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ISM Band “HiFER” Beacons: Part 3

The “Watering Hole”

The frequency segment from 13.555300 to 13.555500 megahertz (MHz) is designated as the “watering hole” by radio hobbyists operating within the experimental, license-free, 22 metre (m) segment of this industry, scientific and medical (ISM) band. Here, you’ll find various QRSS (sending really, really slow) data modes, such as on/off keying continuous wave or OOK CW (Morse code), two-frequency shift keying (2-FSK) CW and 4-FSK weak signal propagation reporter (WSPR) mode 2 (two-minute transmission time). There’s also a “Canadian corner” higher up the band where fast CW beacons operate. To monitor and/or work within the watering hole is the same as for any other data mode: a computer and soundcard, single sideband (SSB) receiver/transceiver and the appropriate digital signal processing (DSP) software. The only 22 m band limitation is that maximum radiated power is capped at 4.6 milliwatts (mW) using no more gain than that of a dipole antenna—about 2.15 decibels (dB).

If you’re a digital modes operator you already have the required hardware interface and mostly free DSP software such as WJST-X (for WSPR2). For receiving and visually decoding “fuzzy logic” (eye/brain decoding) or QRSS OOK CW and FSK CW modes, you just need a DSP program called “Argo”. See Figures 1 and 2 (next page). If you’re only interested in listening, just connect an audio cable between your radio’s audio output and computer soundcard’s line (or microphone) input and adjust the audio level. To use internet remote receivers like the KiwiSDR receiver network, you’ll also need a software (virtual) soundcard program such as the free “VB-Cable”.

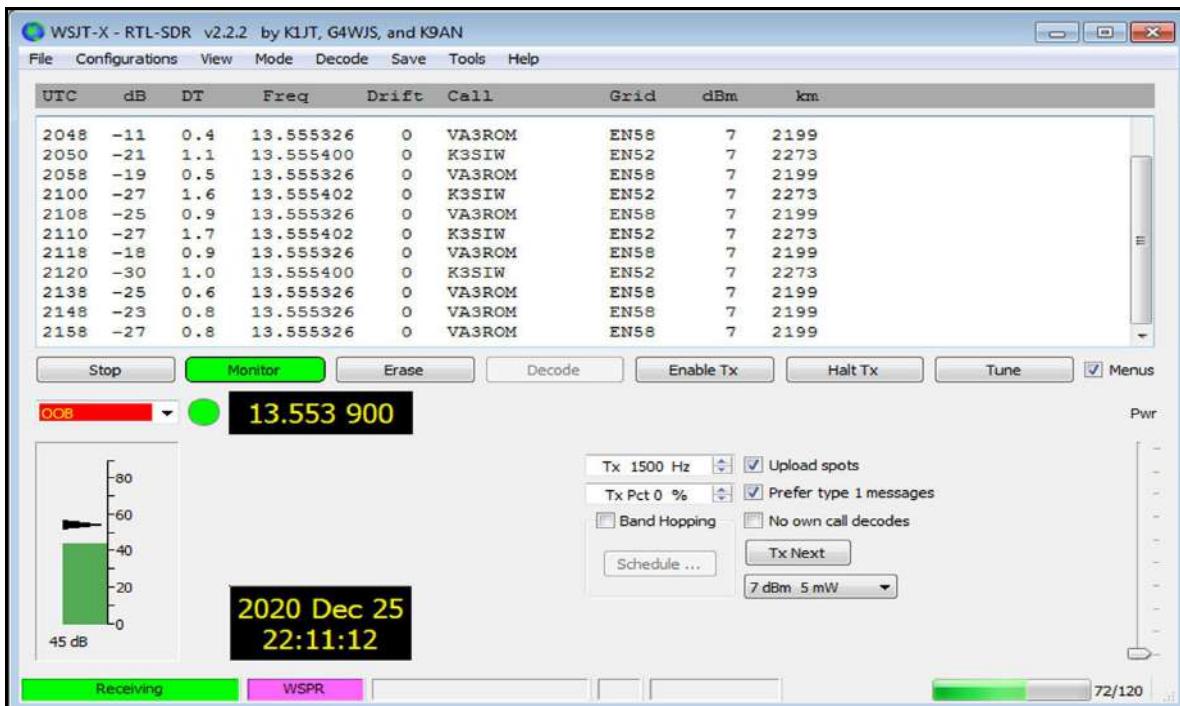


Figure 1: WSJT-X

Via Ron Morell, KA7U's KiwiSDR in Weiser, Idaho on Christmas Day 2020. The WSJT-X decoding software doesn't have an equivalent decibels milliwatt (dBm) for 4.6 mW or 6.63 dBm (the 22 m band maximum) so we use the next best value of 7 dBm (5.0 mW).

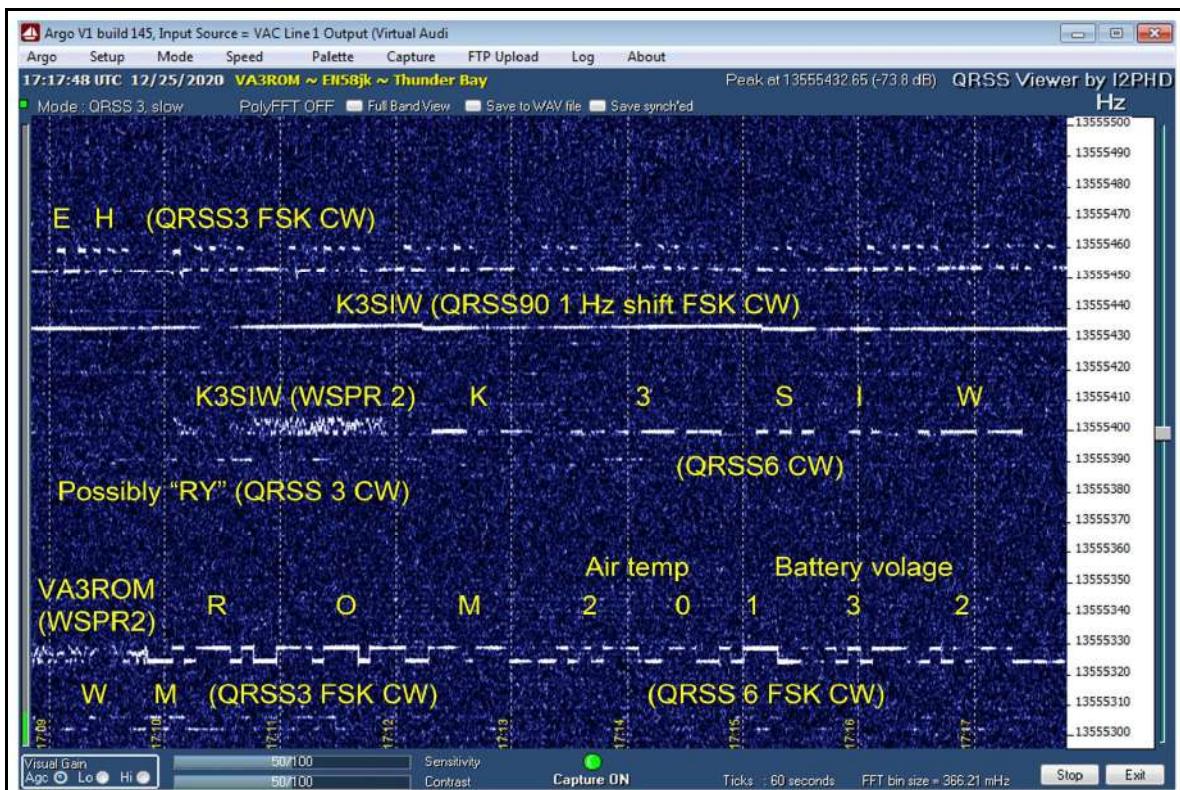


Figure 2: Argo Display of 22 m ISM Band Beacons

WJST-X and VB-Cable provide their own help files; for Argo, I found an excellent tutorial document (see my *Radio Magic* webpage). When using internet remote receivers, your web browser's audio output is routed through the default soundcard (real or virtual) as assigned by you. In this case, we want to route browser audio through the virtual soundcard (VB-Cable or equivalent), and then route the virtual output to our DSP decoding program(s) input.

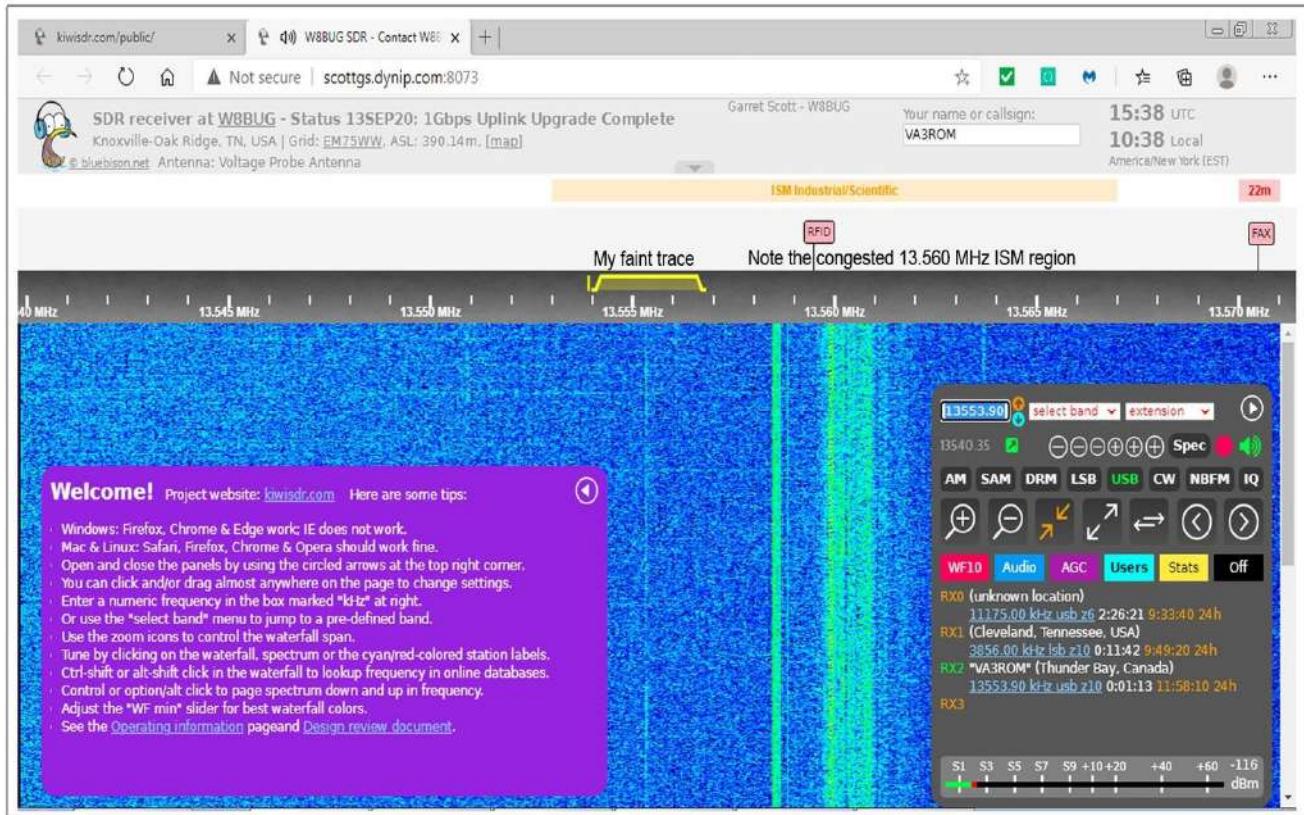


Figure 3: Internet Remote KiwiSDR

All KiwiSDRs have the same web browser graphical user interface (GUI). Once you setup a specific receiver's controls they stay the same each time you use it. All KiwiSDR's have a two-second or so latency or processing delay so your computer's real-time clock (RTC) must always be spot on.

For remote KiwiSDRs (Figure 3), you select a receiver in the network to use, type in your station identification (optional), select upper sideband (USB) mode and type in the dial frequency of 13553.90 kilohertz (kHz). I explained why in part 2. You can leave the other settings at their defaults. Run the DSP software and setup the virtual soundcard. For WJST-X you also add a new out-of-band (OOB) frequency 13.553900 (MHz) to its frequency database.

Prediction v. Real-World Propagation

Propagation prediction programs determine the probabilities of successful transmission/reception to/from areas using a table of predetermined smoothed sunspot numbers (SSN), plus a mathematical model of the ionosphere and the latest version was modeled in 2007. The SSN table data is derived by the Solar Influences Data Analysis Centre (SIDC) from the Belgium Royal Observatory. The SIDC also provides the visually observed daily SSN so you can override the SSN table value(s). The most well-known and widely used propagation prediction program (Figure 4) is the Voice of America Coverage Analysis Program (VOACAP).

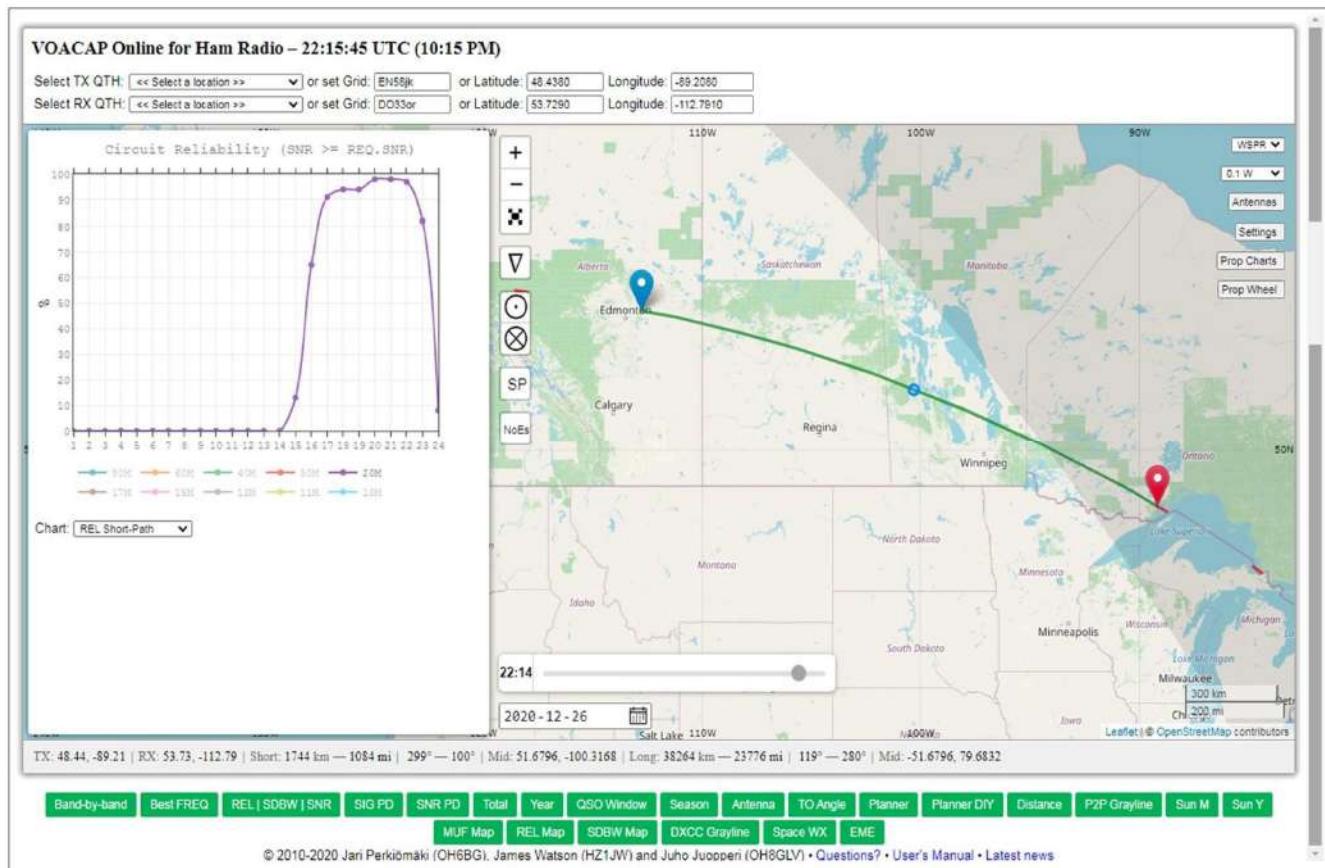


Figure 4: VOACAP Propagation Prediction

Here's a propagation prediction using Donald Moman, VE6JY's KiwiSDR in Lamont, Alberta, on 20 m with a WSPR2 beacon running at 100 mW.

In the case of my sub-5 mW telemetry QRSS 2-FSK CW beacon, was it possible to collect real-time, real-world results using the KiwiSDR network to see if there was some constant percentage difference that agreed closely with what VOACAP predicted for 100 mW WSPR2 transmissions on the nearby 20 m band?

To answer my question, I ran daily VOACAP predictions for 20 m and gathered data for 22 m via the KiwiSDR network over a few weeks. Long story short, there's about a 30% average difference caused more so by the roughly 13.5 decibel (dB) power difference (about 2+ S-units) and less so by the slight propagation characteristic differences between the two bands.

Because QRSS 2-FSK CW and 4-FSK WSPR2 appear to have equivalent power spectral densities (PSD) in watts per hertz (W/Hz), I'm very confident in the results. *Note: I've since added WSPR2 to my beacon, and ongoing side-by-side on-air comparisons seem to confirm the PSD equivalency and 30% propagation probability difference. But proving it mathematically (for me) is another matter so my conjectures must be considered purely anecdotal.*

22 m ISM Band Telemetry Transmitter Design

By trial and error, I discovered that my variant of the SG-8002DC is an ersatz voltage controlled oscillator (VCO)—a fact not advertised by Epson. This means it can produce controlled frequency shifts by manipulating an external control voltage. This added 4-FSK WSPR2 to the telemetry transmitter allowing for better propagation comparisons. You can also control the CW shaping or “K” rise and fall times in milliseconds (ms) of FSK CW, and even can create fancy FSK shaped signals such as: scallops, sawtooths, slant bars or dot-matrix alphanumeric characters, but beyond the scope of this article.

The telemetry transmitter is designed so that you can swap out the low pass filter (LPF) and fix-frequency, preprogrammed Epson SG-8002DC radio frequency (RF) oscillator for any frequency of interest from 1 MHz to 125 MHz. The Epson SG-8002DC was selected over a multi-frequency direct digital synthesis (DDS) RF module (i.e. Si5351, AD9850/9851) because it's so much easier to use and program because no external support code libraries and convoluted coding is required just to sit on one single frequency 24/7/365. The SG-8002DC needs about 5 minutes to reach thermal equilibrium and maintains operating frequency stability down to -20 C or so. The carrier stays on continuously to maintain frequency stability for FSK modes. The SG-8002DC is spectrally purer (no DDS harmonic “spurs” or frequency “jitter”); and it sits nicely in standard dual-in-line package (DIP) sockets (8 or 14-pin).

A 5-pole (number of reactive components) low pass filter (LPF) was designed to use standard (exact) value capacitors and two identically wound toroid inductors. It's a Chebyshev plus Legendre–Papoulis (optimum-L) hybrid LPF. Iowa Hills RF filter designer and LTSpiceVII were used to design them. Molded inductors would work just as well but I couldn't find any close enough to the values that I needed.

Everything is constructed on Adafruit's "perma-proto" half-sized breadboard printed circuit board (PCB) using the PICAXE Electronic Bread Board Layout Emulator ("PEBBLE") to create the new layout (Figure 5) so that it all fits inside the ubiquitous Altoids mints can for very low and low power (QRPP and QRP) Amateur Radio tradition, with a bit of RF shielding the metal can provides (see Figure 6, next page).

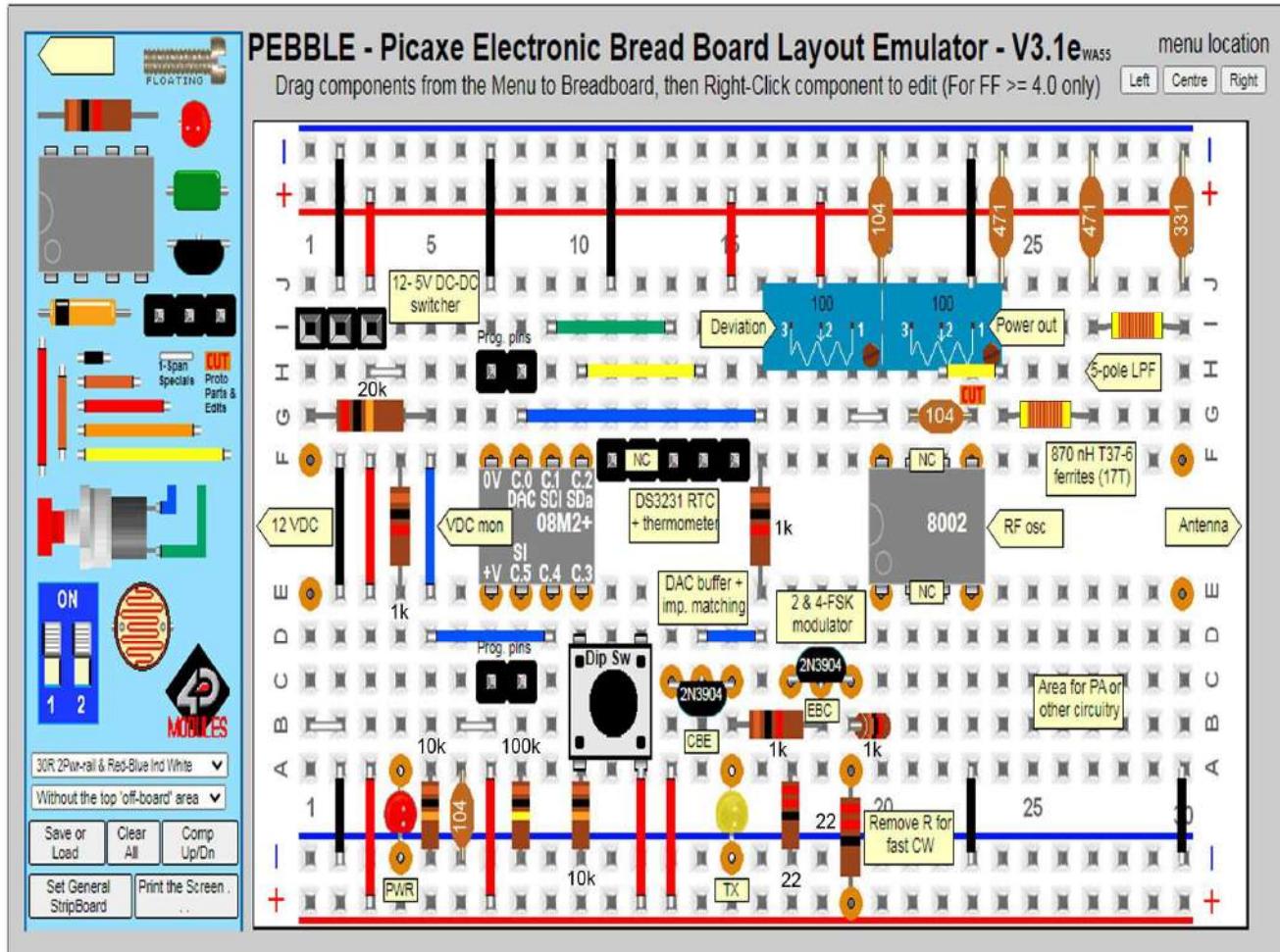


Figure 5: Telemetry Transmitter PEBBLE Layout

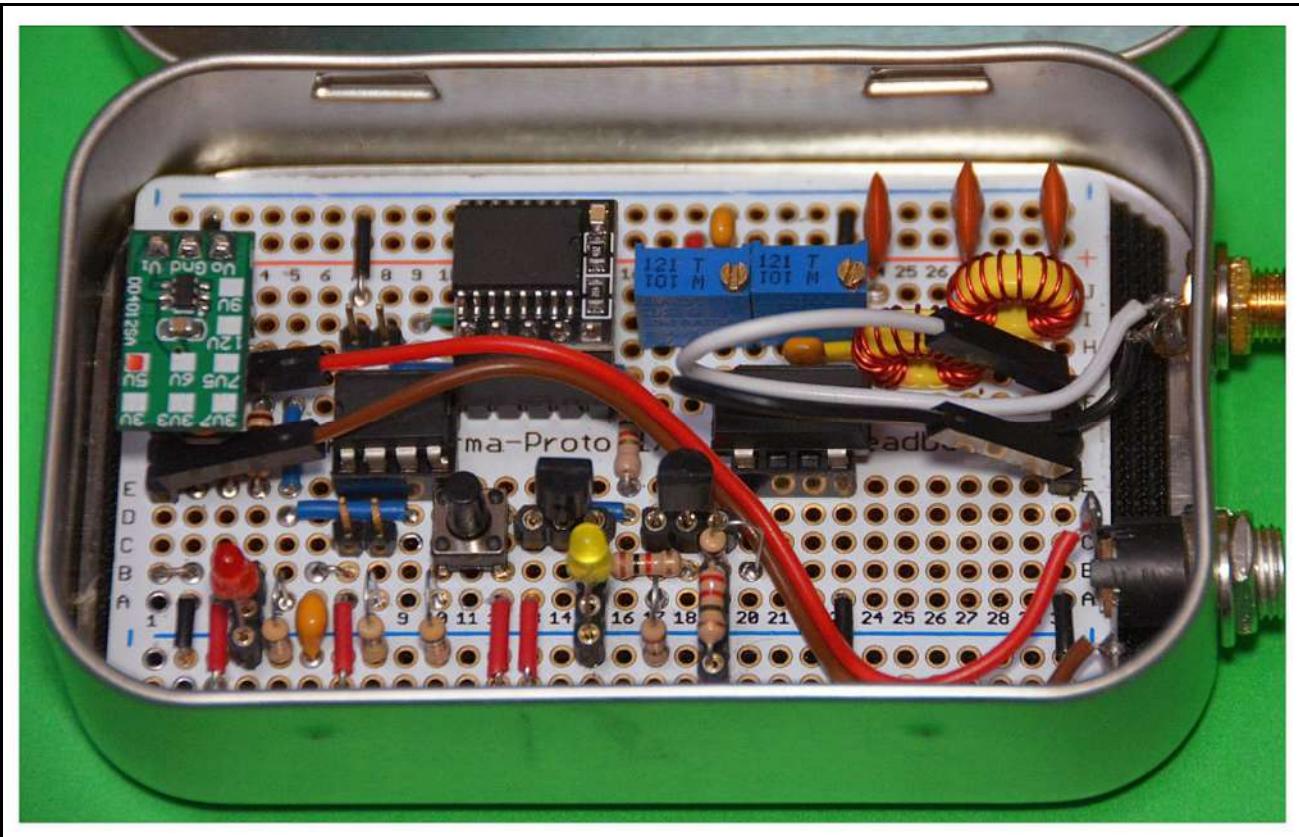


Figure 6: Telemetry Transmitter

The final 22 m ISM band, Altoids mint can, telemetry transmitter. I left room to add a QRP power amplifier (PA) for use on Amateur Radio bands where higher power and gain antennas are used.

Changes were required to the original transistor switching circuitry (see Part 2) to add DAC and WSPR2 plus a DS3231 real-time clock (RTC) for the accurate timing all WSPR modes require. Fast OOK CW now operates as a solo mode because of the changes. In-circuit PICAXE programming pins were added so the μ -controller doesn't have to be removed or the power disconnected; the transmitter automatically goes into idle carrier mode. *Note: The schematic diagram, PICAXE BASIC source code and other material are contained in the RM048 Supplement zip file located on my Radio Magic webpage.*

My Final

Months after starting my exploration of the 22 m ISM band, I'm still having way too much radio magic fun designing, building and experimenting with very low powered (QRPP) telemetry transmitters. But "citizen science" is my thing and perhaps it can be for you and the many other citizen scientists, of all ages, "out there", too.—73