AMATEUR RADIO DIRECTION FINDING: 80 METRES

Les Tocko, VA7OM, Keith Witney, VE7KW and Joe Young, VE7BFK

In the March-April 2017 issue of The Canadian Amateur magazine, we presented an overview of a project undertaken to increase interest in Amateur Radio Direction Finding (ARDF) by making sets of needed equipment available at modest cost to several clubs. This article describes in greater detail the equipment developed for the project.

Rationale

In Part 1 we mentioned that 80 metres is a better choice for introducing ARDF compared to using 2 metres for operational success. An additional benefit is that 80 metre, purpose-built equipment is more amenable to homemade construction.

Some 80 metre ARDF capability for training and practice became necessary anyway because the most recent couple of international ARDF competitions by the International Amateur Radio Union (IARU) have included two additional 80 metre events: the Sprint and FoxOring. A description of these events is provided below. These new events feature short-range setups, low-power transmitters and either faster-cycling or continuous transmissions.

Experience using this 80 metre gear led to the realization that the new events have most of the features that will assist beginners to succeed in learning to find hidden transmitters. In addition, such transmitters can serve as a signal source for individual practice and receiver tuneup. Sets of at least five can be used by clubs for ARDF demonstrations and quick setup practices.

Equipment Needed

The following equipment is recommended for 80 metre ARDF:

1) An inexpensive, handheld, simple, receiver specifically designed for 80 metre ARDF.

2) Sets of low-power, multi-purpose transmitters. The transmitters need to be short range with accurate timing for the Sprint and FoxOring contests, but can usefully include standard contest timing for quick setup training courses.

3) Complete construction manuals for each device. These complete manuals can be found in the reference links below.

Receiver

The receiver enclosure is fabricated from single-sided printed circuit board material. The least expensive version 2 enclosure begins with a piece of PCB stock and all pieces are cut by hand. The version 3 kits used the PCB fabrication process to pre-cut the enclosure pieces for much less assembly work, but greatly increasing the cost of the kits. Use of PC board material enables creating a custom-fitted case, provides complete shielding of the receiver from strong RF when nearby the transmitters, and fabrication of the case with hand tools.

To make the receiver small, it employs surface-mount components wherever possible. For the project kits, the two surface-mount boards were supplied assembled and tested. The layout is not too critical so it would be feasible to use a perf-board construction technique, but this would require much more work to build.

The receiver has a front-end section located within the ferrite rod electrostatic shield part of the enclosure, followed by a switched attenuator in a separate shielded enclosure. The antenna shield

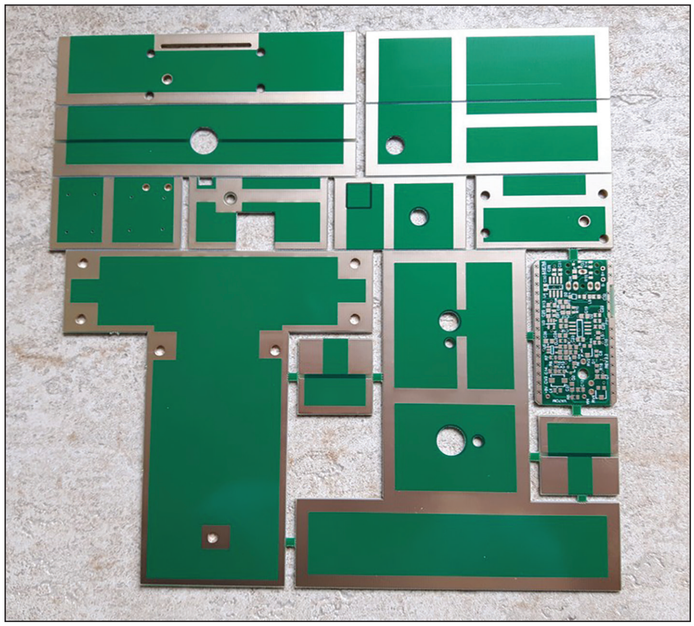


Figure 1: Receiver case pieces as part of PCB fabrication.

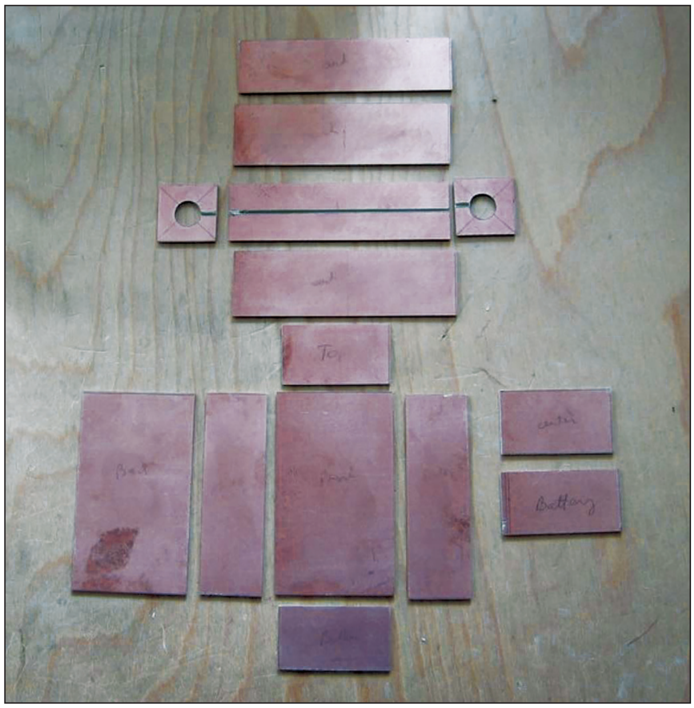


Figure 2: Receiver case pieces hand-cut from stock PCB.

formed from the printed circuit board material has a strip of the copper removed to interrupt the one-turn circuit that would otherwise be formed around the ferrite rod. The ferrite rod is shock-mounted within the shield box in the later constructions.

The antenna has a 3.5 MHz resonant circuit (L1, C4, CV1) which is link-coupled to the attenuator input (L2). To complete the antenna assembly, a signal from the sense antenna amplifier (Q1) is also link-coupled (L3) to the signal received. The omnidirectional sense signal plus the figure-8 pattern from the magnetic loop pickup combine to form a cardiod receive sensitivity pattern. The ferrite rod loop antenna pattern has very

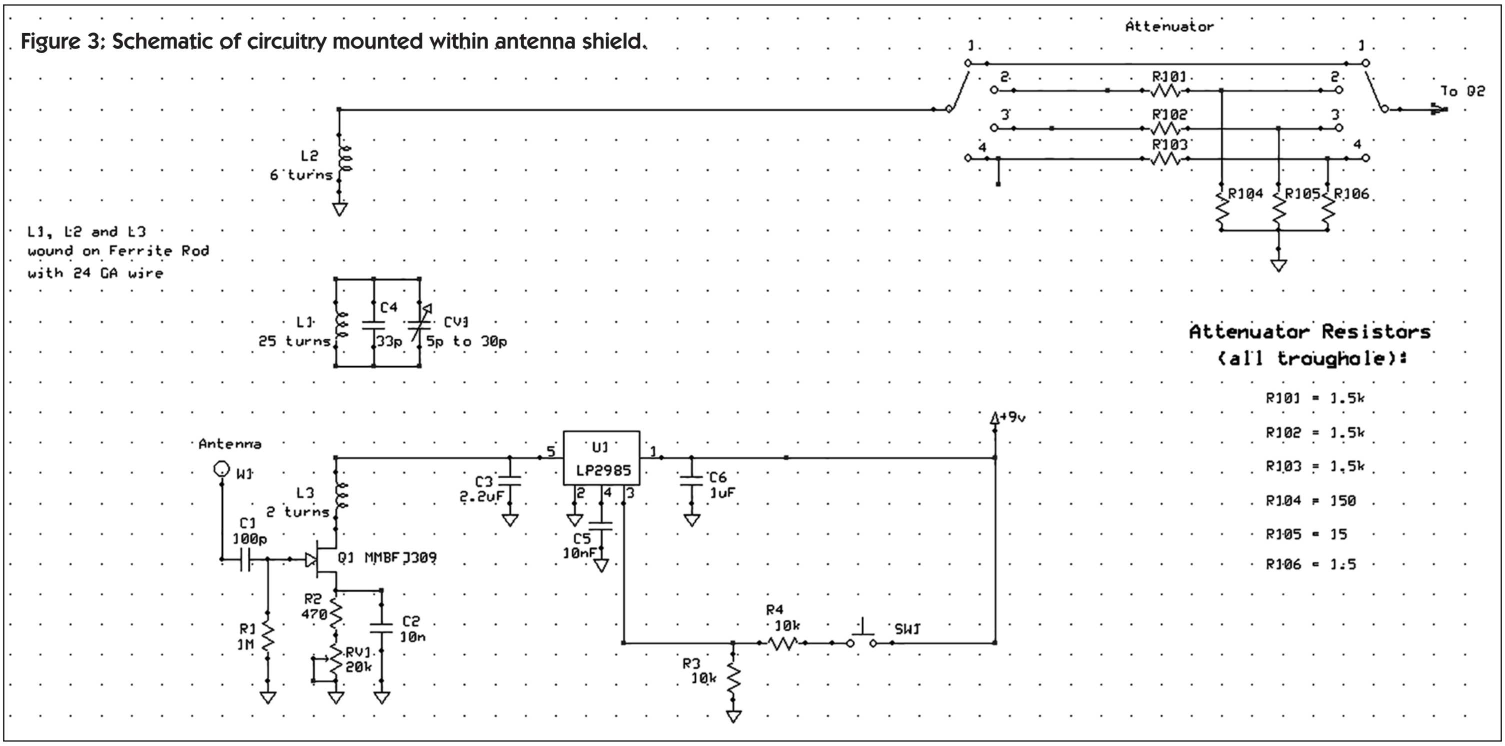


Figure 3: Schematic of circuitry mounted within antenna shield.

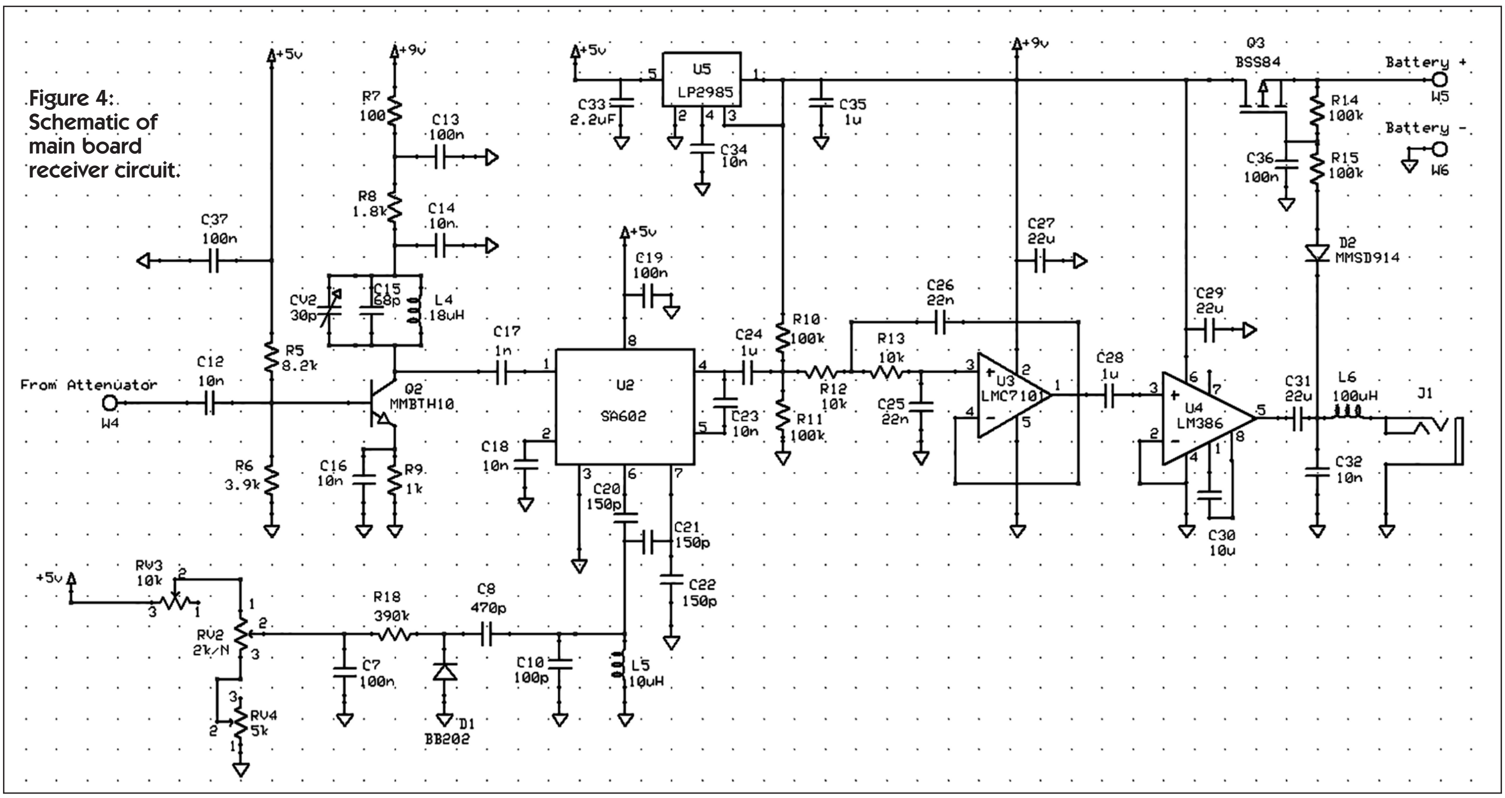


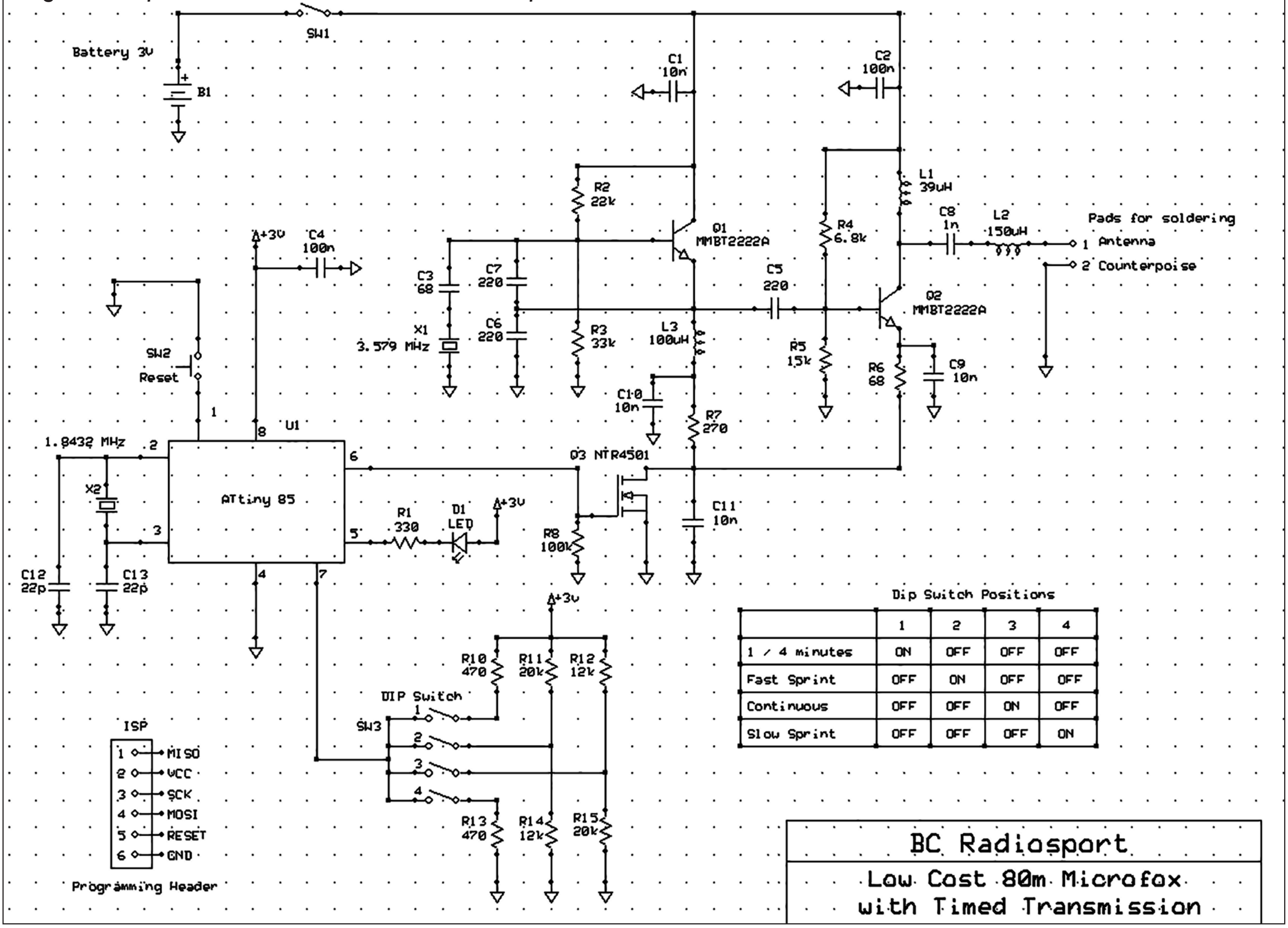
Figure 4: Schematic of main board receiver circuit.

sharp nulls giving accurate bearings, but there are two nulls. The cardiod pattern has one poorly-defined null, but it is sufficient to use to determine which of the two sharp nulls is the direction to the transmitter. The cardiod pattern is turned on and off by switching the power to Q1.

The 4-step attenuator is a set of simple voltage dividers in 20 dB steps. This simple arrangement works because the signal source from the antenna link is low impedance, and the input impedance to the receiver preamplifier is about 2.5 K. Having the attenuator enclosed in its own shielded compartment helps to reduce strong signal feedthrough directly to the receiver preamp input. The receiver sensitivity at the board edge is roughly 0.1 uV for an audible output at the headphones.

The main board signal chain has a preamp (Q2), an SA602 mixer/oscillator IC (U2), an op-amp active low-pass filter (U3), and an LM386 audio output stage (U4). The main power comes from a 9V battery. The power is switched on by enhancement P-channel MOSFET Q3 when its gate is grounded via D2 and the headphones are plugged in. The mixer-oscillator circuitry power supply is regulated to 5V with low-dropout regulator U5.

Figure 5: Low power transmitter circuit with controller microprocessor.



The SA602 oscillator section uses a varactor to tune the oscillator. The tuning is adjusted for a narrow range, 3550 kHz to 3600 kHz, controlled by the front panel potentiometer. The narrow range helps ease first-acquisition of the training signals which are usually 3550, 3580, or 3600. For IARU standard frequencies, the tuning range can be adjusted for 3500 kHz to 3600 kHz with onboard trimming potentiometers. The current from the battery is typically about 10 mA.

The specializations for ARDF are the 60 dB attenuator and the switchable sense antenna. The signal level range needed can be over 100 dB for typical ARDF courses, but a direct-conversion receiver being listened to by typical human hearing already has a large dynamic range, so the attenuator has proven adequate. While developed as “beginner” equipment, the receiver sensitivity and directionality performance is nevertheless comparable to more sophisticated receivers (such as the DF1FO FJRX80).

Transmitter

We used a crystal oscillator transistor (Q1, 2N2222), followed by an output transistor (Q2, 2N2222 or BC547). The output transistor drives one of two very short antennas via matching inductors L3, L4.

The antenna connector is a 4-pin molex which is wired with the antenna to go with its matching inductor. The antenna is designed as a short vertical operating against a counterpoise.

Quite a bit of experimenting went into optimizing the longer antenna for maximum range. The shorter antenna would be used for the FoxOring case where the range is not to exceed about 150 metres.

On earlier versions of the transmitter, the connector also provides power switching by grounding the battery supply. The transmitter operates from a pair of AA cells. The key-down current is about 5 to 10 mA, depending on the antenna and deployment.

There have been several versions of the transmitter made over the course of the project development. The versions differ in antenna size and deployment, power switching and method of selecting the operating modes. This description is representative.

A microcontroller (U1, ATtiny85, described in the next section) capable of generating the on/off keying of the transmitter for the Morse code identifications and controlling the timing of the four modes completes the transmitter.

Fox Controller Microprocessor

The Sprint contest employs two groups of five transmitters deployed in two physically separated groups. Each group of five transmits in a fixed sequence where transmitter 1 starts at an even minute, runs for 12 seconds and stays off for the next 48 seconds.

The second transmitter starts at 12 seconds after the even minute, runs for 12 seconds, then off for 48 seconds. Similarly for transmitters 3, 4 and 5.

The second group behaves the same way, but each transmitter identifies itself with a faster Morse code speed. There is a beacon transmitter on a different frequency marking the midpoint, and another at the finish.

The transmitter identification consists of sending a unique Morse code: transmitter 1 sends MOE, transmitter 2 sends MOI, transmitter 3 MOS, transmitter 4 MOH, and transmitter 5 MO5. That is, the pattern two dashes, three dashes, followed by one, two, ..., five dots. To determine which transmitter you are hearing, you do not need to understand Morse code. You only need to be able to count or have an accurate watch.

The foxOring contest is a combination of fox hunting and orienteering. The low-power transmitters cannot be heard until the searcher has navigated using orienteering techniques to within about 100 metres of the transmitter, then the continuously-transmitting transmitter can be located using the direction finding receiver. The searcher starts out with a map showing the approximate locations of the transmitters to be located.

The “standard” 80 metre ARDF event uses five higher-power transmitters at least 400 metres apart which can all be heard from the start, plus a finish beacon transmitter on a separate frequency. For this event, the timing of the transmitters is one minute on, 4 minutes off.

The control program for the microprocessor is written in the C programming language variant used in the Arduino Integrated Development Environment (IDE). Since version 1.5 of the Arduino IDE, it has been possible to use a variety of different microprocessors other than the original ATMega processors. One of the earliest implemented is the Atmel ATtiny85. There are advantages and disadvantages to using this IDE. The main advantages are: a fairly “friendly” programming environment where much of the low-level I/O and basic timing of activities has already been worked out; a reasonable debugging feedback; and a quick turnaround code/test cycle. The only disadvantage is that one is constrained to using the logical organization designed into the IDE, but even this constraint is not all bad.

The program developed uses the Arduino IDE timer0 along with the millis( ) and loop( ) main program structures for the Morse code generation, and installs its own timer1 interrupt service to generate a one-second timer based on the 1.8432 MHz microprocessor crystal to time the 12 second, 48 second and minute transmit sequence timing.

Mode selection makes use of the single pin 7 as an analog input to choose the mode based on the voltage level on that pin. Ground selects mode 0, Vcc selects mode 3, and voltages at 3/8 Vcc or 5/8 Vcc selects mode 1 and 2 respectively.

The program includes a number of compile time definitions that allow choosing, at compile time, the output signal logic polarity (open-drain, active low or active high), the code speed for call sign ID, the indexing/not indexing of the standard mode and so on.

The controller program uses data stored in the onboard EEPROM to hold the fox number ID code and the call sign ID. This way, the controller may be programmed without using the Arduino IDE, and the fox number and call sign can be changed without recompiling the program

ACKNOWLEDGEMENTS

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RESOURCES AND REFERENCES

Version 2 Rx manual, construction tips, ARDF event info: https://ardf.whyjustrun.ca/

Club presentations slides (see 80m receiver project link): https://ardf.whyjustrun.ca/pages/71 www.ardf.ca

Receiver manual, both versions: http://islandnet.com/~jyoung/

Transmitter manual, controller manual (see Arduino_programs): http://islandnet.com/~jyoung/arduinopgm.htm

Official IARU Region 2 website; links to rules: http://www.ardf-r2.org/

Les Tocko: *First licensed in 1967 as OK3ZAX, he became VE4AMW in 1981, then VE6AWA and finally VA7OM. A retired electrical engineer, Les likes designing various electronic circuits, mostly RF receivers and transmitters. He likes HF DXing and contesting. His preferred mode is CW. Between 1967 and 1975 Les was an active fox-hunter attending many international ARDF competitions.*

Keith Witney: *First licensed in 1964 as VE4EI, Keith holds VE7MID and VE7KW and has operated in a number of DX countries. Keith is a multi-mode Radiosport operator, but prefers CW. A retired electrical engineer, Keith likes designing HF antenna systems and messing with technology in general.*

G. D. (Joe) Young: *First licensed in 1960, Joe has held call VE7BFK since then. He was active on HF, mostly CW, in earlier years, but his recent activity is mostly ARDF. He is a retired electrical engineer who enjoys messing about with various electronic projects.*