pet Tracking System, the Radio Controlled Airplane ELT System, and the Law Enforcement Tracking System. Range of Part 15 compliant transmitters is a few blocks in the city and up to a mile in open terrain with transmitter and receiver elevated. For official law enforcement use, more powerful transmitters certified to FCC Part 95 are available for greater range.



To save battery life, these critter-tracking transmitters are pulsed for a few tens of milliseconds, every second or so. Their low-power signals are so weak at long range that dual-antenna sets and Dopplers are at a disadvantage. Sensitive narrowband receivers and beam or phased-array antennas work best. Professional grade tracking receivers are quite expensive, but the 30-channel Com-Spec Model PR-30 215 MHz range set with Moxon type directional antenna (photo at right) is a bargain at about \$200. Another option is a consumer-type scanner. It must be multi-mode model such as the Icom IC-R10, Trident TR2400 or Sony ICF-PRO80, which include CW/SSB (BFO) modes. For a tracking antenna, you could build a small cubical quad from plans in THRDFS.

If money is no object, consider the complete RDF tracking systems manufactured by law-enforcement suppliers such as Tracking Products, Inc. Also at the high end of the cost range are "hostage tracking" systems sold by "spy market" distributors such as Surveillance Equipment Group and Airtight Investigations. Note that even with their high prices, there are practical limits on range and battery life. All advertising claims must be taken with more than a grain of salt. None of these providers offer any guarantees that you will locate whatever you're tracking or even that you will hear a trackable signal.

For vehicles, don't overlook LoJack and other commercial tracking systems. LoJack transmitters are installed in an undisclosed place in your vehicle or other important asset and activated automatically when it's reported stolen to the police. Then the signal is received and RDF-tracked by police and sheriff cruisers and aircraft (over 400 in the Los Angeles area alone). Ask the LoJack salesman if the guarantee of your car's return is still offered.

There are also non-RDF vehicle tracking systems such as the new GPS-based CyntrX by Enhanced Vehicle Applications of Wisconsin. It is sold by TechWholesale in Ohio. (Reports from users wanted, please let me know your experiences by e-mail.)

Q: What about a pager-sized tracking device to put on toddlers? Parents would carry a pocket-sized receiver so that they could locate the child in case he/she became lost.

A: As you can imagine, the tracking of children is a much more serious and difficult matter than the tracking of cats and sports cars. Here are just some of the many factors that must be considered if direction-finding technology is to be used:



- Size - For sufficient transmitter power and antenna size for tracking over a wide area, the child's device must be bigger and heavier than most people desire.
- Tracker - An effective tracker needs a "wide aperture" antenna for sensitivity and accuracy, so it cannot be pocket-sized. But parents won't want to haul around a big tracker on every trip to the amusement park.
- Battery Life - The longer the battery must last, the bigger and heavier the transmitter on the child must be.
- Antenna - How do you put an effective antenna next to a child's body without detuning it?
- RF Radiation - Is it safe to have a transmitting antenna next to a child's body?
- Liability - Will the maker be sued if parents cannot quickly find their child with the device?
- Security - How do you keep criminals from tracking lost children, too? What happens if a potential kidnapper finds the lost child before the parents do?

Companies such as Xmark Systems make "perimeter protection" systems that sound an alarm if a tag-wearing individual wanders or is taken out of a protected area. These systems are marketed to health care facilities as alarms to provide early notification of wandering Alzheimers or mental patients, or of infant abductions. They are based on RFID technologies (see next question), so they don't have any direction-finding capabilities. The protected perimeter is non-portable, and the tags can't be used to help find the person once he or she is outside the protected area. Care Trak, Incorporated sells a system of wrist/ankle transmitters that combines perimeter alarm and short-range (up to one mile) RDF tracking. In some localities, RDF-proficient volunteers assist authorities in tracking wandering patients under Project Lifesaver.

Some startup "personal tracking" companies, such as Protect Me Toys (now defunct?), eWorldTrack, Wherify Wireless, and Digital Angel (also defunct?) have received considerable press (and resulting investor attention) for their claims of long-range positioning and tracking. None of their systems use traditional direction finding (i.e. beacon transmitter and human-carried RDF gear). Instead, they are based on wearable Global Positioning Receivers with radio transmitters that beacon the GPS data to trackers directly or via cell/PCS phone systems. Currently available models are relatively large, have short battery life, and require a clear view of the sky for accurate positioning. A savvy child abductor would quickly remove such a device from the child or shield it to render it inoperative.

Other RDF-based systems now on the market for tracking children and adults include the medium- and high-end solutions described in my answer to the previous question, with the usual power, range, and battery limitation. If you have personal experience with any of these products, good or bad, or if you discover any other suitable (or unsuitable) systems, please let me know the details by e-mail.

Q: Our construction company is losing small tools, either by accident (falling into holes) or theft. Can a transmitter be inserted into items like wrenches, drills or grinders, with a RDF unit capable of detecting them inside a car trunk?

A: Radio Direction Finding (RDF) technology is typically done at considerable distance (from yards to miles and beyond). To do that, transmitters require long-term power sources (such as batteries) and antennas. They're usually too large to be placed on or in a hand tool. In addition, the transmitted signal can be detected by anyone with a receiver tuned to the proper frequency, so these systems are not covert.



RFID technology at the jobsite exit is probably more appropriate for this tool-detection application. RFID systems track property and objects at relatively close range with unique codes. For instance, chips (also called tags or transponders) can be implanted in pets to provide positive proof of ownership if the pet strays into the pound or is stolen. A reader device, passed over the chip, detects it and reads out the chip's unique ID code. Similar RFID systems sound an alarm when non-paid-for merchandise passes through the doors of a store. RFID done at greater distance in automatic toll collection systems on and elsewhere. At one time, the FasTrack transponders for southern California toll roads could even be used to quickly pay for a McDonald's burger at the offramp. (This feature was discontinued because so many transponders were being stolen out of cars and then used for this purpose!)

In an ideal situation, the chips are "passive," meaning that they don't require battery power. They usually cannot be detected with conventional receivers, but only by a reader or polling device designed to be used with them.

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## Part 4 - Miscellaneous Questions

Q: I'm ready to go on a mobile T-hunt. How do I find one?

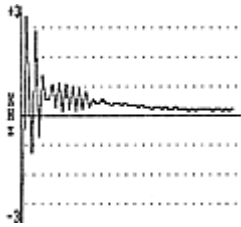
A: If you live in southern California, see the Southern California T-Hunts for Beginners page at this site for monthly mobile T-hunts in the Los Angeles and Orange County area where first-timers are especially welcomed and encouraged. Web sites about other Los Angeles area Saturday night hunts and the southern California All-Day hunts are on the Links page of this site. That page also has links to Web sites and Homing In Correspondents who can tell you about hunts all over the USA, and in some other countries, too. If there are no hunts in your area now, get together with your local ham club members and start them!

Q: My friends and I chat on the local two-meter repeater. Somebody on there transmits beeps and mocks us. We can all hear him on the input of the repeater. Please listen with your direction finding equipment. We need to stop him.

(Believe it or not, requests for me to listen on VHF/UHF have come from hams that are hundreds of miles away from me!) You and your friends need to put some RDF gear on your vehicles and track down the offender yourselves. That's why I have this site and my book --- to help hams like you become proficient at RDF. It's not hard. Once you find him or her, a little friendly persuasion may be all that it takes to eliminate the problem. If not, the chapter on solving malicious interference problems in THRDFS may be helpful in developing a strategy.

You should also find out if the Amateur Auxiliary and Official Observer programs of the American Radio Relay League are active in your area. If so, join them now. Your ARRL Section Manager has more information.

Q: Is it true that transmitters can be "fingerprinted" for positive identification without the user being aware?



A: The concept of transmitter fingerprinting was invented and patented decades ago by Phil Farrell K7PF of Seattle. He licensed his patent/technique to The Boeing Company and to Motron Electronics, which sells equipment for it. The Motron implementation (called TxID) consists of a card that plugs into the expansion slot of a PC, plus software running under DOS. The asking price is higher than most individuals are willing to pay, but it is affordable for repeater clubs. I tested and reviewed the system in *Homing In* for November 1994. The review explains the principles of fingerprinting and shows good and bad points, including comparison of some same-model transmitters. Since then, Motron has added features such as receiver frequency control and readout for remote operation. TxID will control a tape recorder for evidentiary purposes.

A few hams have developed similar fingerprinting systems. The first was "XMIT\_ID" by Richard Rager KB8RLN. It used PC software and an 8-bit Soundblaster card. I have lost contact with Richard and don't know the current status of this project.

"Sherlock" by Malcolm Mallette WA9BVS also runs on a PC and uses its sound card with commercial oscilloscope software. The newest version of Sherlock, which works with Windows XP and Vista, was detailed in a feature article by WA9BVS in the Winter 2006 issue of *CQ VHF* magazine. Click to download this article in PDF format (7 MB), courtesy of WA9BVS.

XMIT\_ID and Sherlock are intended for home experimentation only. Commercial production of any fingerprinting system based on the turn-on frequency changes of a transmitter may infringe on US patent 5,005,210.

Q: What is a Crenshaw Factor and why do I need one?

A: The Crenshaw Factor has been used for many years in southern California T-hunts to normalize mileages and account for odometer differences between various vehicles. Your vehicle's Crenshaw Factor is the odometer mileage you get when you drive a standardized course that runs along Crenshaw Boulevard for about 9 miles. The course was chosen because it is relatively straight and goes up to the start point of the All-day hunts. This makes it easy for hunters to check their factors regularly on the way to a hunt.

A big problem right now is that the landmarks at the start of the Crenshaw have changed. The official start point is in front of a now-gone telephone booth in front of a now-gone Winchell's Doughnut shop on the southwest corner of Artesia Boulevard and Crenshaw. If you can find this point, then all you do is record your odo reading and drive in the left-hand lane along Crenshaw to the stop sign at Crest Road in Rancho Palos Verdes. Your elapsed mileage to that point is your Crenshaw Factor.

Nobody knows exactly what this distance is, but it doesn't matter. To normalize mileages on a T-hunt, each vehicle's elapsed odometer mileage is divided by its Crenshaw factor. The result is in "Crenshaw Units." The team with minimum Crenshaw Units wins.

Example: Say your odometer mileage on the hunt is 35.7 and your Crenshaw factor is 8.8. Your Crenshaw Units are 4.057. You think you won, but another hunter has odo mileage of 36.8 and Crenshaw factor of 9.3. That means his odo reads higher than yours for the same distance traveled. His Crenshaw Units are 3.957, so he beat you.

It is commonplace for two or more hunters to have low mileages within a few tenths of one another. Crenshaw Factors are needed to determine winners on many of our mileage hunts, so it is important for every hunter to have one.

Q: Why has your book's price increased to \$24.95?

A: I don't know. It was done by the new publisher in recent printing runs, without notice to the authors. There are no changes in these print runs, so look for previous-printing books at lower prices, if you can find them.

Q: I have a ham store and would like to carry your book. Do I have to get it from ARRL?

A: Retailers and dealers should get books directly from the publisher. Call McGraw-Hill Trade Order Desk at (800) 722-4726 to place quantity (5 or more) orders.

Q: Is there any difference between ISBN number 007-1560068 and ISBN number 0-8306-2701-4 for your book?

A: The book has two ISBN numbers because one was assigned to it by TAB Books originally, and the second was assigned by McGraw-Hill when McGraw-Hill acquired TAB Books. Booksellers might show stock in either ISBN number, depending on when they ordered the book and put it into their computer system. Sorry for the confusion, but I have had no control over this process.

Q: Why don't you sell copies of old Homing In columns or post them here on the Web?

A: For logistic and contractual reasons, I don't mail out or sell copies of magazine articles I have written. Furthermore, they cannot be posted here or on any other Web site, with only a few exceptions. Your fastest source for back issues of ham magazines is probably a visit to your local library. A nearby ham radio store may also have recent issues in stock. Many ham clubs maintain ham magazine libraries for their members.

Q: Can I make and sell kits and boards for projects in your books and articles?

A: Since Tom Curlee and I don't have the time to get into the board/kit business, we welcome other enterprising hams supplying these products. However, our publishers insist that we protect the copyrighted material appearing in the book and my magazine columns. Kit/board suppliers must not duplicate, sell, or give away any of the TAB/McGraw-Hill or 73 documentation of the projects. Kit/board buyers should be urged to purchase THRDFS for the tune-up, calibration, installation, and operating details. This works out well, because some of our kit suppliers are making extra money by retailing the book! To purchase books wholesale (5 or more copies), call the "trade order" desk at TAB/Mc-Graw-Hill. Please note that Tom and I support the circuits in our book, but we accept no responsibility for performance of third-party boards and products.

## Hardware Resources for RDF Home Builders

Sources for the Roanoke Doppler project

Complete construction plans for the Roanoke Doppler are in Transmitter Hunting---Radio Direction Finding Simplified (THRDFS). The following are sources of printed circuit boards for the display unit. Some may also offer critical parts, complete kits, and/or wired/tested units.

- Directional Systems: Jim Sorenson KA4IIA, PO Box 81881, Conyers, GA 30094, [ka4iia@radio.org](mailto:ka4iia@radio.org)
- FAR Circuits: Fred Reimers KF9GX, 18N640 Field Court, Dundee, IL 60118, [farcir@ais.net](mailto:farcir@ais.net) or <http://www.farcircuits.net> (847) 836-9148. Users have reported errors on older versions of the display boards. They have been corrected in display boards now being shipped. FAR Circuits also has a circuit board for the Wide-Range Antenna Array. There is a minor correction to the marking on this board. [Click here](#) for more information.
- Stephen Douglas K6HZZ of Sacramento, CA, [k6hzz@arrl.net](mailto:k6hzz@arrl.net) or <http://www.marshwildman.com/doppler.htm>. Please note the board errata information on his site.

Disclaimer: The information above, and elsewhere on this page, is provided for the convenience of readers only. These suppliers are independent entities. They have no business association with Joe Moell or Tab/McGraw-Hill. A listing on this page does not constitute endorsement of products. Contact these suppliers directly for offers and prices.

Boards are no longer available from Ed Greany KB6DOL or Tom Lewis AB5CK.

## Sources for RF attenuator projects

Resistive RF attenuators are best suited for mobile HF and VHF T-hunting with directional antennas such as loops, yagis and quads. Pete Ostapchuk N9SFX sells parts for resistive attenuators, including a 6-section enclosure machined from 6061-T6 aluminum bar stock and engraved with attenuation values. Also available from him are switches, resistors and connectors. Plans for his project are in QST Magazine for May 1998. Send e-mail to [n9sfx@aol.com](mailto:n9sfx@aol.com) for details and prices. The above disclaimer applies.

Another source of resistive RF attenuators is National RF, Incorporated (formerly Radio Engineers) of San Diego, CA.

For on-foot VHF/UHF "sniffing" and international-style foxhunting with a beam and handi-talkie or scanner, an "offset" or "active" attenuator is better because it eliminates the problem of signal leakage directly into the receiver's case. Plans for an active attenuator are at this Homing In site, [click here](#).

## Sources for fox-boxes

Hidden transmitter controllers, sometimes called "fox-boxes" are units that provide audio and timed key-up/key-down (push-to-talk) outputs. A fox-box turns an ordinary handi-talkie or mobile transceiver into a cycling hidden T. Here are four fox-box projects for home construction:

1. The Un-Music Box by KØOV is an easy-to-build project using common easy-to-obtain CMOS ICs. No microprocessor programming is required. Provides on-off cycling or continuous transmissions. Callsign is hand-programmed using two switches; shift register memory has battery backup. Complete plans in the book TRANSMITTER HUNTING---Radio Direction Finding Simplified. You can remote control the Un-Music Box with a surplus pager receiver using plans in Homing In for December 1990.
2. PicCon by Byon Garrabrant N6BG uses a Microchip PIC microcontroller and has a variety of programmed on/off modes and tone sequences for mobile T-hunts as well as IARU-standard MOE/MOI/MOS audio, timing and synchronization for international-style radio-orienteeing. DTMF remote control and programming with your HT or external receiver. Delayed turn-on and turn-off timers. Callsign and programming info are held in EEPROM when power is removed. Reviewed in Homing In for March 1997. Complete kit is available from N6BG.
3. TBOX by Ron Seese N6MBR uses an 80C51 microprocessor to provide three programmed tone sequences and/or a CW message. User-programmable on and off times in intervals from seconds to hours. Programmed via RS-232 serial port using commands similar to packet TNCs. Non-volatile memory (EEPROM) holds programming and message when powered down. Optional SmartWatch clock turns fox on automatically at programmed time. Plans for basic unit are in Homing In for October 1991. Assembly, object and binary files for the microcontroller program (10K total) are available at this Homing In site. Contact N6MBR regarding availability of kits and critical parts.
4. Francois Tremblay VE2JX and Jacques Brodeur VE2EMM of Montreal have designed a new PIC-based foxbox for international-style hunts with MOE/MOI/MOS audio, synchronization of 2 to 7 foxes, delayed start of up to 3-1/2 hours in 1/2-hour increments, and automatic shutoff after four hours of operation. Callsign is held in non-volatile flash memory. Callsign changes and mode setup are easily done with dipswitches. This project is fully described in Homing In for April 1998.

## Sources of PIN type RF diodes

For maximum receiving sensitivity and minimum problems with cross-modulation, good RF PIN diodes must be used in hard-switched dopplers such as the Roanoke Doppler. Breakdown voltage and power rating of the PIN diodes are not important in low-level receiving circuits. (You aren't going to transmit through the switcher, are you?) For low loss and good sensitivity, the diodes should have low RF resistance ( $R_s$ ) at the expected forward DC bias current (7.5 mA for the wideband switcher). They should have low capacitance ( $C_t$ ) at the reverse bias off-state voltage. Effective carrier lifetime and reverse recovery time ( $T_{rr}$ ) should be short. (PIN diodes with long carrier lifetime are ideal for current-controlled RF attenuators, but that's not what we want in this application.) Keep the diode leads very short to minimize inductance and make sure signal path lengths, including diodes, are equal for all elements in the array.

Suitable PIN diodes include:

- Narda KS3542 -- DO-34 package, click for data sheet. A ham with a supply of these diodes has offered to make them available in small quantities to home builders of RDF equipment. Send e-mail to me for more information.  
  
Philips NTE555 or ECG555 -- "Replacement" type semiconductor available at local electronics parts houses all over the country. Even some giant computer stores such as Fry's Electronics carry NTE parts. Priced \$1.50 to \$2.00 each. This is an older part with tab leads and unspecified series RF resistance.
- Agilent Technologies (formerly Hewlett-Packard) surface-mount PIN diodes -- Surface-mount parts are best if you're building a doppler for UHF (400 MHz and up). Three types used to be easy to get from RadioShack.com but are apparently no longer available there. Try Arrow Electronics, a major parts distributor in in Melville, New York. The Agilent HSMP-3892 or HSMP-3893 are good choices for a series doppler switcher such as the wideband array on this Web site. On the other hand, the HSMP-3820 is optimized for a shunt switcher such as the one in THRDFS.
- Motorola MPN3404 -- In TO92-style plastic package. 50 cents each or ten for \$4.50 at Circuit Specialists, 220 S. Country Club Dr. #2, Mesa, AZ 85210 (800) 528-1417. \$1.00 each from Debco Electronics, 4025 Edwards Road, Cincinnati, OH 45209 (513) 531-4499. Advertised price is 60 cents each at Dan's Small Parts and Kits, Box 3634, Missoula, MT 59806-3634 (406) 258-2782.
- TRW A5S303 -- Axial lead device formerly available from Tanner Electronics in Carrollton, TX (214) 242-8702. Does anyone have a new source?
- Agilent Technologies 5082-3077 -- Axial-lead low- $R_s$  device available from Newark Electronics. Newark also carries Agilent 5082-3081 and 5082-3080, which are long-carrier-lifetime parts intended for variable RF attenuators and thus not suitable for doppler switches.
- Motorola MMBV3401LT1 -- Surface-mount replacement for the now-discontinued MPN3401. Available from Motorola industrial distributors. Not suitable for perf-board construction.

After I bought some Motorola PIN diodes from Debco Electronics, I mentioned their availability in *Homing In* for April 1995. A reader wrote to me after publication to say that Debco was astonished at the response. The order-taker said that they hadn't sold a PIN diode for over a year and then after the article came out they began selling like hotcakes. Who says hams don't build nowadays?

## Other Sources of RF Parts

Hard-to-find RF parts such as air variable capacitors for tuning HF loop antennas can sometimes be found at dealers of "overstocked" or "industrial surplus" components. Here are three to try:

- Bogdan Electronic Research & Development (Jim & Carolyn), PO Box 62, Lakewood, CA 90712, (562) 634-0911. They sell RF parts by mail and are often at southern California swap meets, too. Note: Jim says that the margin on small quantities of RF parts is so low that it's not cost-effective for him to return calls. (I know the problem!) Therefore, please use e-mail or call back to catch him or Carolyn "live" on the phone if you get a recording when you call.
- All Electronics, PO Box 567, Van Nuys, CA 91408.
- Alltronics, 2300 Zanker Road, San Jose, CA 95131, (408) 943-9773.

For more information about sealed RF "piston" trimmer capacitors and sources, see the *Shrunken Quad* page at this site.

Ferrite beads and cores for the dual-polarization quad (see *Homing In* for February 1997) and other RF projects are available by mail order from Amidon Associates. Locals can save shipping charges by picking up orders at 240 Briggs Avenue, Costa Mesa, California, during normal business hours. Call in advance to 800-898-1883 or 714-850-4660.

ByteMark Corporation, 7714 Trent Street Orlando, FL 32807 (407) 679-3184 also carries Amidon ferrite components and has technical information about Amidon ferrite and iron powder products on its Web site. In addition, ByteMark sells a Windows-based program for calculating the turns for coils on various Amidon cores.

The Philmore line of packaged electronic parts includes unusual items such as Amidon T50-6 cores (used in the ATX80 80-meter fox transmitter), International Rectifier HEXFETs, MPF-102 JFETs, etc. Unfortunately the Philmore Web site does not have a complete product list, but it does include a list of local distributors of these parts.

Crystals for 80-meter foxboxes are available from Brian Carling AF4K in Sanford, FL. He also sells some crystal-can oscillators that may be suitable for building offset attenuators.

Jerry Boyd WB8WFK provides this feedback on ON7YD's Fox Transmitter for 80 meters (ATX80), which was featured in *73 Magazine* for November 2000: "Motorola MC14001B Quad-NOR ICs from Radio Shack (part number 276-2401) didn't work. The oscillator would not start properly. I tried 6 different ones and they all acted the same. I put in an old Fairchild CD4001B Quad-NOR and now it works with no problem. I downloaded data sheets from the manufacturers' Web sites and the internal schematics are indeed different." Fairchild ICs are available from many suppliers, including Digi-Key. KØOV's six transmitters use Signetics (Philips) CD4001B's packaged by Jim-Pak and sold by local parts suppliers nationwide -- they all work fine.



### **Sources for building polar-plot bearing readouts**

I have many requests for sources of unusual electromechanical parts used in two-dimensional bearing indicators such as the KK6CU motorized quad, the WB8WFK and KD6IFZ computer displays, and the NØMKJ Foxcopter. (See the Homing In Index page at this site for articles describing these RDF systems.)

For (relatively) inexpensive surplus sine-cosine potentiometers as used in the KK6CU motorized quad, try Servo Systems Company, 115 Main Road, PO Box 97, Montville, NJ 07045, (201) 335-1007, in USA (800) 922-1103. The last catalog I received from this company included sin-cos pots by Litton, Duncan, N.E.I., Samarius, and Gamewell. There were continuous turning and single-turn models with prices from US\$18.50 to \$69.50.

For a "Cadillac" system, check out these contactless sin-cos resolvers using internal magnets and Hall effect sensors, designed to be rotated at up to 10,000 RPM: Elweco Incorporated, PO Box 909, Painesville, OH 44077-0909, (440) 254-1716.

Small industrial rotary joints (slip rings) in the \$30 price class are suitable for low-voltage uses. NØMKJ used one of these for the two-meter coax feed in his Foxcopter. They are available from McMaster-Carr Supply Company, PO Box 54960, Los Angeles, CA 90054-0960, (310) 692-5911.

Another promising source of rotary joints is Mercotac, Incorporated, 6195 Corte del Cedro #100, Carlsbad, CA 92009, (619) 431-7723. Unfortunately the Web site does not list prices. If you use one of these products in your RDF system, please let me know how it works and what it costs.

Inexpensive electronic compasses with digital output (Vector 2X series) are manufactured by Precision Navigation Incorporated, 1235 Pear Avenue, Suite 111, Mountain View, CA 94043 (415) 962-8777. They are sold by Jameco Electronic Components, 1355 Shoreway Road, Belmont, CA 94002, (415) 592-8097, in USA (800) 831-4242. They are also sold by JDR Microdevices, 1850 South 10th Street, San Jose, CA 95112, (408) 494-1400, in USA (800) 538-5000.

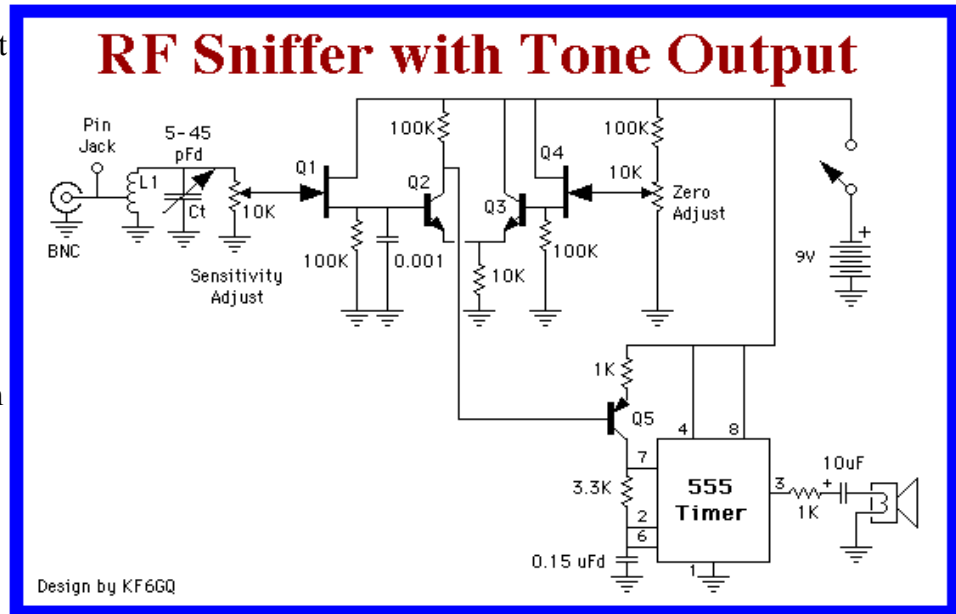
From Peter PB2RDF comes this suggestion for a source of obsolete and out-of-stock electronic components for replacement or for older designs: 1-Source Electronic Components, 591-B Bicycle Path, Port Jefferson Station, NY 11776 (800) 966-8826 or (631) 642-2479.

## RF Sniffer with Tone Output

Here is a neat Sniffer designed by Don, KF6GQ. It produces an audible tone which rises in frequency as the signal gets stronger. It uses 5 transistors and a 555 timer IC.

For a 1 Watt transmitter, sniffing range is about 225 feet using a 3 element Quad beam, or about 100 feet with a 1/4 wave spike antenna.

The Zero Adjust pot is used to set the tone frequency when there is no RF. With knob, field adjustable.



The Sensitivity Adjustment pot is used to control how much signal is required to produce the maximum tone frequency. With knob, field adjustable.

### Parts Not Given on Schematic

L1 = 5 turns, 1/4 inch form tapped at 1.5 turns. (For 2 meters)

Ct = Small RF trimmer capacitor, adjustable over about 5 to 45 pFd. Not critical. Screwdriver adjustment is fine.

Q1 & Q4 = 2N5457 (silicon J-FET)

Q2 & Q3 = 2N3904 (silicon NPN)

Q5 = 2N3906 (silicon PNP)

NOTE: Just about any small-signal silicon transistor of the same general type as specified should work.

### Contact Information

George (Russ) Andrews, K6BMG

BMG Engineering, Inc.

9935 Garibaldi Avenue

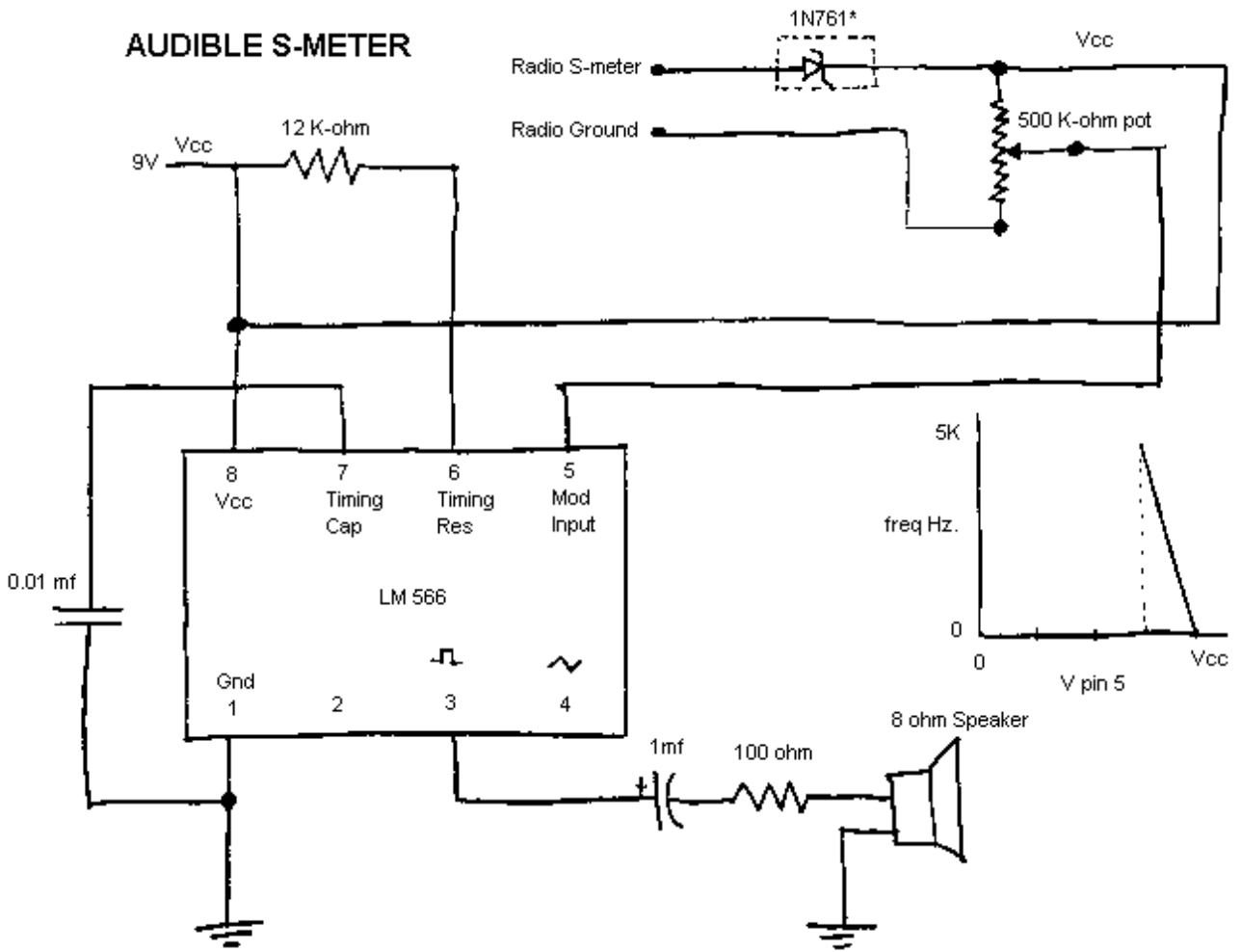
Temple City, CA 91780 USA

Phone: 1(626)285-6963

FAX: 1(626)285-1684 (dedicated line, automatic)

Web: <http://members.aol.com/bmgenginc>

# Audible S-Meter



## The Montreal Audio FS-Meter

### PARTS LIST, 27 JULY 99

R1 = 2M7 1/4 W (2.7 mohms)

R2 = 47R 1/4 W (47 ohms)

R3 = 100K 1/4 W

R4 = 10K 1/4 W

R5 = 10K 1/4 W

R6 = 1K0 1/4 W or 1K0 trimm pot DK# D4AA12-ND for volume adjustment  
if needed (1 kohm)

RV1 = 1M0 to 5M0 POTENTIOMETER (GAIN) (1 to 5 mohms)

RV2 = 10K 1T TRIMM POT, DK# D4AA14-ND

C1 = 2-20 pF RED TRIMMING CAP DK# SG20015-ND

C2 = .001 uF CER

C3, C4 = .1uF CER

C5 = 1 uF ELECTROLITIC 16V

C6 = 100 uF ELECTROLITIC 16V, Mount laying down on the board

C7 = .01 uF CER

D1 = 1N34, 1N60 ETC GERMANIUM DIODE

IC1 = MAXIM MAX495CPA RAIL TO RAIL SINGLE SUPPLY OP-AMP, DK# MAX495CPA-ND

IC2 = MICROCHIP PIC12C671/JW, UPGRADABLE, DK# PIC12C671/JW-ND

OR FOR LOWER COST, PIC12C671-04/P, NOT UPGRADABLE, DK# PIC12C671-04/P

L1 = 2T, 1/4" ID ON COLD END OF L1 #20

L2 = 5T, 1/4" ID AIR WOUND #20

SW1 = SPST MINIATURE SWITCH

### MISC:

3 = AAA BATTERY HOLDER

1 = 18 pins IC socket or 2 = 8 pins IC sockets

1/8" EARPHONE JACK MONO

SINGLE EARPHONE

BNC CHASSIS JACK

PUNCH BOARD OR PCB

METAL BOX for shielding

