Tips and Tricks for the Ill-Equipped Fox Hunter

by VA2MM

Fox Hunting (amateur radio direction finding) can be a fun and challenging activity, even for those of us who don't have sophisticated direction finding equipment. Of course, specialized equipment might allow you to find the fox faster, but it doesn't make it any more fun than using very basic equipment like a 2m HT, plus your knowledge, powers of observation, and your "spidey-senses" about how radio waves propagate.

Specialized direction-finding (DF) equipment can include commercial equipment that can cost hundreds of dollars but you can do very well using a home-brew Yagi antenna that costs less than $10 to build, plus an attenuator (offset or frequency-shifting is best).

What if you don't have any DF equipment at all? You don't really need anything special beyond a 2m HT in order to participate. The goal of this document is to show how you can participate and have plenty of fun, even if you haven't had time to put together a directional antenna or an attenuator. I'll divide the guide into two sections:

- the Far Game, when you are far away and need to determine which way to head,
- the Near Game, when you are getting really warm but need to actually collar the beast.

1) The Far Game:

The metaphorical bugles sound, the Fox beacon is activated, now what? Other competitors take out a bewildering range of DF contraptions then take of all in different directions. What can you do, with only a lowly HT?

a) <u>Estimating Range:</u>

As a first step, take out your HT with its standard antenna to see if you can receive the fox beacon, and note the maximum signal strength at your current location. Try to be in a relatively open area away from buildings. Take a few measurements while slowly moving the HT over a distance of at least 1 - 2 m to get a good maximum reading. As you will see below, the signal strength can give you a rough indication about how far away the fox might be. If you can't receive it at all, that's a hint too, so you'll need to change locations. Also note the geographic topology and other characteristics of your location and of the search area in general. Are you on a hill, or is the area generally flat? Is the area cluttered with trees, houses and other buildings, or generally open? These will all affect the range.

i) <u>Horizon Limit</u>

VHF propagation, to the extent that it goes beyond the horizon, experiences very high losses. For low-power situations like a fox beacon, the distance to the horizon places a practical upper limit on the range for a given height.

The maximum line-of-site distance over smooth round earth can be calculated by $D_{LoS} < 3.6\left(\sqrt{h_{Tx}} + \sqrt{h_{Rx}}\right)$ where D_{LoS} is the maximum line-of-sight distance in km and h_{Tx} and h_{Rx} are the heights in m above ground of the transmitter and the receiver. Don't worry about the formula because I've solved it for you. If we assume that the Fox antenna is less than 2 m above the ground, and your HT antenna is also less than 2 m high, and the ground is flat, the *maximum* line-of-sight distance works out to be 10 km. If you can hear the beacon at all, you can sure it's less than 10 km away (unless you're on a big hill). That's a start but not really very useful so we'll narrow the search area more in the next sections.

ii) Clutter

Most real terrain that you will encounter will be cluttered with houses and trees that obstruct the line of sight. VHF signals can propagate through such clutter, but not unscathed. VHF signals are scattered and they diffract over and around the clutter, albeit with significantly increased losses. Calculating the exact extra losses due to clutter is complicated and depends on a bunch of things that are hard to quantify. So let's not do that. Instead, we can use path loss approximation models such as the Hata model that is based on actual path loss measurements in different broad classes of clutter. If you're interested, there is an online Hata path loss calculator at http://www.wirelesscommunication.nl/reference/chaptr03/pel/loss.htm.

iii) Estimating distance based on Hata clutter type and Received Signal Strength

The signal strength that you receive can give you a very rough idea about your distance from the transmitter, but be careful of this because the calculations contain many assumptions that they can often be way off. If you're on a hill, or behind a hill, the following method won't work well.

We are going to assuming the height of both Transmitter and Receiver antennas are 2m above flat ground, and that the receive antenna gain was about 0 dBi (e.g. a good normal HT antenna). We'll assume that you know or can guess the fox transmitter's effective radiated power (e.g. 1W or 10W).

Step 1: use Table 1 to find the path loss using your HT's maximum S-meter reading. Example: if you get a maximum reading of S-8 (look up 8 in the left column), and if the fox's EiRP is 10W (right column), Table 1 shows a path loss of 139 dB.
Step 2: Decide whether you are in open/rural, suburban, or medium city type clutter then use Table 2 to estimate the approximate path distance over flat earth (depending on clutter type) would give path loss from step 1. Example, in Suburban clutter (look in the Suburban column of Table 2), you see that path loss of 137 dB (pretty close to 139 dB) corresponds to a distance of about 3 km (left column of Table 2). Remember that this is all very approximate, but it gives you a hint that the Fox is probably somewhere around 2-4 km away, if the assumptions are correct.

Table 1: Path Loss Vs. S-Meter Reading

S-Units (VHF)	Rx dBm	Path Loss from 1W EiRP	Path Loss from 10W EiRP
9+20 dB	-73	103	113
9+10 dB	-83	113	123
9	-93	123	133
8	-99	129	139
7	-105	135	145
6	-111	141	151
5	-117	147	157
4	-123	153	163
3	-129	159	169
2	-135	165	175
1	-141	171	181

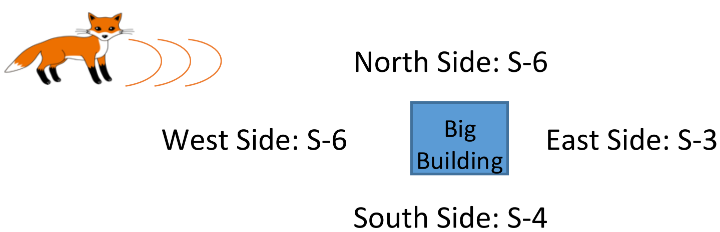
Table 2: Path Loss vs. Distance and Clutter

Distance (km)	146 MHz Hata Path Loss (dB) Tx and Rx Heigh = 2m			Free Space Loss (dB)
	Open/Rural	Suburban	Med. City	
0.5	85	104	108	70
1	98	117	212	76
1.5	106	124	129	79
2	111	130	134	82
3	119	137	142	86
4	124	142	147	88
5	128	147	151	90
6	134	150	155	92
8	137	155	160	94
10	141	160	164	96

Note: Table 1 is based on readings using a standard HT antenna with about 0 dBi gain. If you're using a 6 dBi yagi, subtract 1 S-unit from your reading.

b) **Estimating Direction:**
Distance is one thing but it would be great to narrow down the search area using direction too. This is subtler and will require all your senses of observation. If you don't have direction-finding equipment, you can still try to determine the general direction (N, NE, E, SE, S, SW, W or NW). We can do that using shadows and reflections off of significant obstacles, or simply noting in which direction of travel does the signal strength tend to increase.

i) <u>Shadows</u>
Most large obstacles like buildings or hills will partially block a radio signal. Take signal strength measurements (S-meter) close to a building, on all 4 sides. Once again, move the HT over at least a meter or two looking for maximum signal strength. Signals from the Fox beacon will diffract around the building to some extent, but there should be noticeably weaker signal on the far side or sides of the building from the Fox. For example, let's say you get the following S-meter reading very close to each side of a large building:



In this case, you may conclude that the Fox beacon is probably located to the West or North-West of the building because signals are strongest on the North and West side, and weakest on the South and East sides. This isn't foolproof because signals can reflect off of other buildings to fill in the shadow, but it's often a good clue.

Likewise hills can create a shadowing effect that can hint at signal direction:

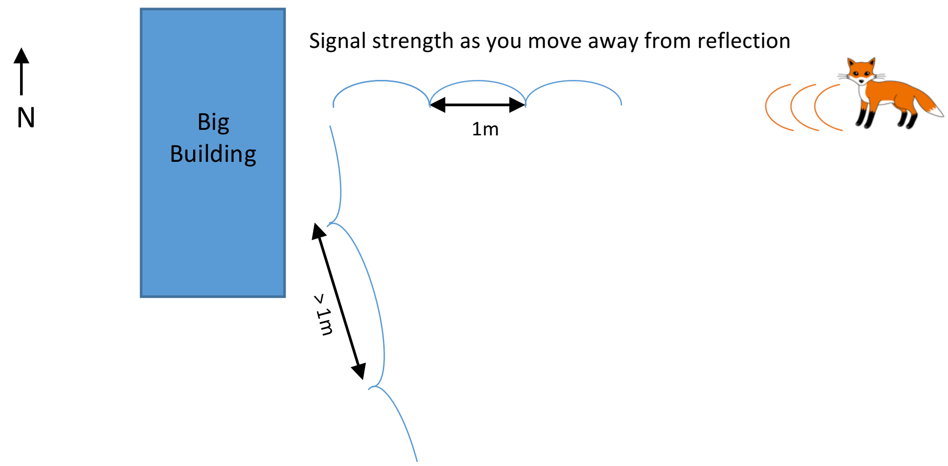
- if signals drop sharply after you go over the top of a hill, this is an indication that you are driving AWAY from the transmitter.
- If, on the other hand, signals increase sharply as you reach the top of the hill, and stay relatively strong as you start to descend the other side, this is an indication that you are driving TOWARDS the transmitter.

As an aside, this is the same method used by sea-plane pilots to judge the wind direction by noting the way waves on a lake are shadowed by an island.

ii) <u>Reflections</u>
We all know (or should know) what happens in an antenna feedline when there are reflections. A standing wave is created in the feedline such that, as we move from the reflection point towards the source, the voltage amplitude increases and decreases periodically (every ½ wavelength). This is caused by the reflected wave adding in-phase with the incident wave in some locations, and adding out-of-phase (subtracting) from the incident wave in other locations. This phenomenon is not limited to feedlines and the same thing occurs when there are reflections in space.

When signals from the Fox beacon are reflected off of a surface, we can detect the standing wave by very slowly moving the HT in a straight line and noting the changes in signal strength, and specifically the distance between signal dips:

- If we move the HT in a direction that is towards the transmitter (East in drawing below), there will be dips in the signal strength that are 1m (1/2 wavelength) apart.
- If we move the HT in a direction that is approximately perpendicular to the direction of the transmitter, the dips in signal strength will be much more than 1m apart because we're moving parallel to the standing wave.



iii) <u>Large-scale Signal Gradient</u>
This is an obvious one, despite the complicated name I gave it. It just means that we should go in the direction that the signal strength increases the fastest. That's it!

c) Lather, Rinse, Repeat. Then deduce.

It usually takes several iterations of the above steps, from different locations before you start to get a sense of where the fox might be hiding. Sometimes you might get contradictory readings that require a tie-breaker measurement. Eventually, you'll have enough clues to arrive at a conclusion about the general area that the signals are coming from.

You'll need a map. It also helps to have a compass, a protractor and ruler. Mark your measurement locations with arrows pointing in directions you measured in section 1b above. Then for each measurement location, mark the estimated distance based on the signal strength (section 1a). Circle the region that generally satisfies the clues, keeping in mind that all of your measurements are approximate and subject to some error.

Now look closely at the map for small areas within the larger target area that would be good hiding places for a fox. You know it won't be on a busy street, or in someone's yard. Make a list of likely areas and go check them out! You'll know when you're getting warm (S-9 +40 dB all the time), then it's time for the Near Game!

2) **The Near Game:**
Too much signal strength can be as bad, or worse, than a marginal signal. This is the challenge of the Near Game.

a) **<u>Attenuation:</u>**
Ideally, you would like a way to attenuate the signal. One of the best ways to do this is to use a frequency-shifting (or offset) attenuator that uses the very sharp IF filters in a super-heterodyne receiver to reject the swamping signal and can provide over 100 dB of attenuation. But what can you do if you don't have this?

Any way to reduce the signal strength will allow you to get closer before your receiver becomes almost useless.

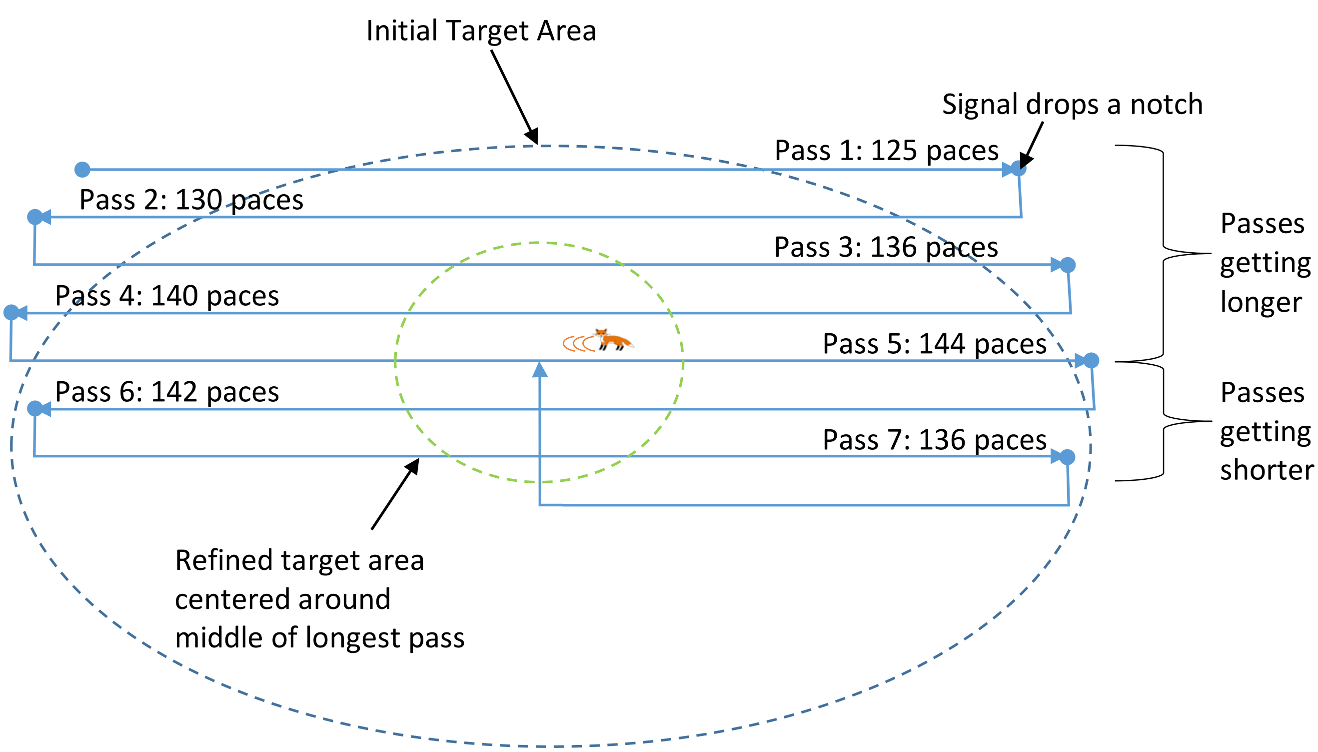
i) <u>HT Attenuator Function</u>
First, read your HT manual to see if it has a feature that allows you to attenuate the receive signal. My Kenwood HT has this feature and while it isn't nearly enough attenuation, it does help you get that much closer.

ii) <u>Air-gap Attenuator</u>
This isn't exactly rocket science, but removing the antenna from your HT can help quite a bit. If your antenna connector is SMA type, just unscrewing it provides a nice variable attenuator. Otherwise, holding the antenna a short distance above the antenna port provides this air-gap that reduces the signal. Eventually, as you get closer, you'll have to remove the antenna completely.

b) **<u>Grunt Work</u>**
No matter how sophisticated your equipment, at some point in the search, as you get very close, you'll probably exhaust its capability for direction-finding or attenuation. Then there is no other choice but to work up a sweat.

i) <u>The Grid:</u>
After having had an initial look around without spotting the fox, a good structured way to approach this is by walking a grid:

- Start at the edge of your narrowed-down target area and walk away until the signal drops by the slightest amount (e.g. drops by 1 S-unit) with maximum attenuation. Mark the spot.
- Turn around and walk in a straight line along the edge of the target area. It is helpful to count your paces. As you go, the signal will very soon increase back to maximum reading but continue walking in a straight line until the signal shows the first tiny sign of decreasing. Mark the spot and note the number of paces that it took you between spots where the signal dropped ever so slightly. The mid-point along the line will be where you were the nearest to the fox.
- Move incrementally farther into the target area, say by 10m, an increment such that you would be able to spot the fox if you walked right by it between two passes.
- Repeat the first 2 bullet points above over and over again. If you find that each pass is getting longer between the points where the signal drops slightly, it means that you are getting closer. Keep your eyes open for visual clues too.
- At some point as you advance, you may find that the length of the passes between points where the signal drops starts to decrease. If this persists, it probably means that you've passed the fox. Go back to the longest pass and look around the mid-point of that walk.
- If that fails, try repeating the grid walk in the perpendicular direction.



3) Conclusion:

It is indeed possible to find a fox beacon transmitter, if you don't have specialized DF equipment; even if all you have is an HT and a map. You might not be the first to find it, but you will probably have exercised more skills of observation and interpretation than someone who simply followed the DF arrow to the target area and then used a 100 dB attenuator to close into the fox's lair (not that there's anything wrong with that). Good hunting, no matter how you do it!