Homebuilt HF Radios for Use Underground

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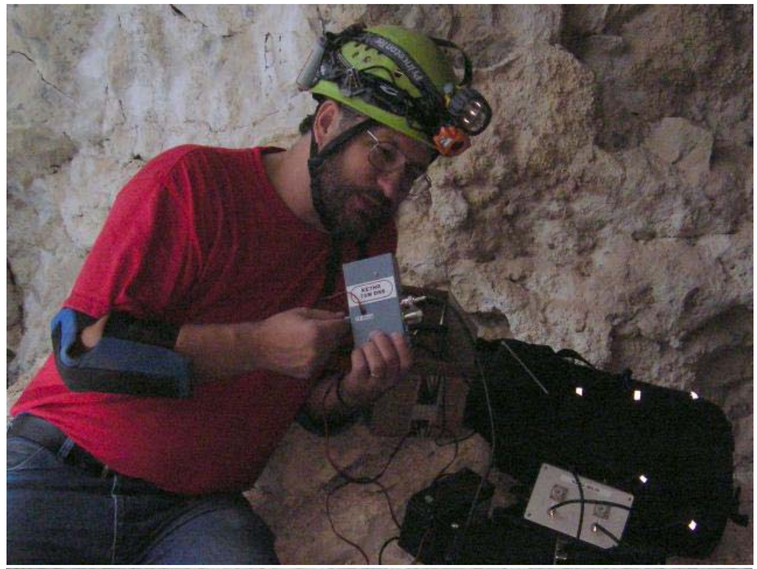

With the good success in using Amateur Band HF radio for underground communications, I started looking for cheaper alternatives to the $500+ commercially available radios. My first project was to build a DSB (Double Sideband) transceiver. DSB is easier to build due to fewer parts and so less expensive to build than a SSB radio. I found a suitable looking project on the internet called "Wee Willy 75 Meter DSB Transceiver" (http://www.qrp.pops.net/willy.asp) . It seemed to meet all of the needs for a caving radio - small, light weight, simple to use, not too costly, and easy to build. The first project ended up costing about $50.

DSB suppresses the carrier frequency, but passes both sidebands (the parts with the voice information) at once. A SSB radio (Single Sideband) suppresses the carrier and one of the sidebands so it only transmits one or the other (upper sideband or lower sideband). If the carrier frequency was not suppressed nor the sidebands, the transmission would be the familiar AM or amplitude modulated transmission. DSB is more efficient than AM and SSB is more efficient than either. DSB is a compromise between a full blown SSB radio and an AM transmitter, but still useful. Users of SSB radios will not know that you are also transmitting on the 'other' sideband!

I chose to use the 'ugly' or 'dead bug' style of construction. I built the receiver and transmitter on different small bits of printed circuit board. The frequency determining part (crystal control or variable oscillator) was something that I wanted to experiment with, so I designed so that it would be outboard from the main parts of the transceiver.

Looking at the circuit diagram and reading the text of the project, I decided to modify the amplifier section so that it ran from the 12 volt battery. I used a voltage regulator to keep the voltage safe for the mixer, a NE602. Since I only had 5 volt regulators, I used the old trick of putting a switching diode in the ground lead to raise the output voltage by the forward conducting voltage of the diode. I used two diodes in the in the transmitter circuit and one in the receiver circuit. See the schematic for my changes to the circuit in red. This modification allows the transmitter to put out about 2 watts - double the original! I also found the regulator needed an additional bypass capacitor to stop instability. I substituted a different transformer than that called out for, which worked quite well. I made the operating frequency switch between the transmitter and receiver with the TR or transmit-receive switch.

Tests with the radio and a dipole antenna showed that the receiver (a direct conversion circuit) was wide banded and was able to hear transmitters off frequency a bit. It was, however, quite sensitive - the first night I had it together I was hearing station from TX, OK, NM, CO, AZ, NV, and CA from my home in Phoenix, AZ. I had to turn down the RF gain control to have comfortable listening to the louder stations (which also saves a bit of battery power). For portable use, headphones will work fine but the audio amplifier has sufficient output to drive a small speaker to a good volume. The RF gain controls the volume as there is no 'volume control' on the audio amplifier.

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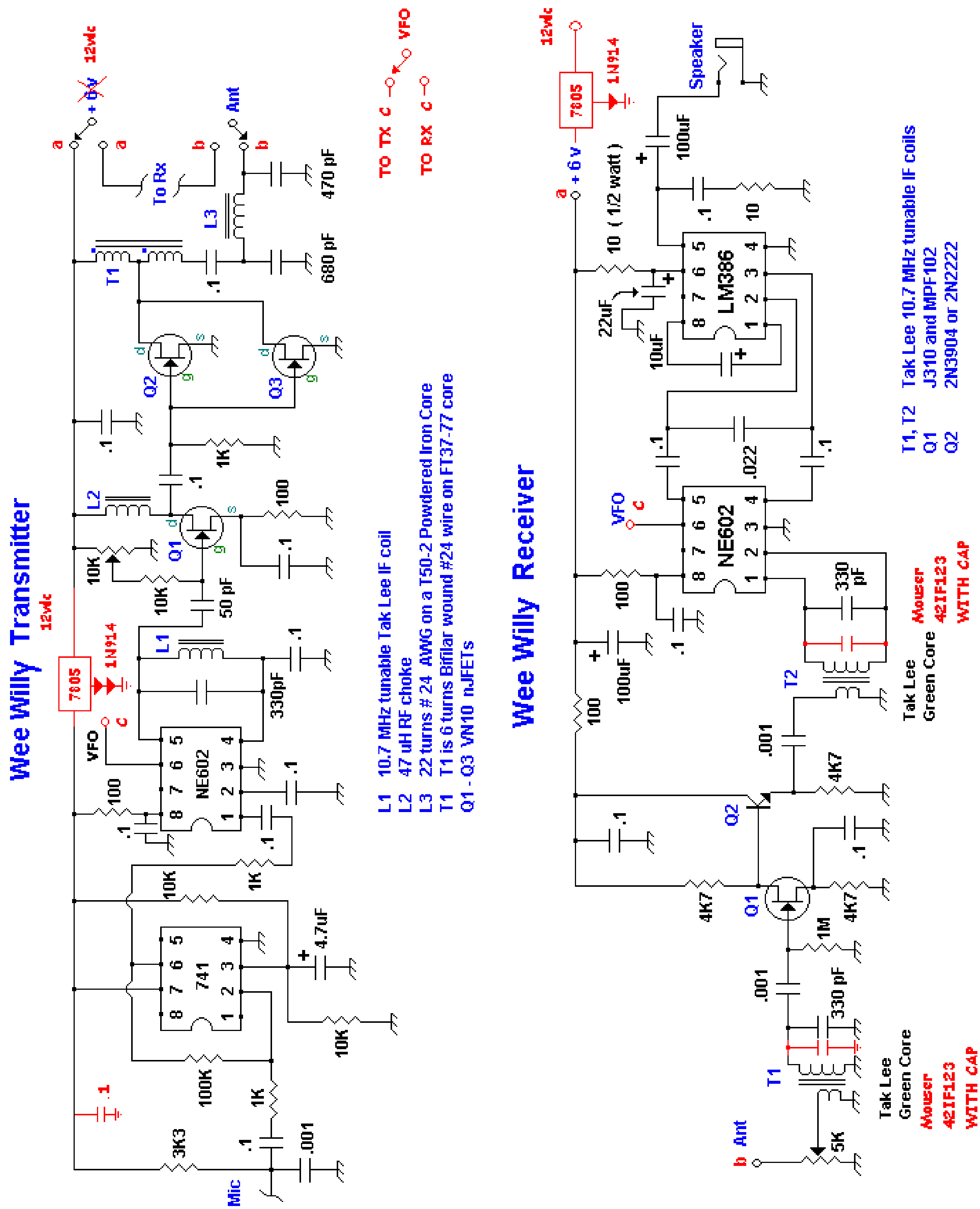
The transmitter has a similar power level to the FT-817ND that I used underground on other occasions. The photo on the top of the page shows me speaking to the surface 220 feet above with perfect clarity.



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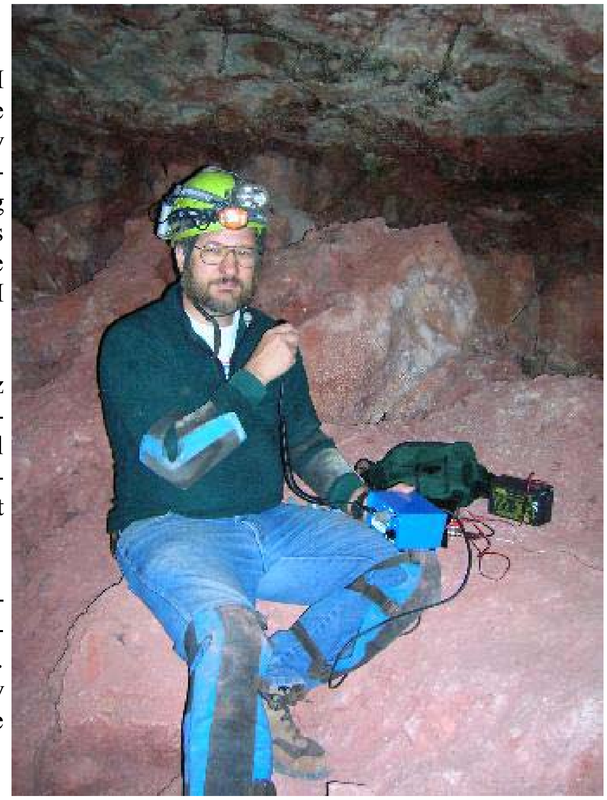

After building the DSB project, I wanted to try building a SSB rig. I searched the internet for a simple circuit that would be easy to duplicate and have a fair chance at success. My search narrowed to a design by Steven "Melt Solder" Weber, KD1JV. Steve keeps a website with projects at http://kd1jv.qrpradio.com/ that had a '(Fairly) Simple SSB Rig with PTT for 75 Meters' project that sounded exactly like what I was looking for. When Steve published the printed circuit diagram for the 'Revised (Fairly) Simple SSB Rig' (with a separate final amplifier), I started building.

The radio is a single conversion super-heterodyne radio with a 5 MHz variable frequency oscillator (VFO) which mixes with a 9 MHz intermediate frequency to produce the approximately 4 MHz lower sideband signal in the 75 meter ham band. The project VFO was actually a PTO or permeability tuned oscillator that was stable on the workbench but not great in the field. More on that later.

The radio features a four element crystal filter to select the proper sideband. The filter, and other parts of the circuit, is switched between transmit and receive by an analog switch IC circuit. This works quite well. NE612 mixer chips are used for both transmit and receive circuits. They are very reliable and widely used in amateur circuits, but may become more scarce in the future like all IC chips…

I found one tiny error in the PCB artwork - one bypass capacitor, next to the voltage regulator, did not have pads for drilling. I just added the part to the underside of the board, since it is small. I did not have the 7mm IF transformers that were called for so instead used 10mm transformers that I soldered extensions, made of resistor lead cutoffs, to fit the board. The wires could be bent into place, but it would have been nicer to have the smaller part. All of the other parts went on the homemade PCB quite well.

I purchased a couple of cheap speaker microphone combination units on eBay. To keep the project compact I wanted to use a speaker mic instead of having to fit an internal or external speaker. This presented a problem as the circuit did not completely mute the input to the audio amplifier. Depending upon the microphone gain and speaker volume, the speaker would feedback and howl like mad, but only with the speaker mic and not an external speaker. After a bit of head scratching, I came up with a scheme to ground the input to the audio amplifier using an additional 2N7000 transistor which is switched along with the transmit-receive changeover. This solved the problem (and I later found out that Steve had the same problem and solution).

One more change that I made was to allow a switched gain increase of the audio amplifier from 20 to 200. All this took was the switch, a resistor and a capacitor. In testing, I found that I use the high gain switch setting almost all of the time and would hard wire any future radios to that position. There is a bit more background noise, but the clarity of a weak voice signal is better, in my opinion.

Building the 'Revised (Fairly) Simple SSB Rig' allowed me to tailor the final amplifier to be similar to the power output of the FT-817ND commercial radio. Steve's design for the 'Revised (Fairly) Simple' radio had a 25 watt amplifier, but I kept the 5 watt design from the original plans. The increased battery requirements for the amount of gain was not considered to be worth the extra effort. The power amplifier is built 'ugly' style on a piece of board attached to the radio case for heat sinking.

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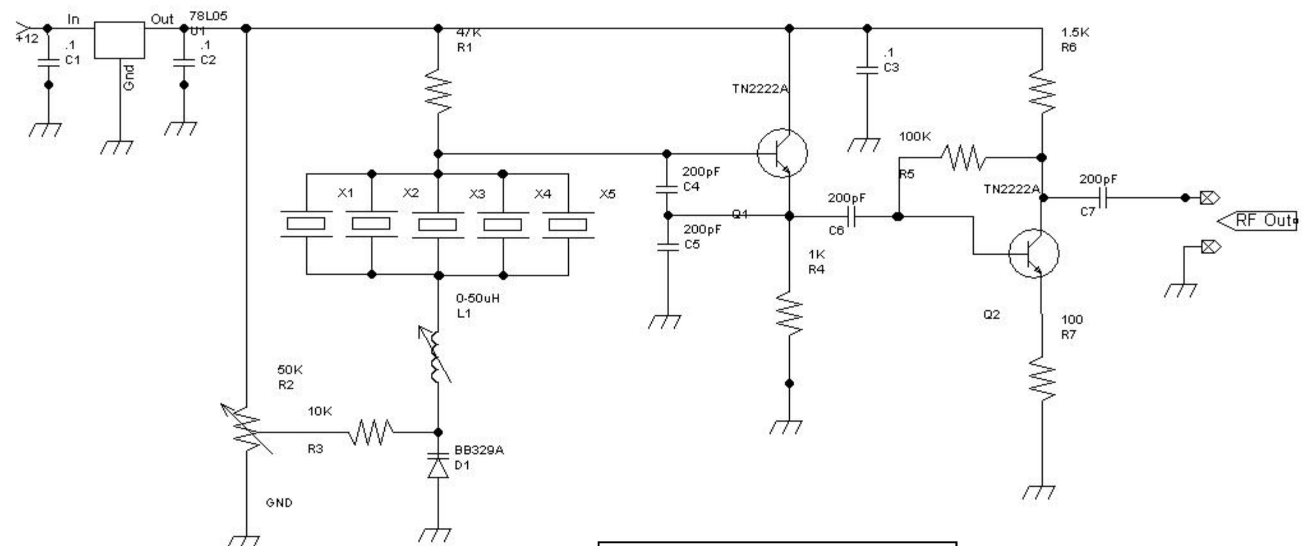
The PTO VFO outlined in the original article worked great on the bench and in the ham shack. But, out in the field with temperature changes and other concerns there was some instability. I wanted to come up with a way to vary the frequency but still keep a steady frequency control, like crystal control. I had seen several designs that used a VXO or variable crystal oscillator. A VXO uses a variable element but still bases the frequency on the crystal. The normal variance of a VXO at the 5 MHz frequency that I needed was not much for a single crystal. Circuits were published on a ‘Super VXO’ that used two crystals to achieve greater frequency range. I wondered about extending that even further with more crystals. I found that the circuit was stable and had wider range with five crystals (where I stopped trying!). The package for the VXO was a mint tin, so my space was limited. I also wanted to have two variable channels, so that made for a total of ten crystals and the circuit board to fit into the small box. It works very well. I have about 5 KHz of frequency range around two different frequency ‘channels’. If there is interference the frequency can be shifted a bit or even changed to the other channel to have communications. The variable aspect of the VXO is rock solid and not so wide that a user can get far from where the other station expects! The schematic only shows one bank of crystals but there are really two switched banks to achieve the two ‘channels’.



KE7HR 5 Crystal VXO

The whole radio is easy to use and readily reproducible. Because it is operating on Amateur Radio bands a valid General Class or above (USA) license is needed to operate. (The Morse Code requirements have now been removed from licensing so go take the tests!) The basic circuit layout for this radio may also lend itself to being shifted in frequency to the LF band around 185 KHz where other transverters and radios have been used in North America.

Performance of the SSB radio underground has been everything that I expected. The clarity of transmission and reception from deep underground raises eyebrows from those who have not heard it before. Contact between the DSB and SSB radios was fun! The additional complexity and cost of the SSB radio are made up for by it’s performance. The SSB radio project has become a kit currently available for the 7 MHz band and available from http://www.qrpkits.com/ as the “MMR-40 Transceiver” for $110. It should be easily modified to work on the 75 meter band. By the time a few additional items are added on (microphone VXO, etc.), the price for a functional, cave capable, radio should still be less than $150.

For further expansion on the individual parts of the project see my Caver Radio website http://members.cox.net/caveradioat/ .

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