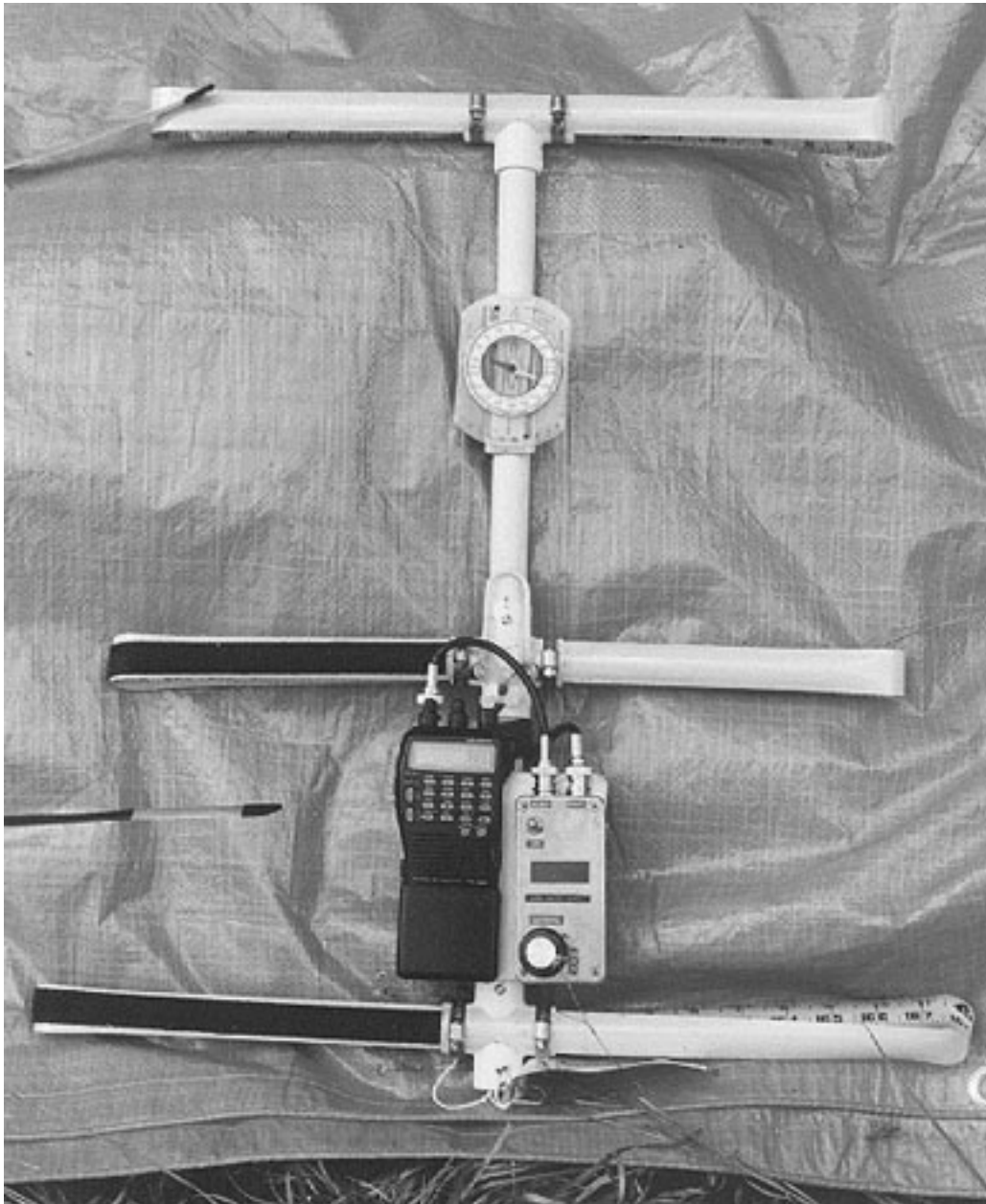


RDF and Hidden Transmitter Hunting



Barrie Amateur Radio Club
Fox Hunt

Radio Direction Finding

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updated March 2006

Radio direction finding or RDF has been around since before World War One. From the time of the invention of radio, there has been a desire to know from what direction a radio signal was arriving at the listener's radio receiver.

Amateur Radio has found several uses for RDF:

- Hunting down interfering radio signals, both accidental and malicious interference to repeaters (affecting both ham and commercial communications, including emergency services).
- Helping to locate downed aircraft by DFing their emergency locator beacons (ELT).
- The entertaining sport of "fox", "bunny" or T-hunting.

It is "fox hunting" that has spread through many ham radio clubs around the world as a very exciting and fun aspect of the hobby. Fox hunting can take many forms of transmitter hunting, from a person hiding within a few blocks of the starting point with his handheld and periodically making a transmission while others try to find him on foot using directional antennas; to a competition with multiple unmanned automatic transmitters scattered over a course that can be several hundred kilometers long – the entrants being required to find each transmitter in proper order with a minimum number of kilometers driven. Another variation includes jogging or running from one low power fox transmitter to another while carrying RDF equipment.

What makes fox hunting so popular?

- The social aspect of getting together with others with similar interests.
- Anyone can take part - you don't need a ham license since only a receiver is required.
- The satisfaction of building your own equipment such as an antenna for use in RDFing.
- The fun and competitiveness of the hunt, which also can involve both physical and mental exercise (walking while searching, and the calculations and map plotting required to determine where the fox may be located).
- The outdoor aspect of the sport (sunshine and fresh air).

The "fox" has several basic requirements:

- Be able to move to a location unobserved by those who plan on taking part in the hunt.
- Be able to hide well enough at the location he has chosen so he will not be accidentally spotted. The hunters should have to almost stumble over him in order to find him.
- Be equipped with enough handheld battery capacity, water, lunch etc. for the expected duration of the hunt - it could be one or two hours or more in length, depending on the distance the fox is from the starting point and how well he is able to confuse the hunters as to his probable location.

An unmanned, automatic fox transmitter is the better choice since it can be hidden hours or even a day before the hunt and can be turned on remotely via a sequence of touch tones.

The “hunter” needs several things to make it possible for him to find the fox.

- A 2 meter portable receiver with some sort of signal strength indicator.
- A portable antenna with directional characteristics so that the signal peak or null can be used to determine the direction to the fox.
- A means to attenuate or reduce the signal strength from the fox transmitter so that it will remain near the halfway point on the receiver’s signal strength indicator. As you get nearer to the fox transmitter, the signal will keep getting stronger - it will have to be attenuated to enable you to be able to locate a signal peak or null.

A fox frequency of 146.565 MHz in the 2 meter ham band is most popular in Canada and the U.S., although any open simplex frequency could be used.

Any 2 meter handheld transceiver can be used, or a portable scanner covering the 2M band. During the mobile part of the hunt when you are driving toward the probable location of the fox, a mobile 2M rig could be used, but eventually you are going to have to get out of the car and complete the final stage of the hunt on foot – so a portable receiver is a requirement.

Some of the best antennas for fox hunting are homemade ones such as the quad and yagi designs included here. There are many other types of RDF antennas such as the loop or ZL special in addition to many electronically augmented designs such as the TDOA (time difference of arrival) and switched antenna system.

Occasionally you can find a bargain at a flea market on a suitable RF attenuator for use on 2M. It can be either a switched type or a slider type like the design included here, but in order to be useful for RDF and fox hunts, it should be capable of 60 to 100 dB of attenuation (of course 2 attenuators can be connected in series to obtain this value). Just remember that you cannot transmit through an attenuator without damaging either it or your transmitter.

What – no equipment?

Just because you don’t have a radio, antenna or other equipment required for fox hunting, doesn’t mean you can’t get in on the fun too. Team up with someone else, you can help with map plotting and navigation or even driving. This will allow you to learn some of the tricks and techniques used by others. If you have a portable radio or scanner but no antenna or attenuator – then you can get involved in the hunt by trying a few of these tricks.

- Take off the antenna to reduce the signal strength of the fox when it becomes strong, or if that’s too much of a decrease, try a small nail, paper clip or piece of wire for an antenna. You just need enough signal strength to get a mid-scale reading on your meter.
- Next try “body fade” to determine what direction the fox is transmitting from. This involves placing your radio receiver close to your chest and slowly turning around until you find a minimum signal strength from the fox. You now know that the hidden transmitter is behind you, since it was your body getting in path of the signal that caused it to decrease.
- You can determine when a signal is weakest by listening to the amount of noise on the signal – full quieting into your receiver means strong, and lots of “hiss” means weak. Often the squelch will cut off the audio when it is weak, this can also be useful.

- Variations on the “body fade” method are to use a rectangle of cardboard with aluminum foil glued to one side. Hold or fasten your handheld up against it so that the foil is blocking the direct path from the fox transmitter to your radio or rubber duck antenna. Then slowly turn around until the foil “shield” blocks the maximum amount of signal. Another idea is to place your handheld inside a large metal can with only one side open to let in the RF.
- If you are close to the fox, the signal may be just too strong to reduce it to a half scale reading on your S-meter. If this is the case, try tuning your receiver off frequency 5 KHz (higher or lower). You can also tune to your receiver’s less sensitive image frequency.
- In cases where the strong transmitter RF is finding its way into the receiver through its plastic case, try wrapping the radio in aluminum foil (just make a small hole so you can see the signal strength meter), making sure the foil is in good electrical contact with the grounded part of the radio’s antenna connector. You should tape over any battery charge contacts on your battery pack first. This will work as an RF shield so that the signal will have to enter the radio through the antenna connector.

Let’s get started

As soon as the start of the hunt is declared, listen for the fox on the receiver, rotating your directional antenna to find a most probable direction. Hold your antenna out to the side at arms-length and turn your body around slowly, this will minimize the effect of your own body on the directional antenna pattern. On a map of the area, pencil in a straight line along the estimated bearing, starting from your present location.

If the fox transmits long enough, you might want to change your position by 10 or 20 feet perpendicular to the estimated direction and take another reading to see if it still agrees. Stay away from parked cars or other metal objects that can block the signal or cause a reflection of the RF from the fox transmitter.

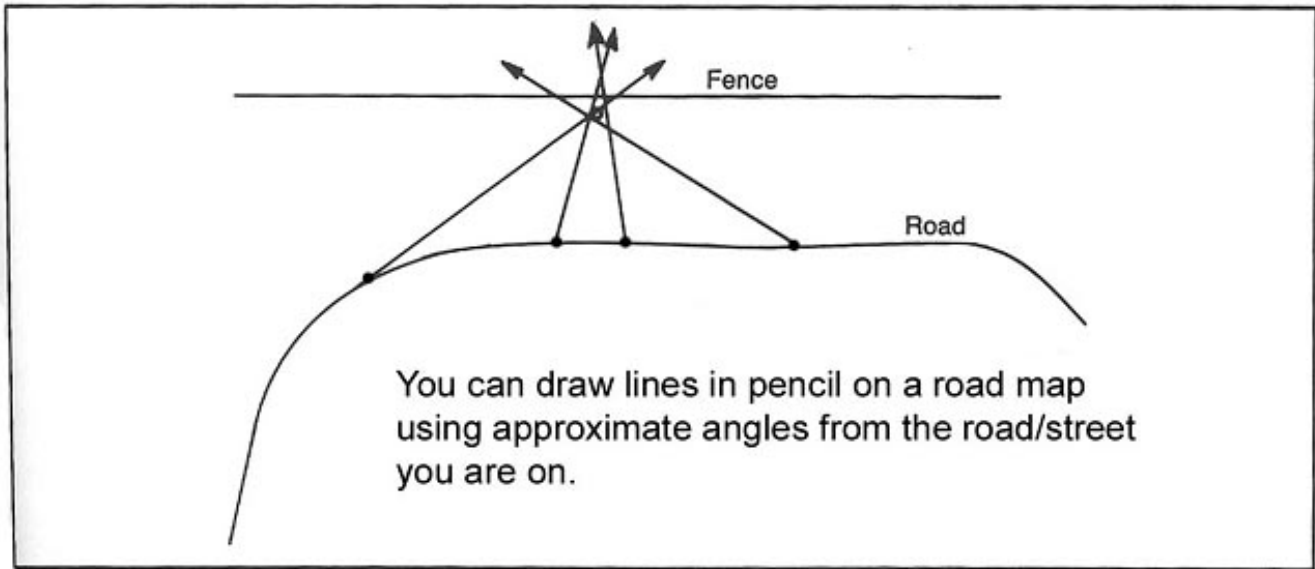
Its now time to drive closer to the fox, using your map as a guide as to which streets/roads to take - remember that the fox might be fairly close and using low power, or several kilometers away using 1 to 5 watts of power. Stop periodically at the expected fox transmit times and take another bearing – pencil each new one on your map. Hopefully you won’t be traveling in a direct line toward the fox when taking each new bearing, you want to be far enough to one side so that the lines you draw on the map show an intersecting area where the fox may be located.

Don’t get fooled

Not being familiar with your fox hunting equipment, or reflections of the fox transmitter signal off buildings hills or other objects (such as nearby cars) could lead you in the wrong direction. You should practice taking bearings on transmitters (such as a local repeater, or a friend’s handheld transceiver) that you know the location of. This will help you learn the shape of the antenna pattern you are using, and the effects of holding your antenna horizontally or vertically. Sometimes it is better to use the “null” or minimum signal direction of your antenna instead of the “peak” or maximum signal direction.

Remember that the bearings you are plotting during a fox hunt are only approximate and could be in error by plus/minus 20 degrees or more. This will still let you estimate an area of the city that the fox could probably be located in. As you get closer to the fox and take a few bearings that cross on your map, the probable search area will get smaller.

Be sure to take (and plot on a map) enough RDF readings to enable you to discard any that don't make sense.



Example of triangulation from a vehicle on the road to determine off-road transmitter location.

Once the bearings you are plotting on a map show that you are getting very close to the fox, it's time to start searching on foot. Even as you get to within 100 feet from the hidden transmitter, you must watch out for reflections or too much signal getting into your receiver causing erratic and changing directions. Sometimes the last couple of hundred feet can be the most difficult, especially if the fox is well hidden from casual or accidental discovery. Read the section "What – no equipment?" above, for some ideas.

Some solutions to the problem of too much signal strength:

- Use a dual band transceiver and a directional 440MHz antenna. Tune the radio to the third harmonic of the fox transmitter – 439.695MHz. The amount of 3rd harmonic RF radiated by the 2 meter fox transmitter is very low – in the milliwatt range.
- Use an "offset attenuator" between the directional antenna and the receiver. This electronic device mixes the fox transmitter signal on 146.565MHz with an internal 4MHz (for example) crystal oscillator so as to cause the fox to appear on your receiver either 4MHz lower or higher than the original signal. You would tune the receiver to either 142.565 or 150.565MHz depending on which frequency was the most free from interference. The sensitivity of the receiver is adjusted by varying the amount of 4MHz signal that is mixed with the fox transmitter signal.
- An "RF sniffer" or field strength meter and a directional antenna. This is not a radio receiver but rather a much less sensitive device using a tuned circuit to reduce the effect of signals outside the frequency of interest. The signal strength is indicated on a meter or bar graph display. This is a case of using a relatively "deaf" receiving device so that it is not overloaded by the strong signals encountered near the fox transmitter.

The more fox hunts you can get involved in, the more experience you will gain in how to (and how not to) find a hidden transmitter.

Some rules of the game (lets play fair)

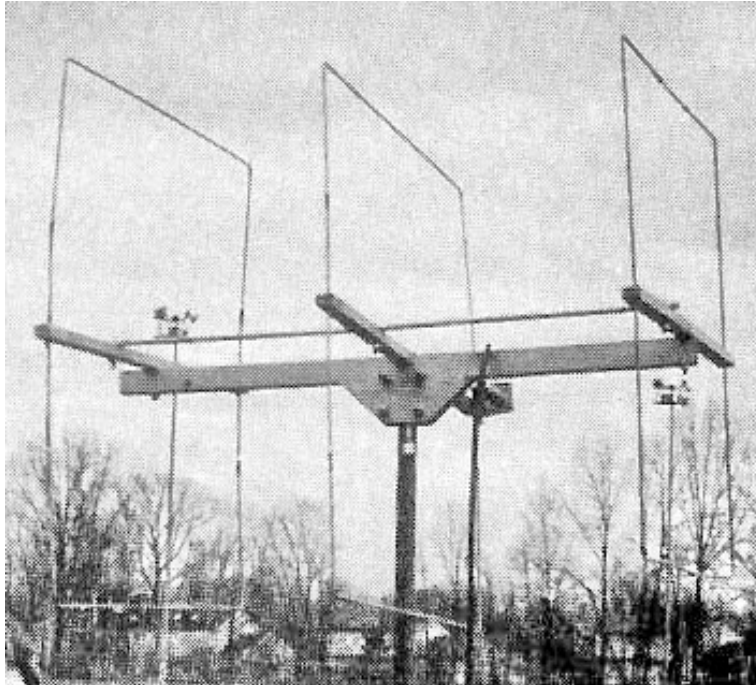
- **Do not transmit on the fox frequency** (146.565 MHz or other designated), only the hidden transmitter uses this frequency. Use a local repeater (such as VE3RAG on 147.000+) for your communications so that you do not interfere with others in the hunt.
- **The hidden transmitter will always be located on publicly accessible property.** You should never be required to trespass on private property. The fox may appear to be located on private property, but there will be access to its location, even though there may not appear to be (look for a less obvious route)
- **Two separate categories** should be used to classify the hunter's equipment (this should preferably be done before the fox hunt starts):
 1. Those using manually operated and aimed non-electronic antennas such as the Yagi, Quad, Switched Cardioid, ZL Special, Phased Array, Loop, etc.
 2. Those using electronic or automated antenna systems such as the Doppler Systems unit, Roanoke Doppler, Little L-per DF, Happy Flyers DF, BMG SuperDF etc. Note that a mechanically spun Yagi or Quad using computer augmented or oscilloscope pattern display and other similar systems fall into this category.

The category 1 entrant's use of accessories such as switched, adjustable or offset type attenuators, external S-meters, external filters or preamps and electronic field strength meters such as the Sniff-Amp etc. do not affect his classification as category 1.

The use of two categories means there will be two winners for each fox hunt – and it helps avoid a technology race where only the highest-tech user can win a fox hunt.

- **An intermittent transmitting pattern** will usually be used by the fox. This could be transmit for 30 or 60 seconds, silent for 5 or even 10 minutes. The transmit start time is “by the clock”, which allows searchers to know exactly when the next transmission will occur. The driver can then pull over to the side of the road safely and prepare his RDF equipment in preparation for the next transmission.
- **A tear-off sequence of numbered sheets of paper** can be used (this is a requirement when the fox transmitter is automated and un-manned). The first person to find the fox gets to tear off the first sheet marked with a “1”. Each subsequent hunter who finds the fox takes the next numbered sheet of paper. Don't feel bad if you didn't get sheet number 1, remember the two category system – you might still be the first in your category.
- **After finding the fox, leave the area** – don't spoil it for everybody else by hanging around and thus tipping off others that something is up. Just tear off the numbered sheet of paper and exit like nothing was there. It's OK to mislead others who may be watching you by pretending to still search for the fox after you found it.
- **Don't say that you found the fox** over the air or talk about how you found the fox. You can brag as much as you want after the hunt is over.
– break this rule and you could be disqualified.
- **The end of the hunt can be declared after a reasonable amount of time** such as after two hours. In some cases it is not feasible to wait until every last person in the hunt has found the fox – **OR**
- **The end can be declared after the 1st, 2nd or 3rd place winners of each category are known.** This works if each hunter were to immediately take his numbered sheet of paper to a “judge” who would declare the end of the hunt. The judge can be the person who hid the automated fox transmitter, since he cannot take part in the hunt.

Folding 3 Element 2M Quad by WX8G



This folding three-element quad is designed to work well across the entire 2 meter band, and has excellent gain and front-to-back ratio, as well as good side rejection. It is also easily folded, and unfolds in a matter of seconds. The secret to the folding quad is a notch in the boom which the driven element drops into when unfolded. The driven element is mounted to the boom with a spring-loaded bolt (see Figure 3) which holds it firmly in position. To fold the quad, you simply hold the boom with your hand while pushing up with your thumb on the spring loaded bolt. When the support for the driven element clears the notch, you simply fold it up. The elements are connected together with a wooden tie rod which keeps them parallel to one another. In its folded position, the folding quad easily fits into the trunk of the average compact car, which makes it ideal for fox hunting.

Using the dimensions shown in Figures 1 and 2, cut all the supports and the boom from a piece of construction-grade southern pine. The notch in the boom is very important. When not folded, the support for the driven element rests in this notch. I recommend cutting the support for the driven element, and finishing it first. Then, using it as a cutting guide, make the notch in the boom. The fit should be as close as possible, without being too tight when the quad is unfolded. After the pieces are cut and drilled, sand them smooth and finish them with at least two coats of varnish.

The elements are made of 1/8th inch brazing rod. It is readily available, rigid, and easily bent – with the help of a propane torch. I used eight 36” lengths to complete this project. To bend the brazing rod, clamp it into a vise, heat it until almost red hot with a propane torch and bend it very gently.

Refer to Figure 2 for the dimensions of each element. I found it easiest to make my first bend before inserting the rod through the hole in the support. Since it takes a little more than two rods for each element, you’ll need a union to join the rods to one another. I use a short length of small diameter copper tubing purchased from an auto parts store. Using a pip cutter, cut off a piece about an inch long, drill out to accept the brazing rod if necessary. To join the rods, shine them up near the ends with steel wool, insert into the copper tubing and solder them in place with a high wattage soldering gun.

The ends of the driven element are attached to holes drilled in the plastic “feed-point bracket” (Figure 6). I took a piece of scrap plastic (1.5”x 4”x 3/16” thick), warmed it until it was pliable, and bent it at a 90 degree angle. Then I drilled as shown in Figure 6, mounted the SO-239 (a BNC connector could be used), and mounted the assembly to the support, using wood screws. The driven element is attached to the feed-point bracket with nuts and bolts.

Using Figure 4 as a guide, attach the elements to the boom, paying special attention to the spring and washer placement on the driven element. Next, attach the tie rod. This completes the mechanical assembly of the quad. Matching for minimum VSWR is done by varying the length of the jumper wires between the ends of the driven element and the SO-239 connector. Once you are satisfied, put some RTV on the ends of all the bolts to keep the nuts from loosening. Use two U-clamps with wing nuts to fasten the antenna to a broom handle mast. This project will require a straight length of 1”x 4” pine, and eight 36”x 1/8” brazing rods, plus miscellaneous hardware.

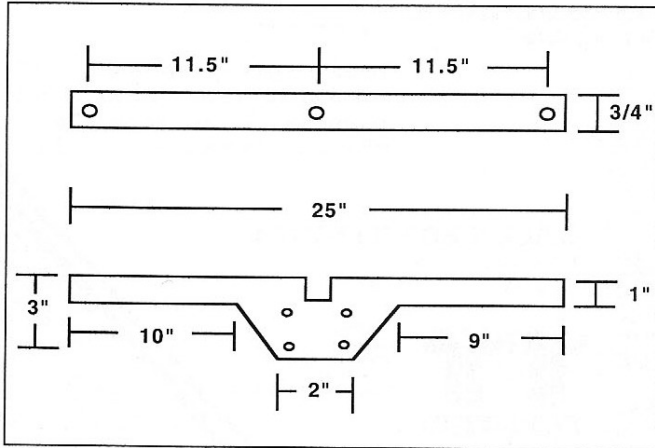


Figure 1. The boom: Cut and drill as shown.

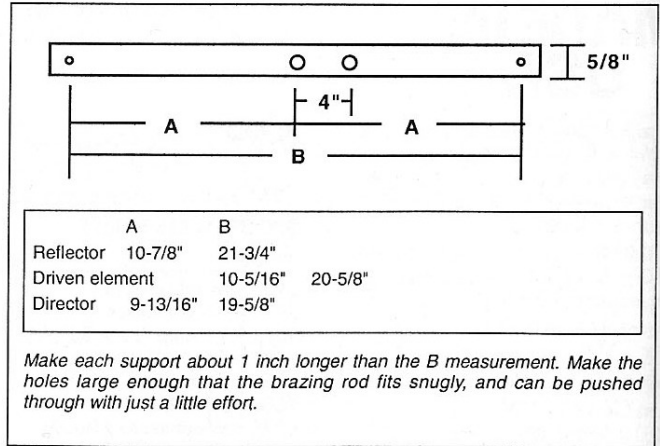


Figure 2. Dimension table for the quad.

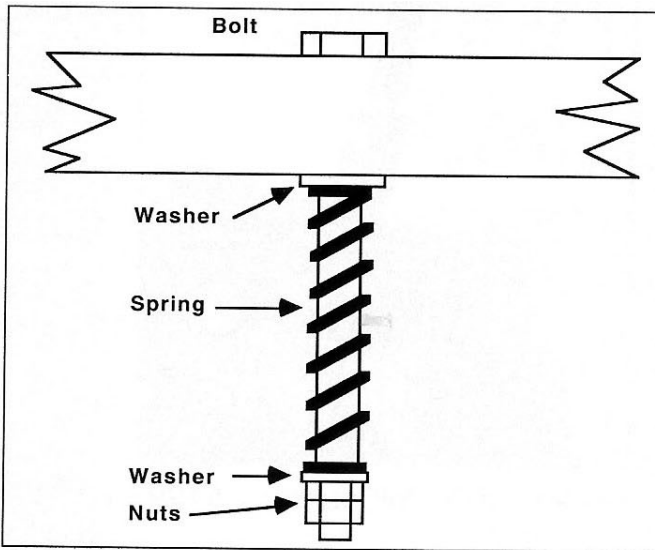


Figure 3. Close-up of the spring loaded bolt which makes up the pivot point of the quad.

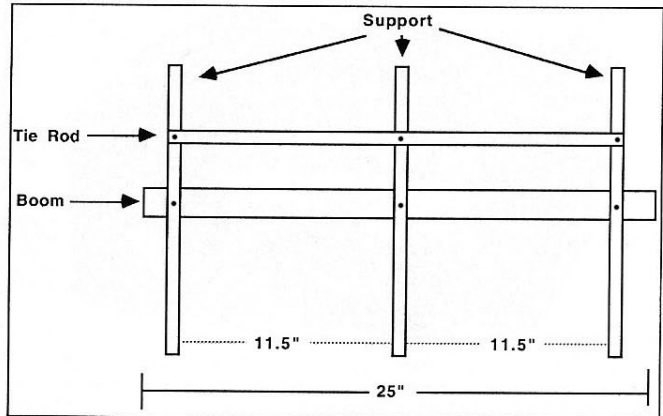


Figure 4. Top view of the folding quad. The spacing shown is 0.15 wavelength.

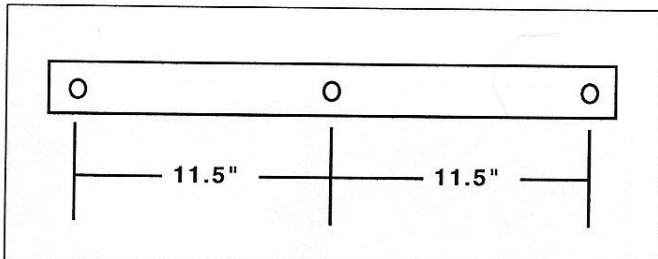


Figure 5. Tie rod—this is made from a thin piece of wood. The only dimension that is important is the one listed. Its purpose is to tie the elements together, and keep them in alignment, while folded and unfolded.

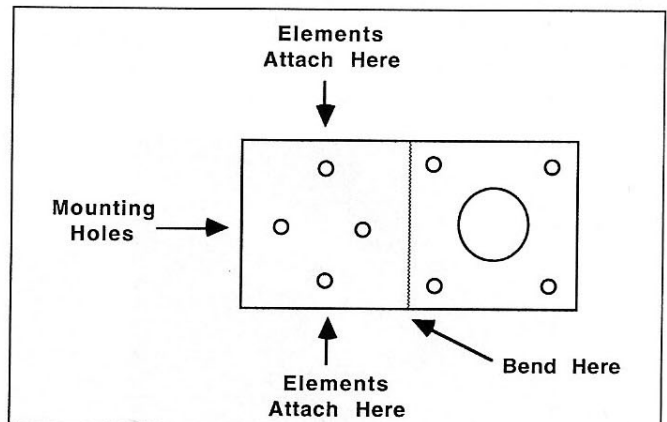
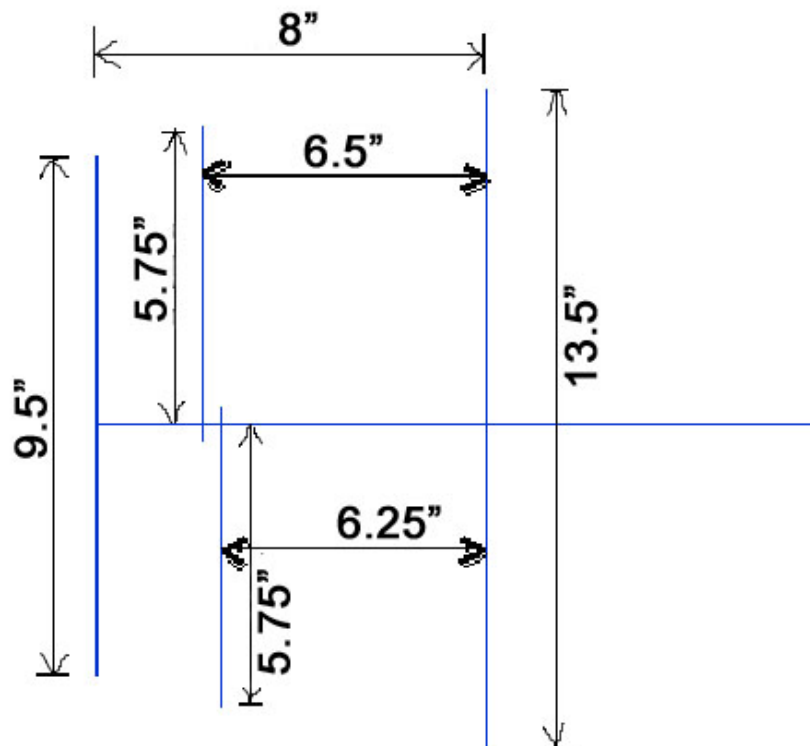
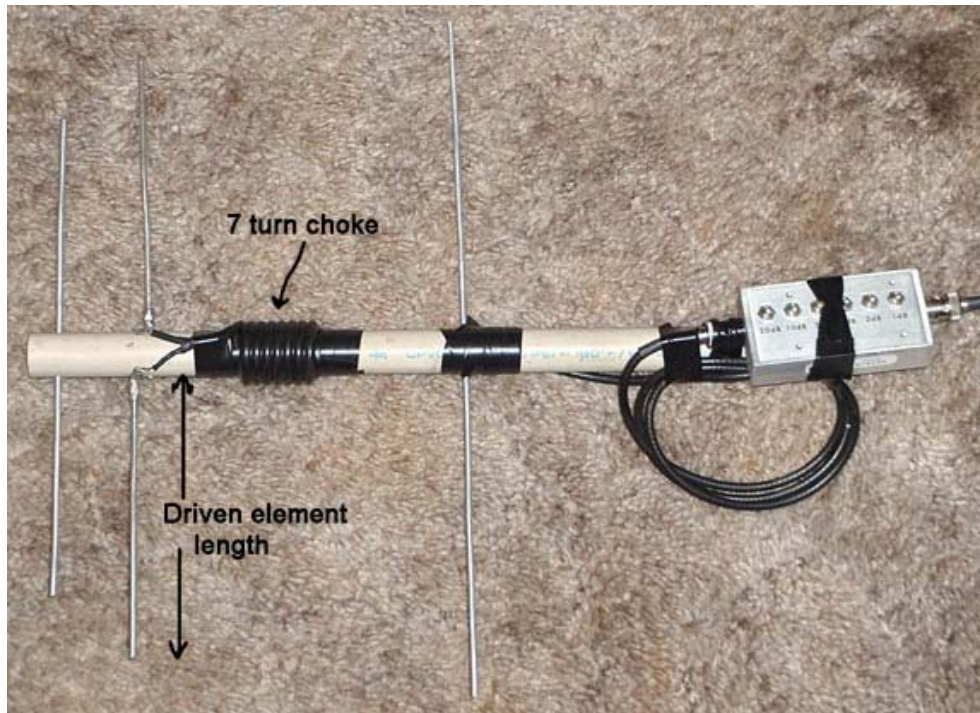


Figure 6. Feed-point bracket. Mount SO-239 on the right side. Mount to the face of the bracket, using 6-32" x 3/8" bolts, attached from behind. Run jumpers from SO-239 to the elements (see text).

3rd Harmonic Yagi (creator unknown)

This small yagi was optimized for hunting the 146.565 third harmonic, 439.695 MHz, on foot. It has great front-to-back ratio as well as front-to-side. The boom is a 3/4" CPVC pipe and the elements are lengths of 9 gauge aluminum ground wire from Radio Shack. Driven element halves stick through boom about 1/8", the RG58 is soldered to crimp-on lugs. Nothing fancy here, but it works great!! The 40db attenuator gets me to within 3 or 4 feet of the transmitter.



Super Simple Attenuator by K3OF

This is a continuously adjustable attenuator using capacitive coupling.

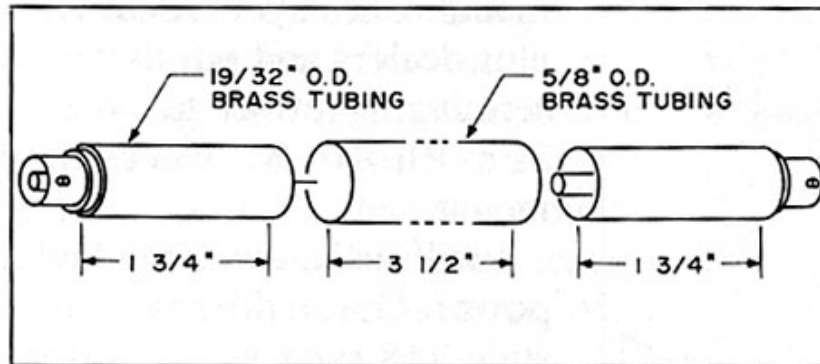


Figure 2. Tube dimensions for the attenuator.

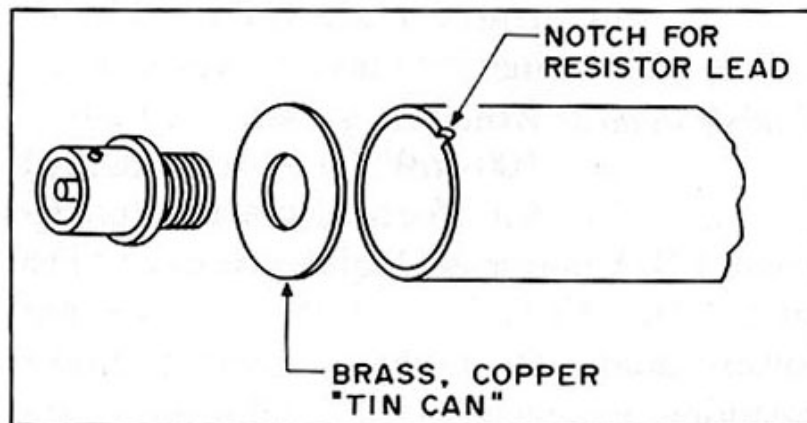


Figure 3. BNC connector attachment details.

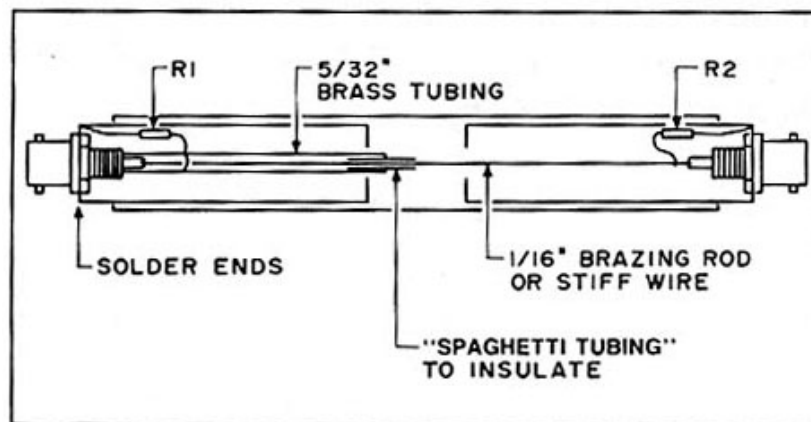


Figure 4. The final assembly of the attenuator.

From the January 1989 issue of 73 Magazine

Constructing the Super Simple Attenuator

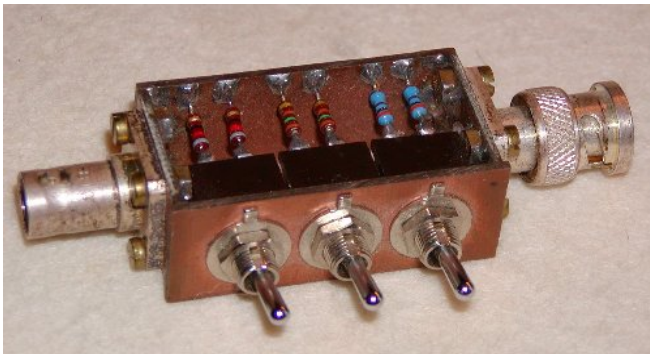
R1 and R2 are 47 ohm, ½ watt resistors. Thin wall brass tubing from a hobby shop is used, just pick two sizes that will slip into each other. The end washers that are soldered to the ends of the brass tubing can be brass or copper and can even be made from pieces of double-sided PC board. Make sure the nuts on the BNC connectors are properly tightened before soldering the end caps in place. The 1/16 inch brazing rod is insulated with a piece of plastic spaghetti tubing, or some small diameter heat-shrink tubing.

Solder the brazing rod and the 5/32 inch brass tubing to the appropriate BNC connector, taking care to keep them aligned with the center axis of the connector. Solder one end of each resistor to the center piece, leaving the other end free so it can be brought out through the small notch in the outer tube during assembly.

Now assemble everything as shown in Figure 4. Place the large brass tubing sections in their closed position, and the two connectors (mounted in the end pieces) into their final position. This assembly, before soldering the end plates, puts everything into alignment. Solder the end plates and the 47 ohm resistor leads to the large tubing. File off any excess metal from the end plates.

Another simple slide type attenuator is at <http://www.ardf-uk.co.uk/equip-slideatten.html> and another one here: http://home.att.net/~jleggio/projects/rdf/p_atten.htm

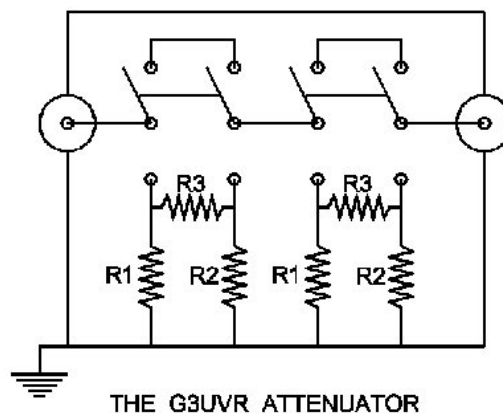
The step (switch) attenuator:



Example of a home-made switchable attenuator
The complete article can be found at:

http://www.merseyworld.com/wadarc/Technical_Topics/Attenuator/Attenuator.htm

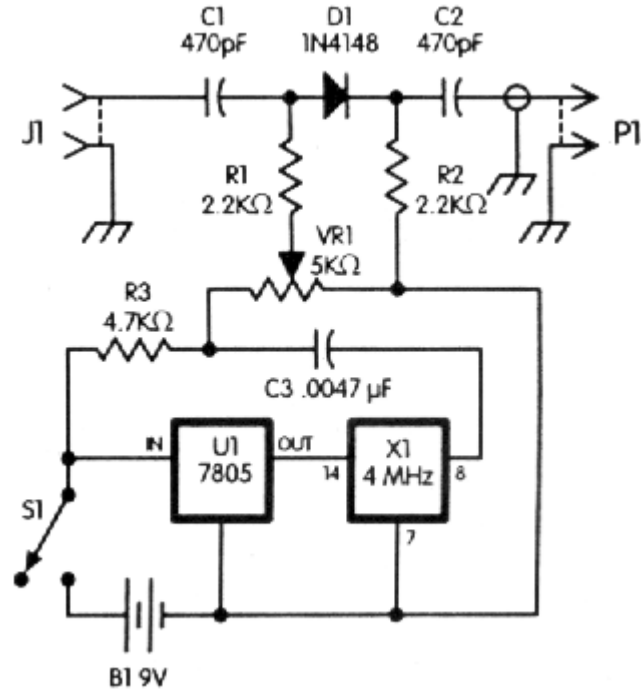
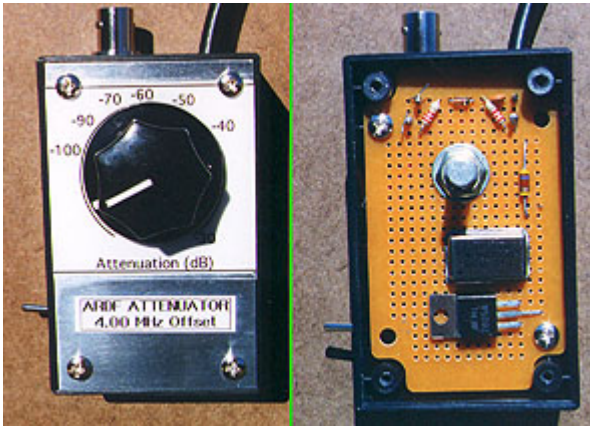
Atten	R1	R2	R3
3db	292	292	18
6db	150	150	37
10db	96	96	71
12db	84	84	93
15db	72	72	136
18db	64	64	195
20db	61	61	248
24db	57	57	395



and another is at: <http://www.arrl.org/tis/info/pdf/9506033.pdf>

also check out the Arrow Antenna attenuator at <http://arrowantennas.com/inst/igif/ifha.gif>

The **Offset Attenuator** is the best but most complex design. It uses a crystal oscillator and a mixer. This causes the signal you wish to receive to be heard on your receiver at a frequency 4 MHz (for example) higher/lower. Thus, in order to monitor 146.565 MHz, you would tune your receiver to 150.565 or 142.565 MHz. The amount of attenuation is controlled electronically by the attenuator circuit and can reach 100 dB. This design solves the problem of the transmitter RF getting into the receiver through the plastic case, since you are not tuned to the transmitter frequency.



Example of an Offset Attenuator and the circuit diagram. The complete construction plans can be found at: <http://members.aol.com/joek0ov/offatten.html>

and another one here http://home.att.net/~jleggio/projects/rdf/a_atten.htm
 Additional information is at http://w0ky.kearney.net/offset_attenuator_manual_i.pdf

Plans for an “RF sniffer” for use when very close to the hidden transmitter can be found at:



A home-made RF sniffer for use on 2 meters

http://www.merseyworld.com/wadarc/Technical_Topics/Sniffer/how_to_construct_a.htm

and another field strength meter at: <http://www.qsl.net/kh7o/rdf/ad8307.html>
 simple tone output sniffer: <http://members.aol.com/bmgenginc/ToneSnif.html>
 audio field strength meter: http://www.qsl.net/ve2emm/pic-projects/fsmeter/mtl_aufs.html
 audible field strength indicator: <http://www.qsl.net/nz0i/projects/fsm/fsm.html>

The Fox

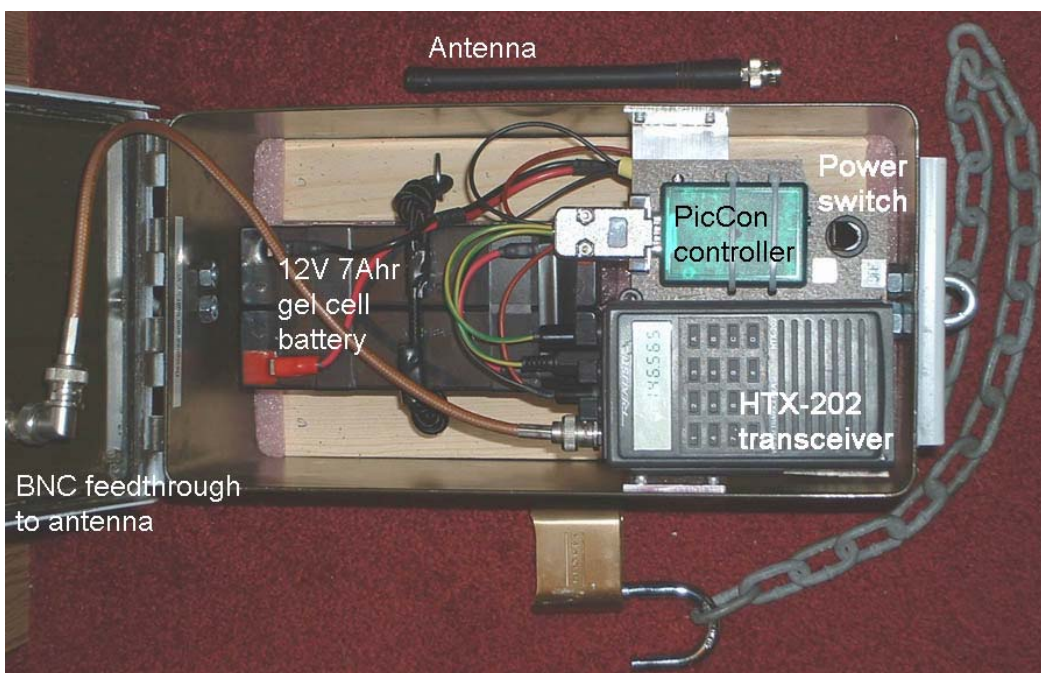
For those interested in building a fox, a good automatic handheld transceiver controller (the PicCon) can be purchased from Byonics at <http://www.byonics.com/piccon/>. A handheld transceiver, the PicCon and a gelcell battery can be mounted in a weather-proof (lockable) box with a BNC connector installed on the top to attach a rubber duck antenna. The PicCon listens to the receiver audio for the touch-tone sequence required to start the fox transmit sequence. This would allow the fox transmitter to be hidden somewhere before the hunt. It can then be triggered from the starting location when everyone is ready.



The BARC Fox Box

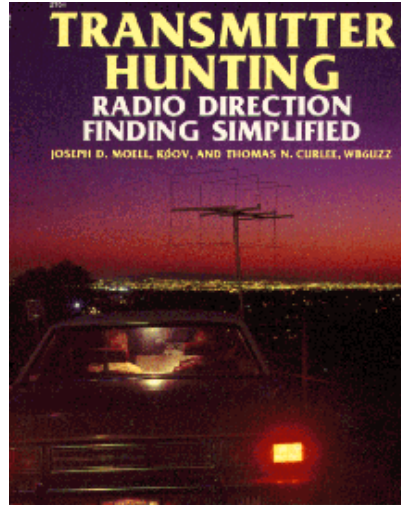
A surplus ammunition box is used as a weather-proof housing.

It may be a good idea to inform your local police force about club activities such as this, just in case the hidden transmitter gets reported as a "suspicious object". Also, seeing a bunch of people wandering around with antennas and other equipment can raise a few eyebrows.



PicCon Controller

A lot of good information related to amateur radio fox hunting can be found on the internet – just do a Google search with key words like: RDF, antenna, fox hunt. An excellent book on the subject is “Transmitter Hunting – Radio Direction Finding Simplified” by Joe Moell, K0OV, his web site is at <http://members.aol.com/homingin/>.



Fox hunting is for everyone

Check the Barrie Amateur Radio Club web page for upcoming fox hunts in the Barrie area.
<http://www.barriearc.com/>