The FOXFINDER-80 WEB UPDATE

(DRAFT v2.0 SUBJECT TO CHANGE)

A lot of modifications have occurred since the introduction of the original article. This update incorporates them and also corrects some errors that got into the original published text. Also modifications to the FAR circuit boards are described along with modifications from other users.

Introduction

The purpose of this article is to describe how to build a simple ARDF receiver for 80-Meter international style transmitter hunting. The criteria for the receiver is that it must be easy to align with out expensive lab equipment and all the parts must be easy to locate. In the case of this receiver the majority of the parts were purchased from Digikey, Newark, Radio Shack and Radio Shack Unlimited. One component was purchased from Amidon associates and another part was located at a local surplus store (10 turn knob pot used for VFO control).

80 Meter CW ARDF Receiver

Unlike VHF direction finding equipment, very little information about complete 80-meter DF sets can be found in the United States. Bits and pieces of information relating to DF antennas can be found in books such as the current edition of the ARRL antenna handbook. Another source of information is a book by Joe Moell K0OV titled “Transmitter Hunting Radio Direction Simplified”. Also a new book by Joe Carr is a good source of information about loop antennas, its title is “Joe Carr’s Loop Antenna Handbook”.

Information on small CW receivers can be found in the ARRL handbook, QRP handbooks and the Internet.

Back in May of 1999 I started developing my first portable receiver for use in the Portland games. The result was an operational receiver that was used in the games. I was the only US contestant with my own 80meter equipment. All other US contestants used equipment provided by the Europeans.

The receiver described in this paper is my second-generation design. My first version receiver shown in figure 1 was the one that was used in the Portland event. It was a Superhet with an 8MHz IF and a ferrite rod antenna with a vertical sense whip (more on why a sense antenna is required later). Several improvements where made based on my experience using the original receiver during the 1999 hunt. Its my hope that this receiver will inspire the beginning of experimenting with homebuilt HF DF sets in the United States.

Figure 1 Receiver used in 1999 Portland games by Jerry Boyd WB8WFK

Size and weight reduction efforts where undertaken. The first generation receiver was awkward to carry and I decided that the next receiver must be as small and light as possible. After all, an ARDF course can be up to 8 km in length and weight becomes important. A plastic case was used for both receivers. To provide shielding the inside is lined with copper foil.

Next cost reduction efforts were used for the second-generation receiver including the design of the loop. This would make it more affordable to reproduce. The $15 ferrite rod used in the first receiver was replaced with a loop wound inside ¼ inch copper tubing using wire wrap wire.

Also the IF frequency was changed from 8Mhz to 455 KHz so low cost AM radio IF filters from Digikey (or surplus sources) could be used. The 8Mhz version used a homemade crystal filter in the IF made from microprocessor crystals and required a crystal selection process. I thought that that would not be easy to reproduce without test equipment to verify its operation. This receiver has a “no tune IF”.

Another improvement was the addition of electronic switching of the sense antenna. This appears to be a common feature in European designs. This allows the sense enable switch to be located in a location that is easy to operate with one hand. A normal open pushbutton switch is used for the sense switch.

Block Diagram and receiver operation

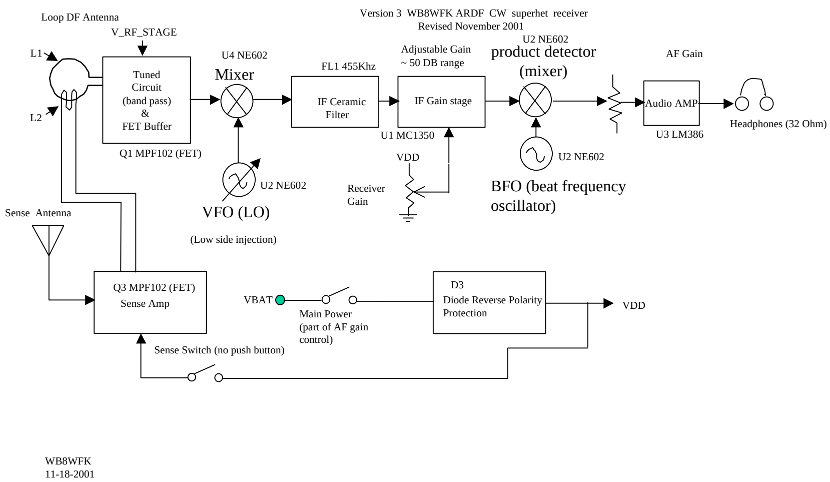


Figure 2 HF DF receiver block diagram

Refer to Figure 2 for an overview of the receiver. The signal is first picked up by L1 the primary DF antenna (L2 the sense-coupling loop will be discussed later). L1 and L2 are housed in a faraday shield made from ¼ inch copper tubing. L1 presents the typical figure eight pattern (refer to figure 3A) The voltage induced into the DF loop is amplified by Q1 FET amplifier.

Following amplification by Q1 the signal is passed on to U4 a Phillips NE602 (or SA602). U4 is configured as a Gilbert cell mixer and varactor diode tuned VFO. The VFO is operating 455Khz below the desired received signal (referred to as low side injection). The data sheet specifies a conversion gain of 14DB at 45 MHz. No graph was provided to determine the value at HF.

After conversion to the IF frequency the signal is filtered by FL1 to remove undesired signals. FL1 has a 6DB bandwidth of 4Khz. U1 is an IF amplifier with adjustable gain control. The data sheet specifies a gain of 50DB (at 45 Mhz) and a gain control range of 60DB (at 45 Mhz). Adjusting the AGC voltage controls the gain of U1. The electronic gain control circuit pot accomplishes this. Following amplification by U1 the signal is converted to base band (audio) by product detector U2 and BFO U2. A low cost ceramic resonator determines the BFO frequency. U2 is also a Phillips NE602 (or SA602).

After conversion to base band the signal is amplified to a level to drive a stereo headphone by U3. U3 is a national semiconductor LM386 configured for a gain of about 50 (set by 1Uf ceramic capacitor C7). The headphones can be any set that has Z of 32 ohms. A quick note about using cheep headsets, they may have lower efficiency than name brands. I can notice the difference between a Sony set verses a $5 no name. However the $5 version works.

Electronic gain control is provided via the IF stage by using a gain control voltage supplied via a variable resistor (POT). Manuel control is desired for a DF receiver, this is because automatic AGC action would adjust the gain of the receiver as the loop is turned, this could make finding the null difficult because of AGC trying to maintain a constant volume level.

Because the loop provides a figure eight pattern two nulls would occur, thus a 180-degree ambiguity exists. The nulls are perpendicular to the loop axis (figure 3A). The sense antenna and sense amplifier is used to modify the pattern of the loop to allow solving the ambiguity. When the sense switch is closed VCC is applied to the drain of Q3 amplifying and voltage induced in to the sense antenna. The amplified signal is summed with the signal being received by the DF loop by coupling loop L2. A cardioid pattern (figure 3B) results thus producing one null and a peak.

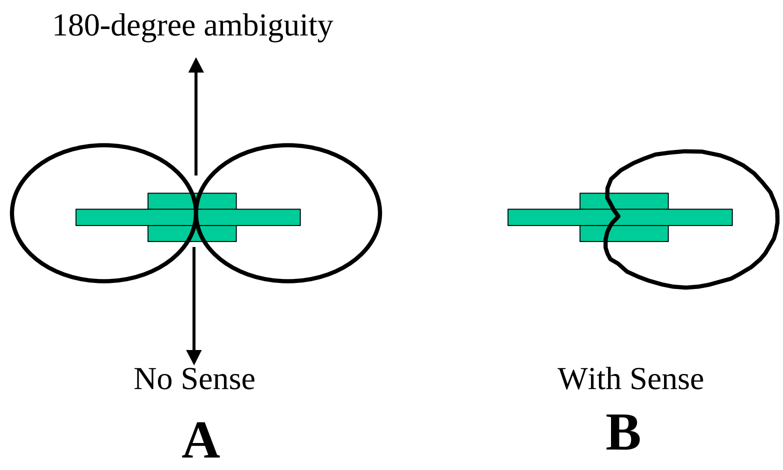


Figure 3 Loop antenna patterns (viewed from above looking down onto receiver)

Construction of Loop and sense antenna

Loop antenna construction. This section describes the construction of the loop. With the faraday shield and coil winding detailed.

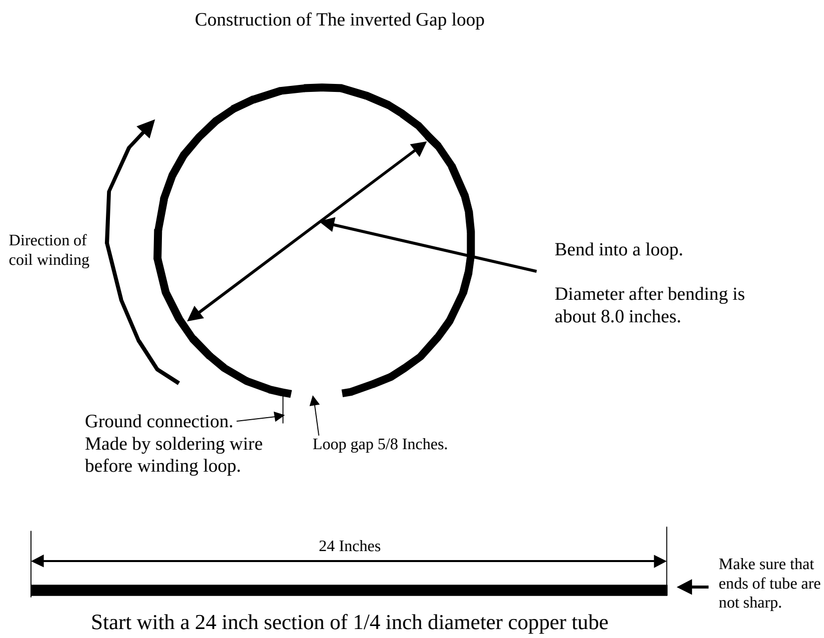


Figure 4 Faraday shield construction

Refer to Figure 4. To form the faraday shield start by cutting a 24-inch section of ¼ inch copper tubing. After cutting the tubing it is very important to remove any sharp edges on the ends. This will prevent damage to the coils during and after winding (sandpaper was used for this operation). Next bend the loop as shown in Figure 4.

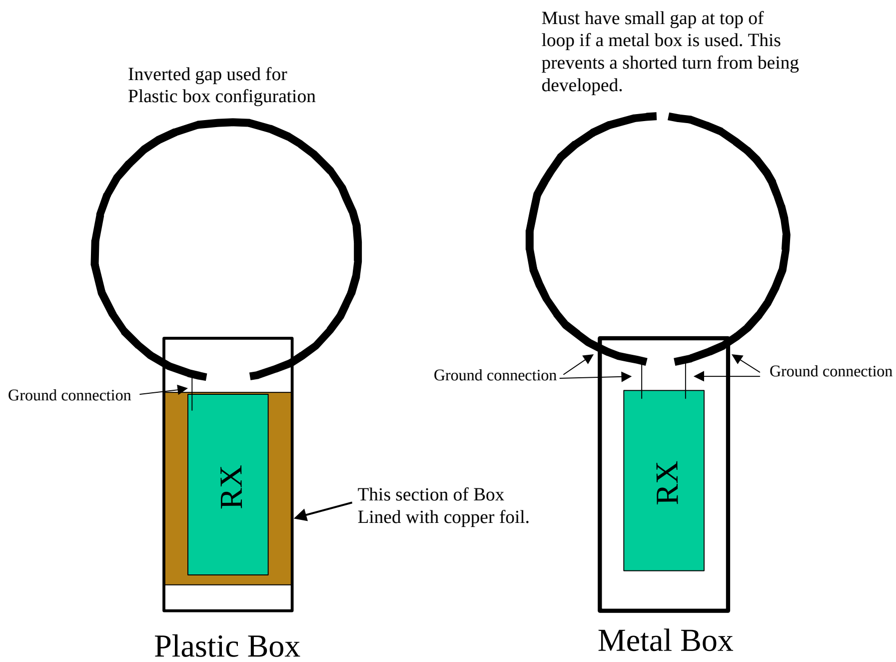


Figure 5 Attaching faraday shield to box

Next we attach the loop to the box after bending the loop. My version used a plastic box so I used the inverted gap configuration described in figure 5 (left side). If a metal box is used its very important to use the configuration shown on the right hand side of figure 5. The reason for doing this is to prevent the faraday shield from forming a shorted turn. If the inverted gap configuration is used with a metal box the receiver will not work. Also if a plastic box is used you need to provide some shielding for the receiver board. Do not extend the shielding above the position shown. This shielding is connected to the receiver circuit board ground.

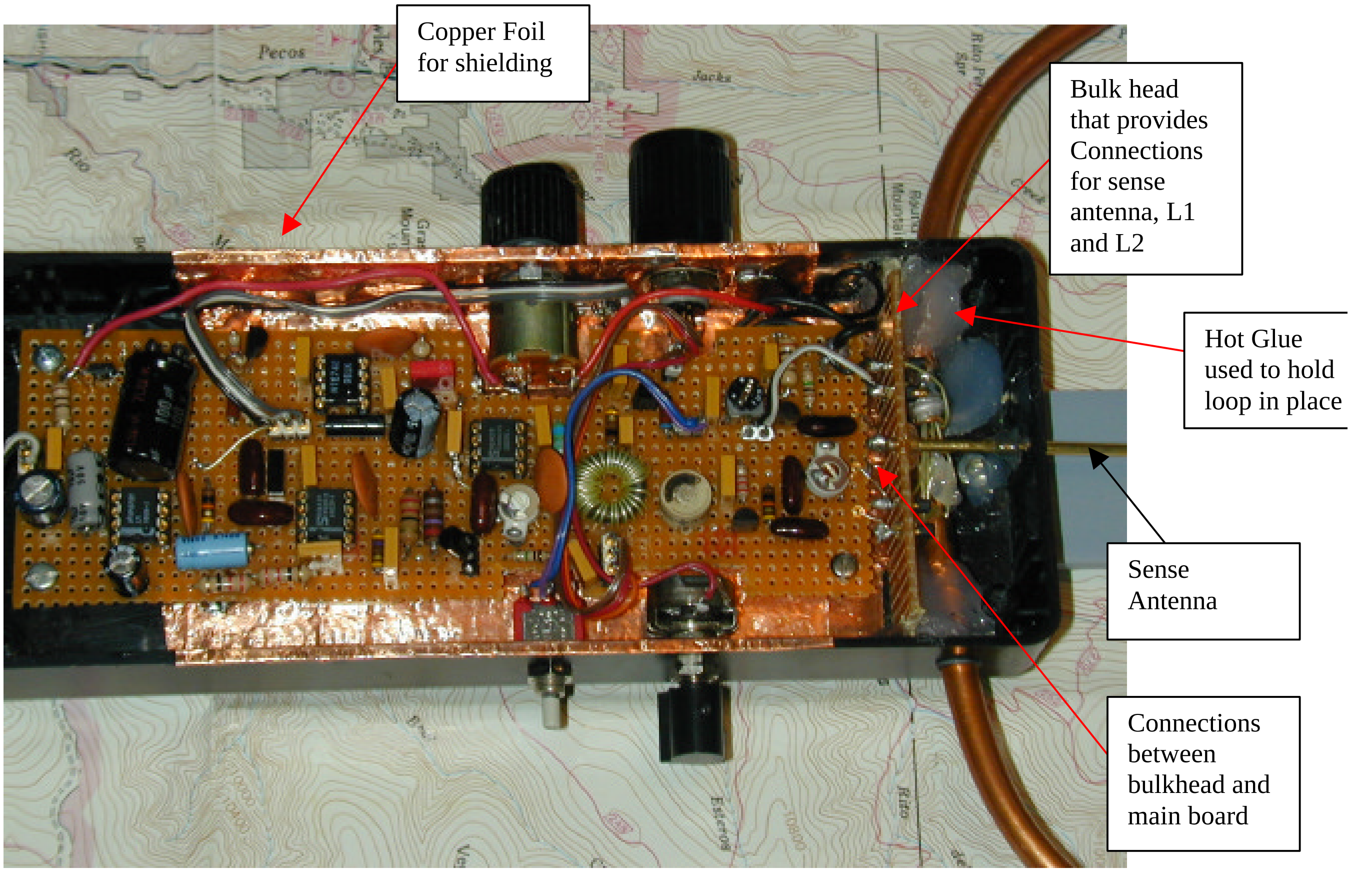


Figure 6 inside view of receiver

After gluing the loop in place the coils L1 and L2 are wound. First coil L1 is wound using 5 turns of #28 wire wrap wire. The wire ends are connected to the bulkhead (see figure 6 and 7). Next the sense-coupling coil L2 is wound using 2 turns of wire wrap wire.

The sense antenna is made from a 20 inch section of 3/32 bronze rod purchased from a local welding supply store. The sense antenna is attached to the bulkhead and hot glued in place. Next connections from the bulkhead to the main board are made for the sense antenna, L1 and L2. For safety purposes a small round wood or plastic ball (painted red or orange) should be attached to the end of the sense antenna for eye protection.

Assemble and install the receiver board after the loop is constructed. Refer to Figure 10 for approximate location of active stages. Be sure to use good high frequency wiring practices and keep leads as short as possible. Note that T1 is also wound using number 28 wire wrap wire. The Primary is 32 turns and the secondary is 3 turns.

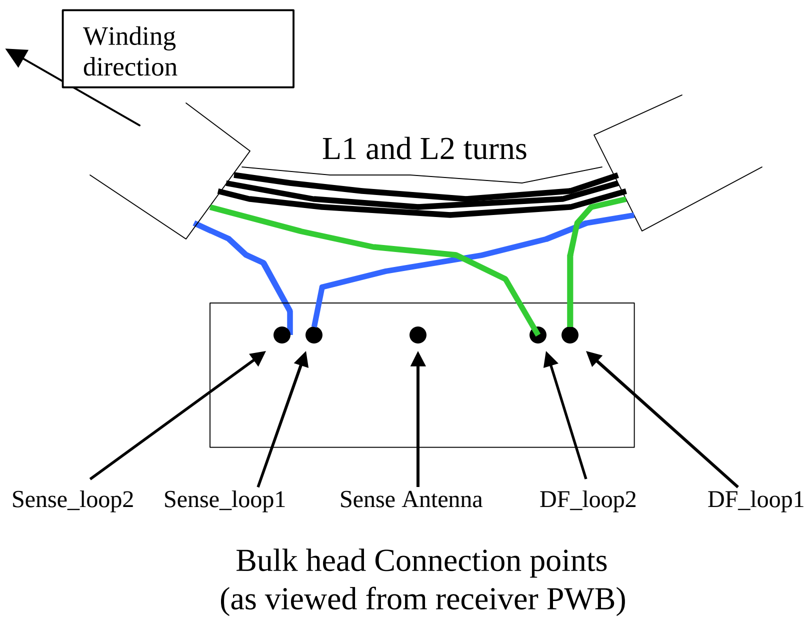


Figure 7 Bulk head connections

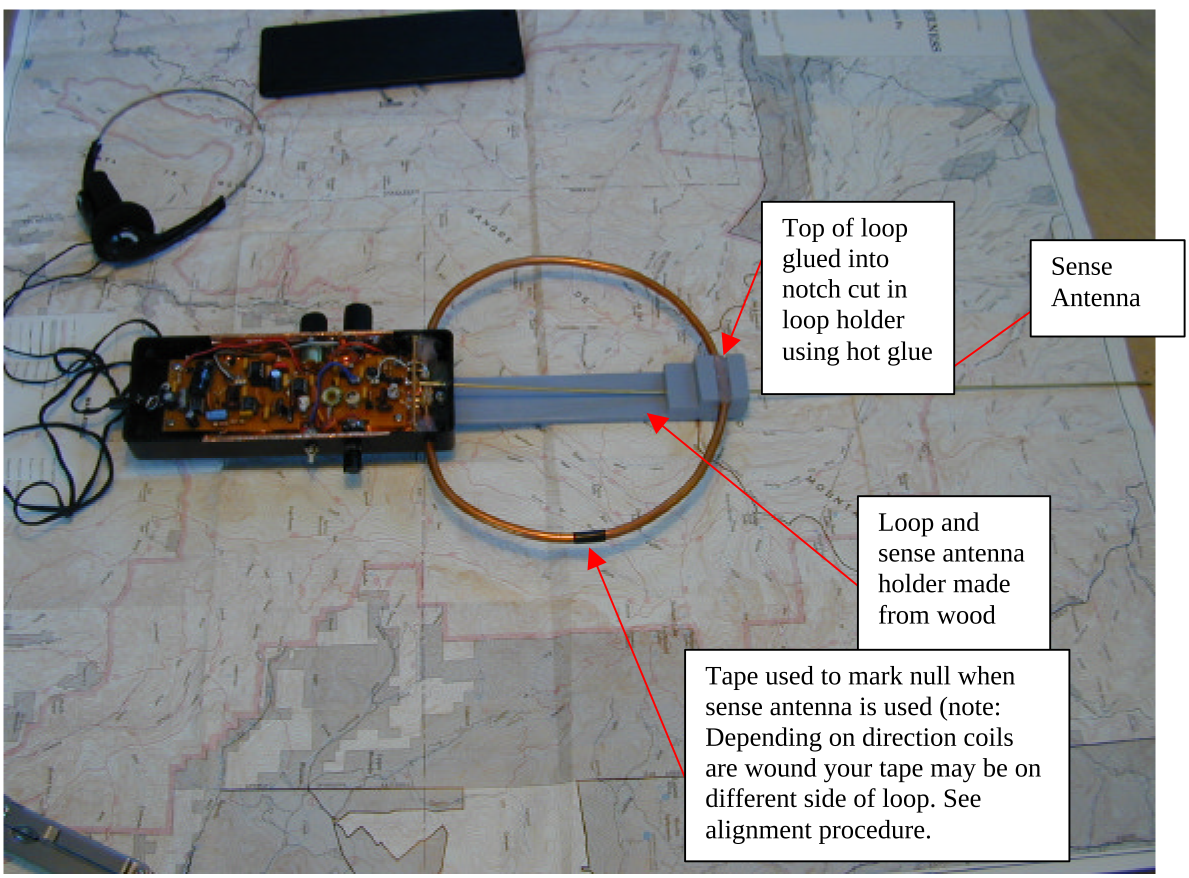


Figure 8 another view showing how sense antenna and loop are attached

Figure 9 removed

Alignment testing and operation

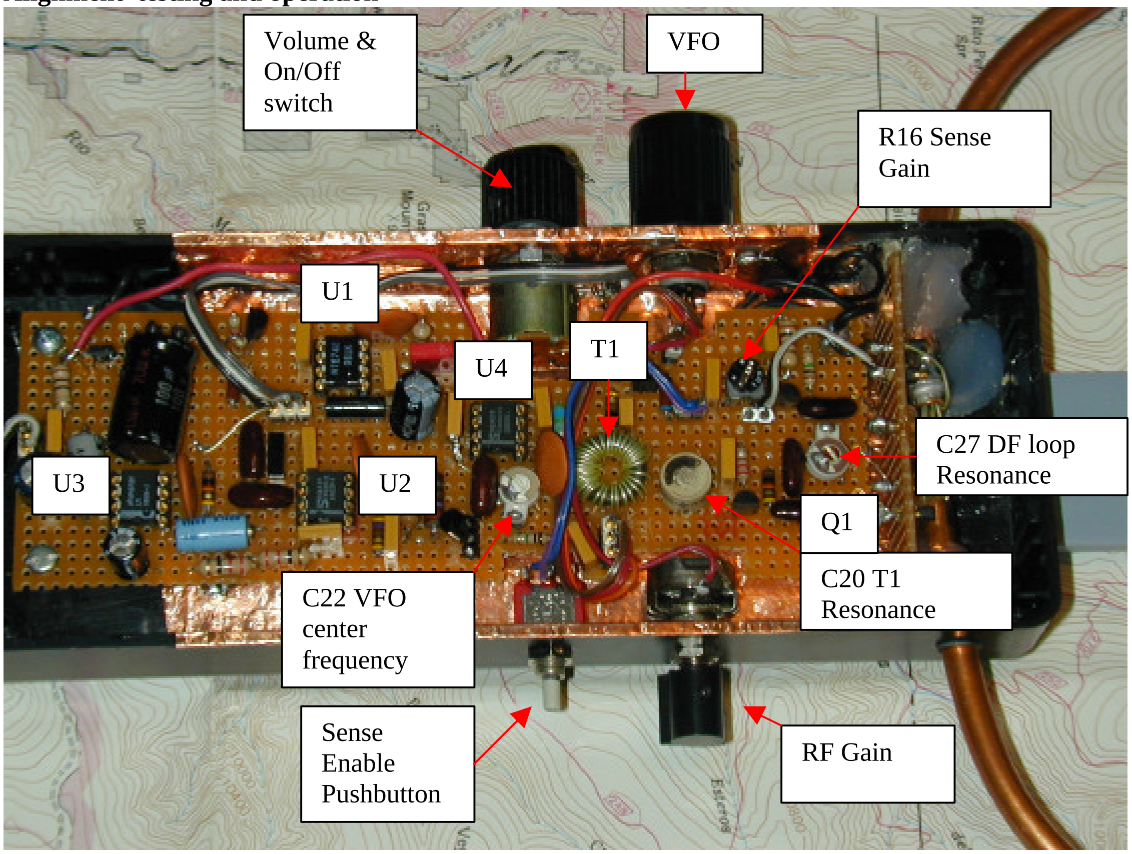


Figure 10 Location of Adjustments (replace photo with one that has a FAR circuit board)

Before starting, preset the controls to the following conditions:

1. Set the VFO control for center scale (if the knob pot is used its 5 on the dial).
2. Adjust the RF gain control for maximum RF gain.
3. Set the volume control for a low audio level.
4. Using a voltmeter, adjust the sense gain control (R16) for maximum voltage at the drain of Q3.
5. Note the next steps will temporarily allow the receiver to tune a very wide range (about 1 Mhz) for alignment purpose only. This will make VFO tuning very fast but it's only a temporary condition. After the receiver alignment procedure is completed the VFO tuning range will be 3480 to 3800 KHz.
6. Using a voltmeter connected to FREQ 3, adjust R24 for zero volts.
7. Using a voltmeter connected to FREQ 1,
8. adjust R23 for maximum voltage.

Note: Use a plastic alignment tool when adjusting the variable capacitors. This is most important for C22 the VFO frequency adjust.

Next you will need a signal source set to 3579.5 Khz. Couple to the loop by placing a small loop connected to the signal source near the receiver DF loop.

The process for adjusting the bandspread capacitor and peaking the front end is as follows:

1. First set the VFO so the receiver receives 3579.5 Khz. This is accomplished by adjusting C22 until you hear the signal.

2. Next use a communications receiver set to 3124.5 Khz to hear the LO. Use a probe made out of wire as the antenna located close to the NE602. This will verify that an image is not being received and that the VFO is on the correct frequency.

3. Align the front end by adjusting C27and C20 for maximum signal and listening to the signal as each adjustment is tuned. As necessary, reduce the signal generator amplitude.

To set the VFO tuning range:

1. Set the signal source to 3800 Khz tune the receiver to hear the signal, and measure the voltage at the arm of the VFO pot. Write down this voltage as V high.
2. Set the signal source to 3480 Khz. Tune in the signal and also measure the tuning voltage. Mark it down as Vlow.
3. The next steps will have to be repeated about 6 times because the adjustments interact.
4. Connect voltmeter to FREQ 3 and adjust R24 for V low.
5. Connect voltmeter to FREQ 1 and adjust R23 for V High.
6. Repeat until the two measurements equal V high and V low.
7. Your receiver will now tune from 3480 to 3800 Khz. This tuning range is outside the bandwidth of the front end. However this range was chosen to allow the receiver to be operated during a low battery condition when the voltage regulators are out of regulation. Drift during normal operation is small. Large drift indicates a battery near the end of its life. You can pick a narrower range by finding a new V high and V Low. Just use the new V high and V low in steps 4 – 5.

After the receiver is working the sense amplifier gain is adjusted. I used my 80-meter QRP ARDF transmitter. Its important to use a local source. Do not attempt to adjust the sense circuit using a long distance signal that is arriving via sky wave. According to the ARRL handbook it is possible to get poor (or no) nulls on a signal that is via sky wave (page 14-5 ARRL antenna handbook 18th edition). I aligned the sense antenna system at a distance of about 500 feet from the transmitter. So far testing indicates the sense antenna works over the useful range of the receiver. The only thing I noticed is the sense antenna does not produce a null or peak at a distance less then about 15 feet from the transmitter. However the loop still produced nulls. In a real ARDF event you can see the markers at a distance where the sense is still working.

To adjust the sense antenna perform the following sequence:

1. At a distance of about 500 feet (minimum) from the transmitter rotate the receiver and find the null. Now rotate the receiver 90 degrees from the null (for now any direction). Push the sense switch and rotate R16 through its range. If you are in the right quadrant you will find a place in the adjustment range of R16 where the signal will dip. If you continue adjusting R16 the signal will pass the dip and increase in strength. If you don't find the dip, rotate 90 degrees in the opposite direction from the null. You should find it. Adjust R16 for a dip in signal strength. Mark the side of the loop pointing toward the transmitter (where the dip occurred) with tape.

2. Test the operation of the sense by finding the null. Knowing the direction of the transmitter rotate the loop 90 degrees (use the end that is not marked with the tape). Push the sense switch. The signal should increase.

3. Go back to the null (with out the sense switch pushed) rotate the loop (end marked with tape) 90 degrees toward the transmitter. Push the sense switch. The signal should dip.

4. Another simple test is to hold in the sense switch while rotating the receiver. The signal should dip when the end marked with tape is pointing toward the transmitter (the dip is 90 degrees offset from the null obtained with no sense). The signal should peak when the end of the loop with no tape is pointed at the transmitter.

Operation (refer to figure 11). Safety first! Always watch out for power lines and where the sense antenna is pointed.

First find the null with out the sense antenna active. After the null is found rotate the receiver 90 degrees from the null and active the sense (figure 12). Note the strength of the signal before and after activating the sense. If the signal dips or slightly decreases the taped end of the loop is pointing toward the transmitter. If the signal increases the non-taped end of the loop is pointing toward the signal. After the 180 degree ambiguity is solved, deactivate the sense and use the null with out sense. That null is usually deeper.

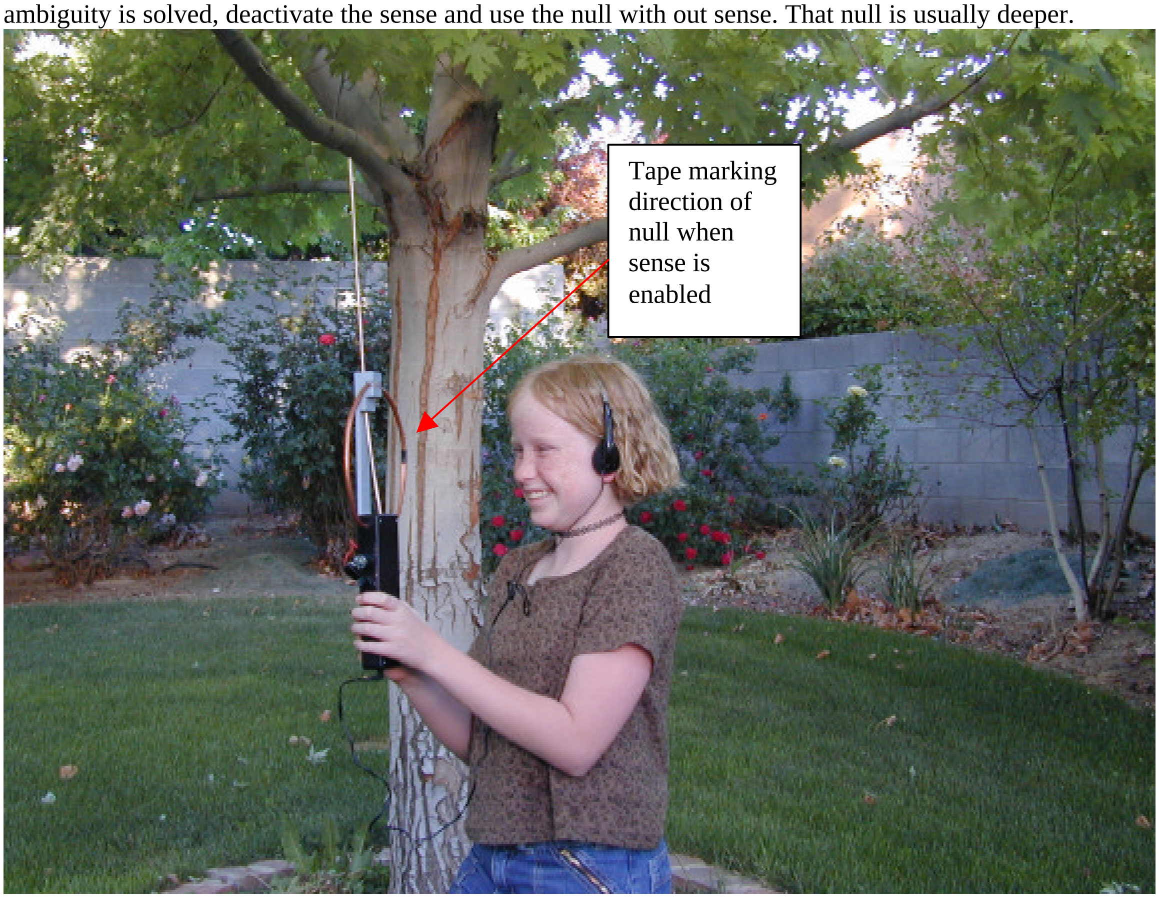


Figure 11 Megan finds null with out sense.

Figure 12 Megan activating sense and notes that the signal nulls

Modifications to receiver since original publication

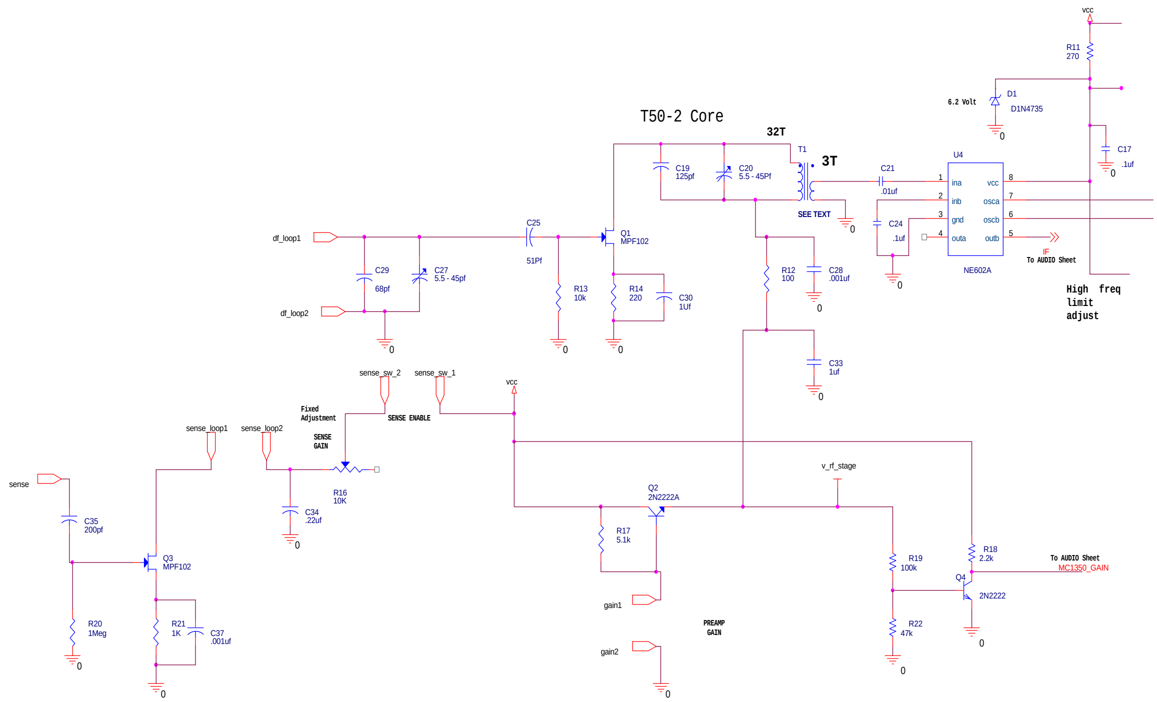
The following modifications are "must do" modifications that improve the performance of the radio.

The "Sam Smith" gain control modification.

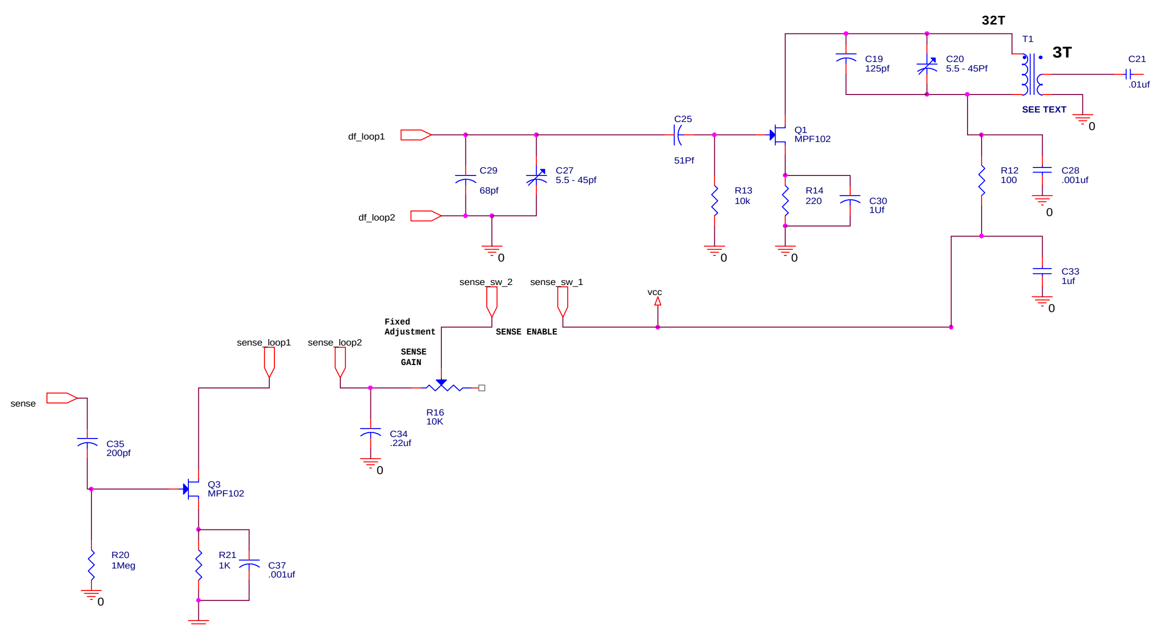
To perform the Sam Smith (N4MAP) gain modification first remove Q2,Q4 and all associated components. Next to get VCC connected to the front end, first connect a shorting Jumper between the collector and emitter pins of Q2. This will put the FET front end in normal operational mode. This stage has enough dynamic range to handle a 3 watt 80 meter ARDF transmitter.

Next wire the gain pot as shown per the post modification schematic. This modification provides very good gain control operation. (Note in my version I did not use the 22K resistor, I just connected the bottom of the pot to ground.)

Schematic showing receiver front end before modification. Note Q2 and Q4 and associated components. Remove these parts and rewire per the after modification schematic.



Schematic showing receiver front end after modification.
(Also refer to post modification IF diagram for gain control pot connections)



The next modifications are a series of VFO stage modifications to correct a board layout error and IF stage modifications to workaround the FAR circuit board layout LO feed through problem.

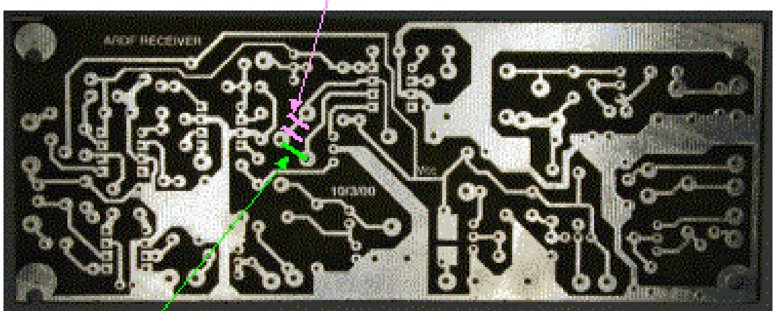
Modifications to Foxfinder-80 receiver FAR circuit board

(only applies to artwork revision dated 10/03/2000)

Modification number 1

Problem corrected: Board layout error.

Problem effect: Layout error prevents LO from operating.



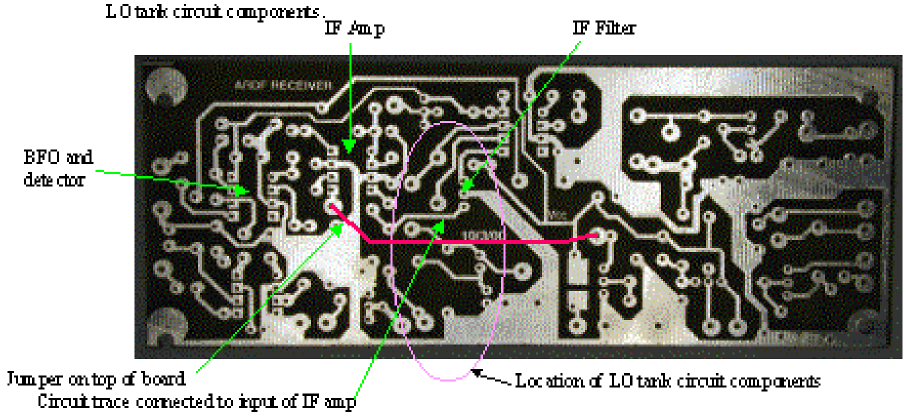
Modification number 2

Problem corrected: LO feed through into IF system then up converting in BFO sub circuit.

Problem effect: Two items where causing this problem. Item 1: Location IF amp input trace from IF filter around LO tank circuit components allowed a large amount of LO energy to bypass the IF filter. This signal was then amplified by IF amplifier U1. After amplification the LO leakage signal mixed in BFO U2 to produce a large signal at the desired RX frequency[455Khz + LO] in effect the receiver was self jamming.

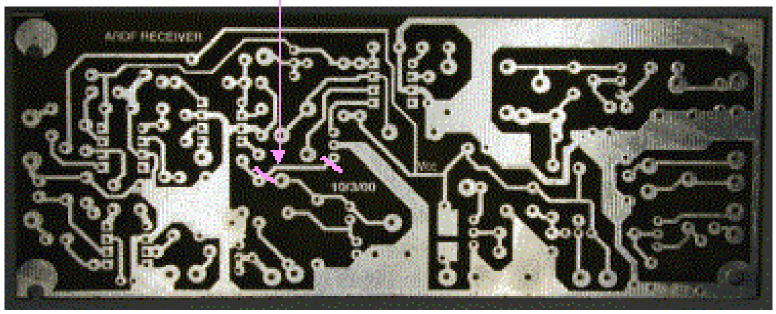
Item 2: the jumper on the top located on the parts side of the board picked up a large amount of LO and was also a contributor to this problem.

To get a understudying of this problem review the layout below. Note the location of the IF amp and LO tank circuit components.



Modification number 2

Step 1 cut and remove this trace

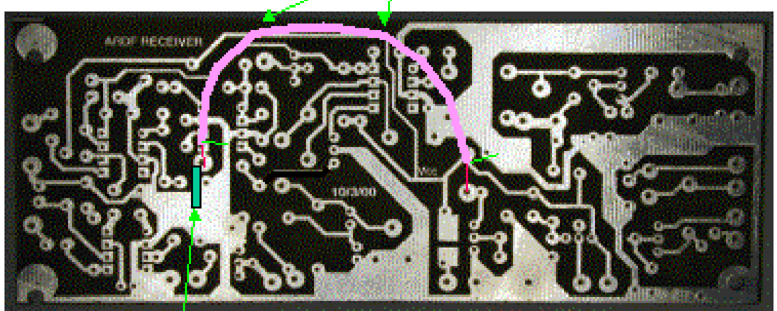


Modification number 2 (continued)

Step 2 Add section of RG174U coax for AGC jumper as shown

= shield
= center conductor

Step 3 hot glue in this location



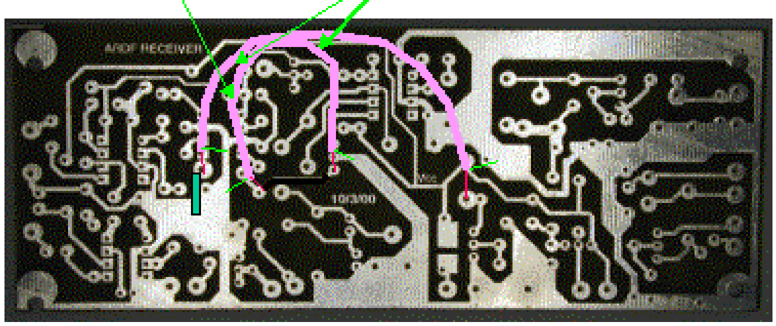
Step 4 add .1 Uf bypass capacitor in this location.

Modification number 2 (continued)

Step 5 Add section of RG174U coax for IF input as shown

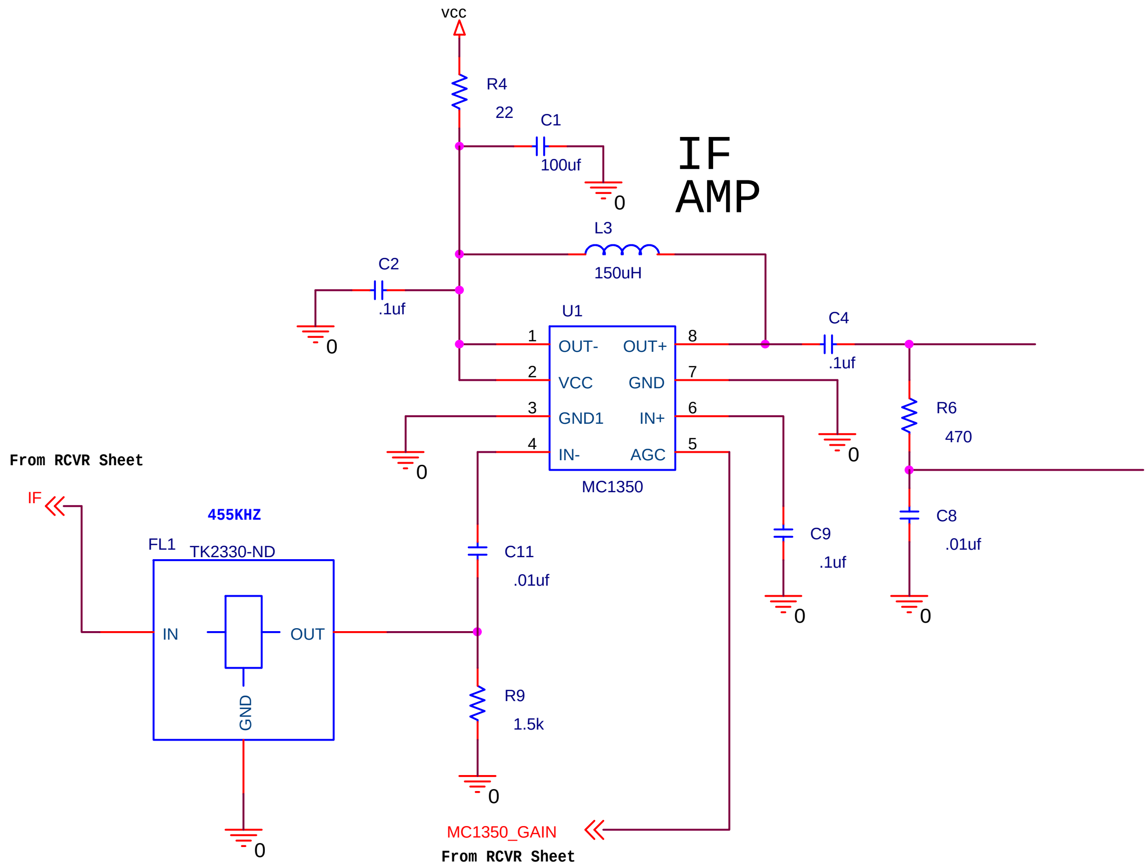
= shield
= center conductor

Step 6 hot glue in to coax in step 2 at locations shown.



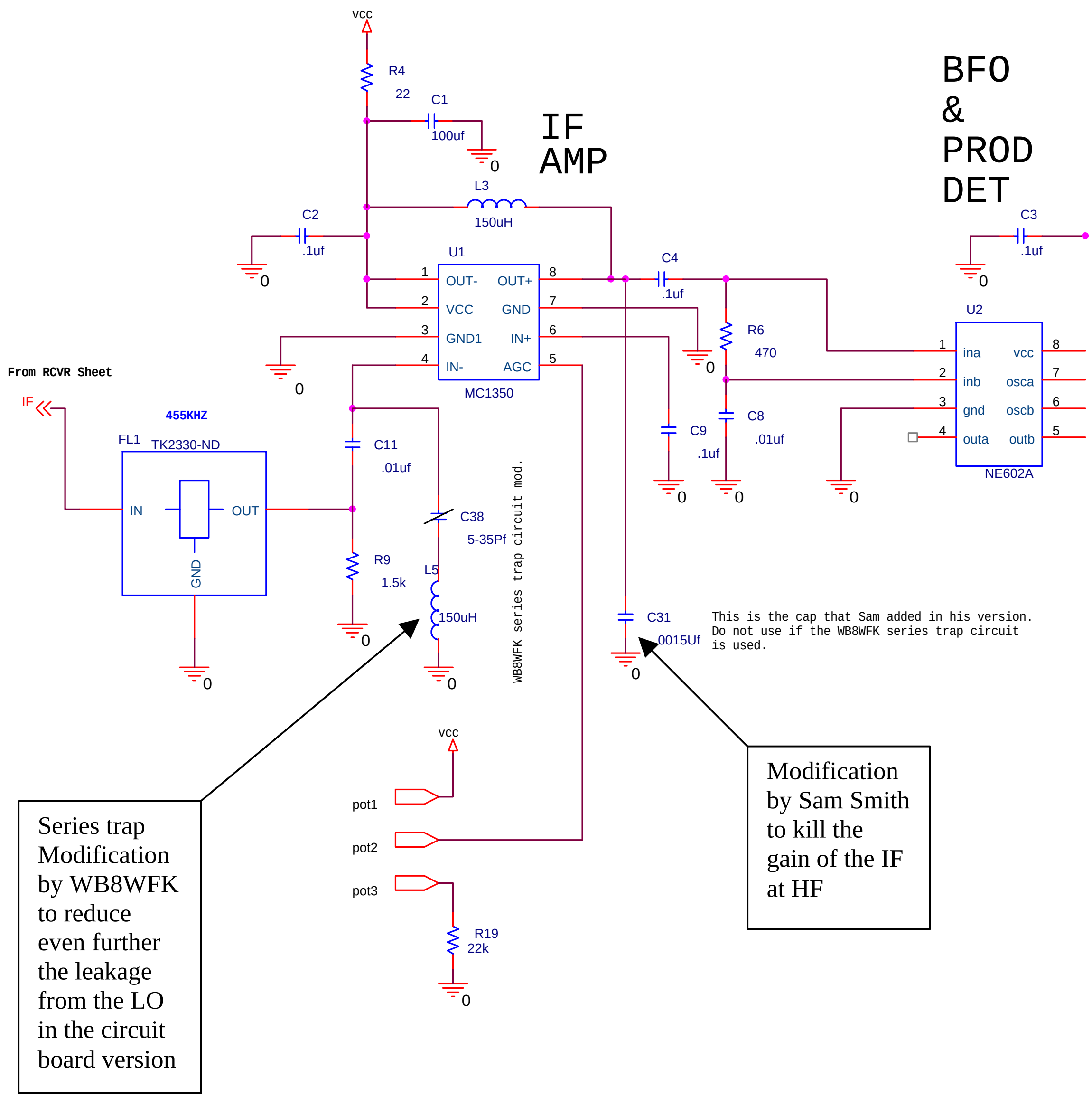
Sam also noted that he added the capacitor C31 to reduce the IF LO mixing problem. My current version is using the series trap circuit on the input to the IF. I plan to investigate making the IF stage a tuned amplifier instead to the wide band version in the schematic. This could be accomplished by using an IF transformer in the output circuit of the MC1350. This would be the preferred solution to the problem. LO leakage is being amplified by this stage and mixing with the BFO to produce the offending signal at HF. There is another signal that appears around 3640Khz. This is the 8th harmonic of the BFO. Its far enough from the hunt frequency and shouldn't cause a problem. Additional shielding of the BFO stage and filtering of the VCC to the BFO stage could be a possible solution in eliminating it.

IF stage before modification



IF stage After modification

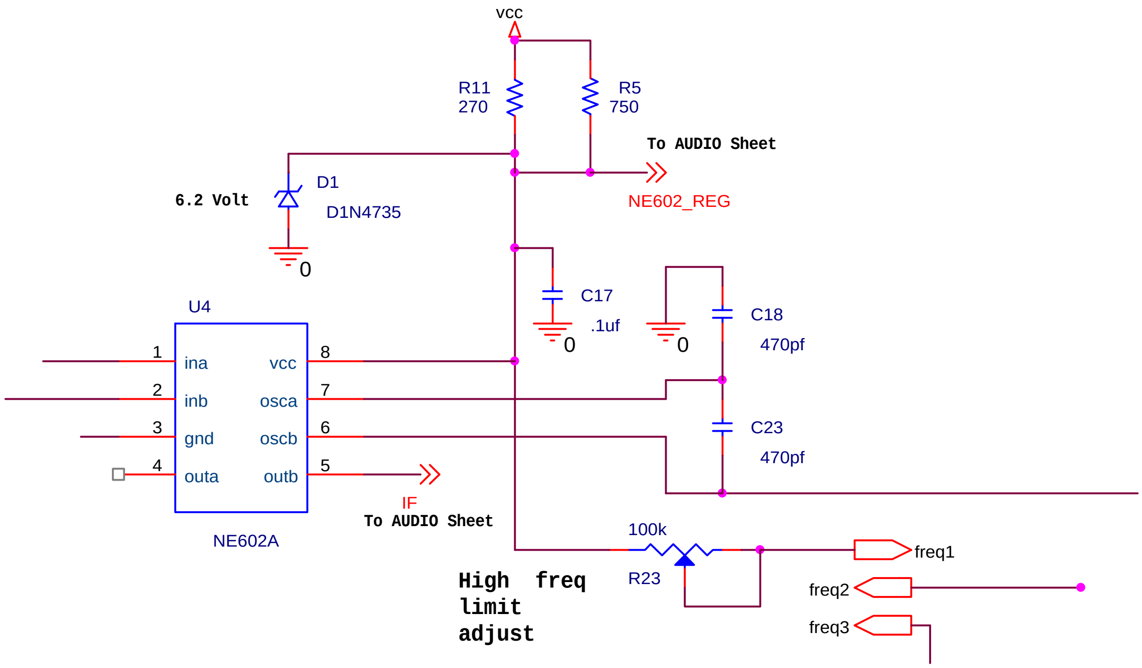
(Note the direct connections for the gain control pot. This was part of the gain control modification.)



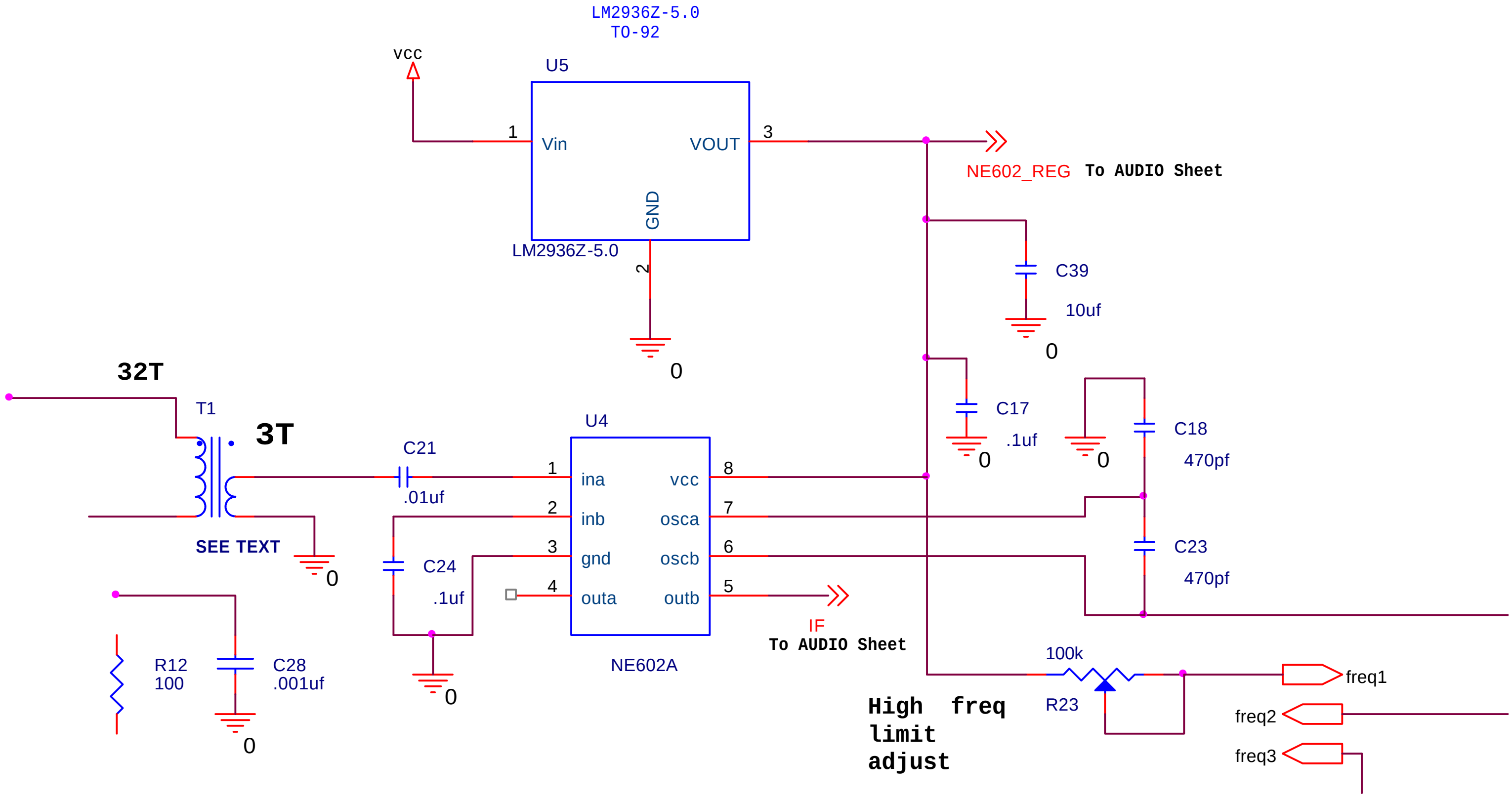
WB8WFK Voltage regulator modification

I also made another modification that replaces the Zener diode regulator circuit with a low drop out regulator. This provided much improved operation over the battery life. The Zener does not regulate very well as the battery voltage goes down with use. However the LDO regulator does a very good job. To perform this circuit modification remove D1, R11 and R5 then install the new regulator circuit per the schematic. Also note that the 10uf capacitor on the regulator output is required. Without it the voltage regulator will oscillate.

Original voltage regulator circuit



Modified voltage regulator circuit



Parts list
A parts list can be downloaded from the foxfinder web page.

Who has built Foxfinders?
This section contains information about other individuals or clubs that has built and used this receiver.
I want this to become a living document and welcome inputs for this section.

Add photos and info about Albuquerque builds

Georgia Radio Orienteering Club
The Georgia radio orienteering club under the direction of Sam Smith, N4MAP did a large group build of the Foxfinder-80. A very nice write up is located on there website. It is located at the following URL:

http://www.mindspring.com/~sam.smith/gro/projects.htm

To date this is the largest group build of this design that has occurred.

They report good results and this was the receiver used by the Georgia Radio Orienteering Club on the 80-meter hunt during the USA 2001 ARDF championships near Albuquerque.

Add info about any California builds

Any others?