A TDOA Antenna Unit for Fox-Hunting

At some point in your hunt for the elusive "fox", you will (with luck) be so close that simple field-strength direction-finding techniques may no longer work. The "fox"'s signal will be so strong that it will swamp your attenuator and leak through the plastic parts of your radio's case, resulting in "S9+" signal-strength readings in every direction, regardless of attenuator settings or antenna orientation. A "Time Difference of Arrival (TDOA)" antenna unit will put you back on the "hunt".

(How big a truck will I need?)

A TDOA antenna unit is simple and easy to build, and will work with any 2m FM mobile or handheld. There are many different designs of TDOA units, and some have additional "bells and whistles" (such as left/right indicators), but the basic design (which is all you really need) consists of a small dual-antenna array and an electronic antenna-switching unit.

The antenna array usually consists of two vertical dipole antennas separated 12 to 36 inches apart, often mounted on a T-shaped support so that the array can be rotated. The purpose of the antenna-switching unit is to alternately and rapidly switch the input of your FM receiver between the two dipoles. The switching rate is typically 1000 times per second. Switching is accomplished by a square-wave oscillator which alternately forward- or reverse-biases diodes connected in the circuit path between each dipole and the receiver. Common silicon switching diodes will work OK, but PIN diodes work best.

(How does it indicate direction ?)

The TDOA works by detecting the difference in the phase of the RF signal received by each dipole. If both dipoles are exactly the same distance from the RF source (the "fox"), the phase of the RF signal will be the same at each antenna. If you rotate the array, or the RF source moves to the left or right, then one dipole will be closer to the source than the other one, causing a small phase difference between the signals received. Your FM receiver will then detect an abrupt change in the phase of the RF signal it receives as the antenna switching unit switches rapidly back and forth between the two dipoles. To the receiver, the signal looks like square-wave- modulated FM ! Your receiver's speaker will emit an audio tone at the antenna-switching frequency. As the phase difference increases, the tone becomes louder. When both dipoles are equidistant from the source, the tone almost completely disappears.

One disadvantage of the TDOA is that when you have found the "null" or antenna position where the tone disappears, you cannot tell if the source is directly in front of you or directly behind you. Fortunately, there are other ways to determine this. A quick way, if you are using a handheld, is to use the "body shield" method - disconnect the antenna, hold the handheld close to your chest so that you can see the signal strength indicator, and turn your body. When the indicated signal strength is minimum, the source is somewhere behind you. Another technique involves converting the TDOA antenna to one which has a cardioid or heart-shaped radiation pattern - the null (which corresponds to the "notch" in the heart-shape) can be used to point a rough bearing to the source.

A quick (1-2 evening) TDOA antenna unit

You can build a simple TDOA unit in an evening or two for about $10 or less (depending on the size of your junk-box). The circuit, shown in Fig. 2, is based on one in an article by Paul Bohrer (ref 1). U1 is a 555 timer powered by a 9V battery, oscillating at about 1kHz. R1, R2 and C1 determine the frequency of oscillation. The output of U1 is a square-wave from +9V to ground. C2 allows the square-wave to be level-shifted to between +4.5V and -4.5V. The positive half of the

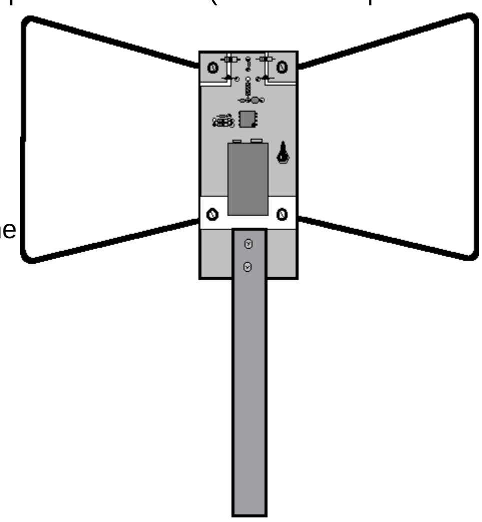

Fig. 1 - The assembled TDOA antenna unit - coaxial cable to receiver runs behind the PCB and through the PVC pipe handle.

square-wave's cycle turns on (forward-biases) D1 and turns off (reverse-biases) D2; the negative half of the cycle does the opposite. R3 and R4 limit the forward bias current for each diode to about 9mA. When the diode is turned on, the RF signal received by that diode's dipole is conducted through the diode and coupled through C4 to the coaxial cable to the receiver. When the diode is turned off, the RF signal (from that diode's dipole) is blocked. RFC1 presents a high impedance to the RF signal so that it is not shunted by the oscillator circuit, but passes the relatively low-frequency square-wave to the diodes. RFC1 together with C3 also comprise a low-pass filter to prevent the high-frequency components of the square-wave from getting into the antenna circuit and the receiver. If you forget to install C3 (I did), you'll hear a continuous "hash" of switching noise.

A rough PCB layout with approximate dimensions is shown in Fig. 3. Layout is not critical, but try to keep the wiring between the antenna elements, diodes and coax as short as possible. I also tried to keep the battery and coaxial cable exactly centered so that they would not affect one antenna element more than the other, but I'm not certain if this is really necessary. The coaxial cable lead to the receiver runs down the back of the PCB and through the PVC-pipe handle.

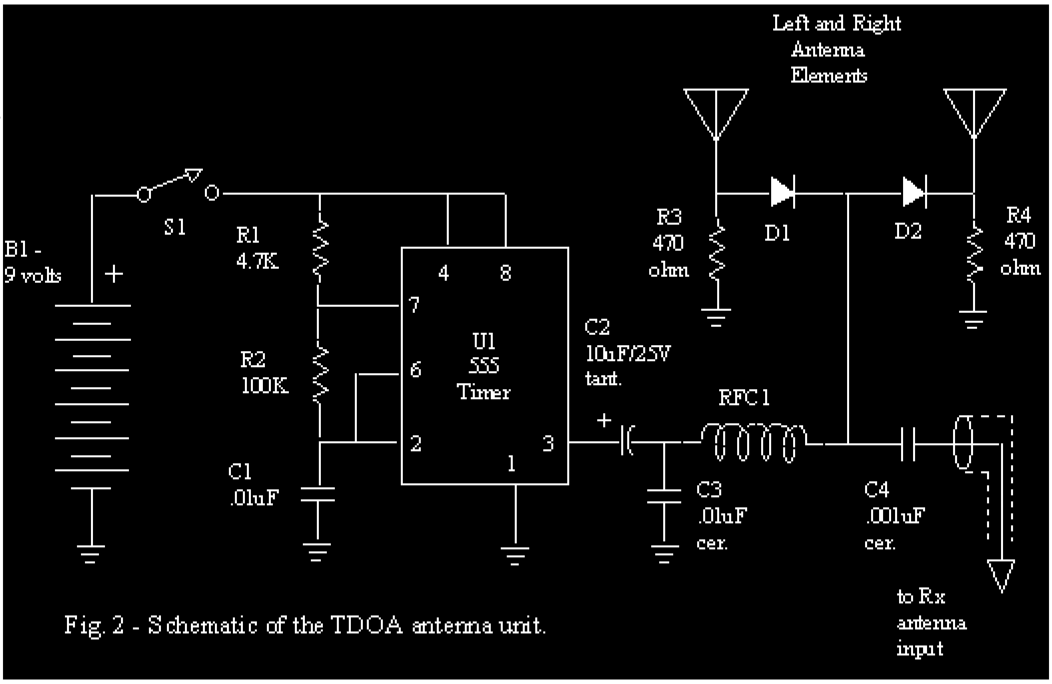

Fig. 2 - Schematic of the TDOA antenna unit.

The PCB can be "etched" using a sharp exacto-knife (watch your fingers!) and a drill-bit. Score around the areas of copper-clad that you want to remove with the exacto-knife, then peel away the copper. I use a pad-cutter tool to isolate pads in the copper, but you can clear the copper around holes with a sharp 1/8" drill bit - for a handle, use a 1/8"-shaft knob with set-screws. This prevents shorts between the copper ground-plane and component leads which pass through holes in the PCB.

I made a "bow-tie" antenna based on the "Handi-Finder" article (ref 2). Each element is a square "U", 6 inches across the bottom with 6-1/2" long arms. Each arm has a loop at each end for mounting to the PCB with #6 nuts and screws. It does not give as loud a tone or as sharp a null as two dipoles spaced 3 feet apart, but it's a lot smaller. I used coat-hanger wire, but stiff #12 copper wire or brass brazing rod would probably be better. The handle can be anything, preferably non-metallic, such as a short length of PVC pipe, wooden dowel or broomstick with a slot sawed in one end for the PCB.

Any 555 timer IC will work with this unit (there must be over 15 different semiconductor companies making them) but the CMOS part will nearly double your battery life. You can adjust R1 and C2 to vary the oscillator frequency (if you find a particular tone annoying). RFC1 is not especially critical, figure 1kohm impedance or better at 144MHz. If you have something in your junk-box, try it out by tuning your rig to a QSO

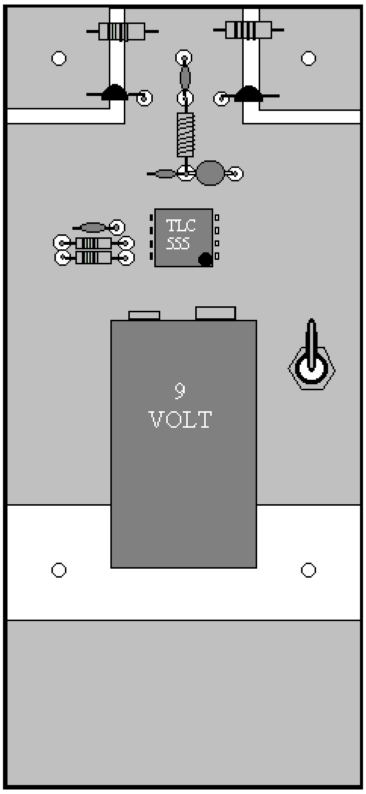

Fig. 3 - PCB component layout.

in progress with the TDOA antenna unit connected but not switched on, then touch the leads of the RFC between ground and the connection between D1 and D2. If the signal strength drops appreciably, then the RFC does not have a high enough impedance at VHF.

Using the TDOA antenna unit

TDOA antenna units are not designed for transmitting. If your handheld has a "TX inhibit" feature, it's a good idea to enable it when foxhunting with a TDOA. Transmitting into the TDOA may damage your HT, the TDOA, or both.

The TDOA works best with a strong, vertically-polarized signal. Strong multipath reflections caused by nearby vehicles, buildings, fences, powerlines, steel lamp-posts, etc. can make the null difficult to detect, or even appear on a wrong bearing. (Note that wily foxes look for places just like these to hide). If possible, look for open areas clear of obstructions and reflectors when taking bearings. If the bearing appears to change as you move around, your location may be affected by multipath. With practice, you'll be able to tell from the tone whether you have a good signal or one distorted by multipath.

Parts List for the TDOA Antenna Unit (Fig. 1)

1. U1 - CMOS 555 timer
2. R1 - 4k7, 1/4W, 5%
3. R2 - 100K, 1/4W, 5%
4. R3,4 - 470R, 1/4W, 5%
5. C1 - 0.01uF, 50V ceramic
6. C2 - 10uF, 25V tantalum
7. C3 - 0.01uF, 50V ceramic
8. C4 - 0.001uF, 50V ceramic
9. D1,2 - PIN diode, MPN3404
10. RFC1 - RF choke, 8 turns magnet wire space-wound over 1/4W carbon comp resistor (100k or greater).
11. S1 - Switch SPST (toggle or slide)
12. Misc. - PCB, 9volt battery, battery holder, stiff wire (for ant.), RG-58 coax and BNC connector.

Parts Sources - Toronto Area

- **Electro Sonic, 1100 Gordon Baker Rd., Toronto**
- -- PIN diodes : Motorola MPN3404
- -- 555 timer : National LMC555CN, Motorola MC1455P1
- -- 9V battery holder : Keystone No. 1291
- -- switches : Mode Electronics
- **Double-H Electronics, 3800 Victoria Park Ave., Toronto**
- **Daiwa Semitron, 3800 Victoria Park Ave., Toronto**
- -- copper-clad PCB (single- and double-sided)
- **Radio Shack**
- -- 555 timer : Texas Instr. TLC555
- **(all locations listed above carry the resistors and capacitors).**

References and related articles

1. "Foxhunt Radio Direction Finder", Paul Bohrer, W9DUU, 73 Magazine Jul '90, pp.9-11, (construction article for TDOA unit with left/right indicators).

2. "Build the HANDI-Finder!", Bob Leskovec, K8DTS, QST May '93, pp.35-38, (construction article). See also "Sense the Right Way to Go with the Handi-Finder", by Joe Moell, K0OV, QST Oct '93 Technical Correspondence, pp.77-78, for cardioid pattern modification.
3. "The HANDI-Finder", Dave Martin, W6KOW, 73 Magazine Dec '93, pp.26-27, (product review).
4. "Homing DF Units", Chapter 8, "Transmitter Hunting - Radio Direction Finding Simplified", Joseph D. Moell K0OV and Thomas N. Curlee WB6UZZ, TAB Books, 1987.
5. "Monitoring and Direction Finding", Chapter 38, The ARRL Handbook - 1993 (70th Edition), the Amateur Radio Relay League.
6. "Direction Finding Antennas", Chapter 14, The ARRL Antenna Handbook - 1991 (16th Edition), the Amateur Radio Relay League.
7. See also the "Homing In, Radio Direction Finding" column by Joe Moell, K0OV, every month in 73 Magazine.

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