40-Meter Shortwave Receiver Kit Assembly Instructions

This easy to construct kit can be assembled in an evening and will open up the world of shortwave radio to you. The kit was designed to be simple to build, requiring no complicated winding of coils or alignment procedures.

Despite its simplicity and low cost, the receiver is remarkably sensitive and can receive signals hundreds or even thousands of miles away using an antenna consisting of a long wire.

It is designed to receive CW (Morse Code), digital, and voice (AM and SSB) transmissions in the approximate range of 6.7 MHz to 7.5 MHz, including the entire 40-meter amateur radio band.

The receiver can be powered by a voltage source of between 9 volts and 15 volts. A battery holder for a 9-volt battery is included.

For those who wish to experiment and improve the receiver, several paths are available building upon this receiver kit. The project website will be updated with hints and improvements by kit builders.

Project website: https://mcwa.org/maker-faire-lake-county-2023-the-mystique-of-shortwave-radio/

For questions and feedback, email us at info@mcwa.org

Assembly of this kit should be done under the supervision of an adult.

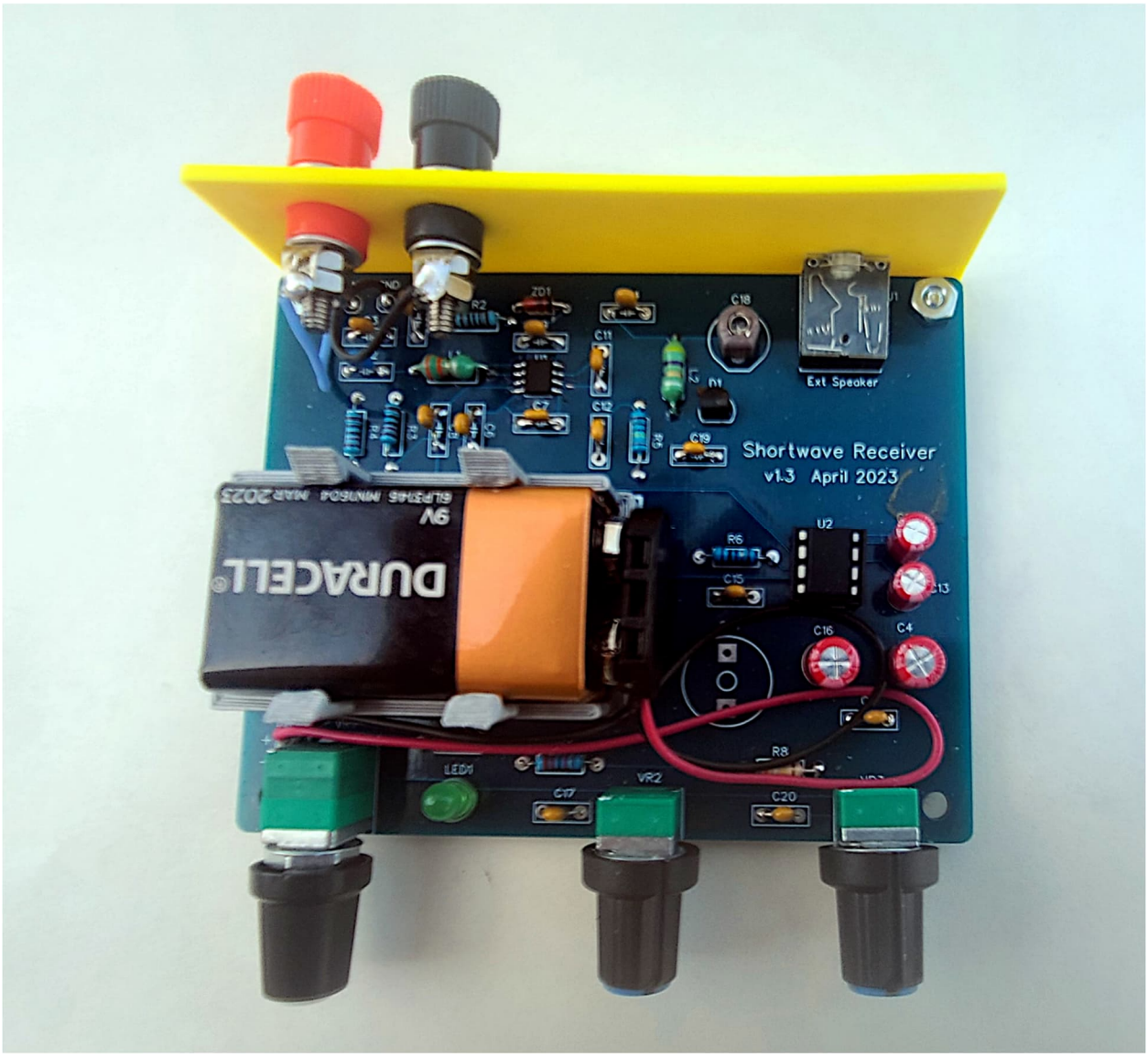
Safety glasses should be worn when assembling the unit, especially during soldering and clipping the excess component leads from the printed circuit board.

Components must be soldered to the printed circuit board which presents a burn risk if care is not taken. Exercise caution when soldering components and setting down the soldering iron between components.

Avoid breathing the smoke from the solder and ensure that you have proper ventilation and fume extraction. Only use solder and flux that is designed for electrical circuits. Acid core solder used for general repairs around the home SHOULD NOT be used and will destroy the circuit board.

IMPORTANT: THE ANTENNA (WIRE) CONNECTED TO THE RECEIVER MUST NOT BE ANYWHERE NEAR ELECTRICAL LINES TO AVOID RISK OF ELECTROCUTION FROM THOSE LINES. DO NOT USE THE HOUSE WIRING FOR AN ANTENNA. OBSERVE APPROPRIATE SAFETY PROCEDURES IF YOU PLACE THE WIRE ON THE ROOF OR TREE.

This is a photo of an assembled receiver. It has received signals from all over the United States, the Caribbean, and South America during its testing.



Before beginning the assembly of the receiver, examine the parts list and then make sure all the parts are in the bag. Each kit was carefully packed and inspected, but mistakes can happen.

The resistors and inductors have color-coded bands to identify them. The color code is shown in the notes. Be sure you have the correct component when installing. To minimize confusion, the inductors are in the big bag and the resistors are in the small, tinted bag.

When soldering the components, note that there is a ground plane that covers the board and any component that is connected to ground may require additional time to heat for proper flow.

Parts List

Name	Designator	QTY	Notes
100pF 50 volt	C11,C12,C14,C19	4	
180pF 50 volt	C2	1	
820pF 50 volt	C3	1	
33nF 50 volt	C7	1	
100nF 50 volt	C1,C5,C6,C8,C9,C15,C17,C20	8	
10uF 35 volt	C10,C13	2	
100uF 35 volt	C4,C16	2	
10pF - 50pF	C18	1	Variable capacitor
10 ohm ¼ watt	R6	1	Brown, black, black
1k ohm ¼ watt	R2	1	Brown, black, red
1.2k ohm ¼ watt	R1	1	Brown, red, red
10k ohm ¼ watt	R3,R4	2	Brown, black, orange
22k ohm ¼ watt	R7	1	Red, red, orange
390k ohm ¼ watt	R8	1	Orange, white, yellow
1M ohm ¼ watt	R5	1	Brown, black, green
10k pot & switch with knob	VR1	1	
10k pot with knob	VR2,VR3	2	
3.3uH	L1	1	Orange, orange, gold
4.7uH	L2	1	Yellow, violet, gold
1N4737A	ZD1	1	Zener diode (glass case)
BB910	D1	1	Varactor diode
LED - Green	LED1	1	
LM386	U2	1	Audio amplifier chip
SA612	U1	1	Mixer/Oscillator chip
Adhesive feet		4	
Audio Jack	J1	1	
Back panel		1	
Battery connector		1	
Battery holder		1	
Binding post - Red		1	
Binding post - Black		1	

DIP socket 8-pin		1	
PCB		1	
Speaker	SP1	1	
Wire - 8"		2	Antenna & speaker hookup

Notes:

The SA612/NE612 (U1) is a surface mount device (SMD) and has been preinstalled on the printed circuit board and tested for you.

The LM386 (U2) is already seated in the 8-pin socket. You can solder the socket with U2 still plugged into it. A socket is provided in case the LM386 needs to be replaced due to an electrical failure (e.g., speaker shorted, etc.)

C18, the brown variable capacitor can be found in the small, tinted plastic bag.

L1 and L2 are inductors, not resistors. The resistors, except for VR1, VR2, and VR3 can be found inside the small, tinted plastic bag. The inductors are in the larger bag to avoid confusion.

The varactor diode (D1) can be found in the small, tinted plastic bag. Note that there are only two pins while the PCB has holes for three pins. Follow the orientation shown on the PCB. The middle pin on the PCB is not connected to anything.

The mounting screws and nuts for the battery holder and back panel are attached to the 3D printed parts.

Assembly

Although the kit can be assembled in a different order, it is recommended to follow the following order, which was based on feedback from our beta assemblers. Verify that you are installing the proper component in the proper location before soldering. Pay special attention to components that are polarized and must be installed in a specific manner.

Install the fixed resistors

Solder resistors, identified by the color bands:

- R2 (1K brown, black, red)
- R3,R4 (10K brown, black, orange)
- R5 (1M brown, black, green)
- R6 (10 brown, black, black)
- R1 (1K brown, black, red)
- R7 (22K red, red, orange)
- R8 (390K orange, white, yellow)

Install the non-polarized capacitors

- C11,C12,C14,C19 (100 pF)
- C1,C5,C6,C8,C9,C15,C17,C20 (100 nF)
- C2 (180 pF)
- C3 (820 pF)
- C7 (33 nF)
- C19 (variable cap, align flat side as shown on PCB)

Install the inductors

- L1 (3.3 uH orange, orange, gold)
- L2 (4.7 uH yellow, violet, gold)

Install the polarized parts

The following components must be installed as described. Installing them backwards will cause the receiver to not function and could damage the part and/or other parts.

- Green LED: The flat side of the diode or shortest lead must align with the flat side on the PCB.
- ZD1 zener diode: The cathode (the end with the line) must align with the line on the PCB. Refer to the photograph of the assembled receiver, if necessary.
- D1 varactor: Align the flat side of the device with the PCB. Note that the varactor diode is a two-pin device, while the PCB has three holes. The middle pin on the PCB is not c connected to anything and will be empty.
- LM386 and socket: Note the notch on the LM386 must align with the PCB. After soldering the socket to the PCB, double check to make sure that the LM386's notch is positioned properly.
- C10,C3 (10 uF): The negative lead (the shorter of the two leads) must be aligned with the PCB. There is a white stripe on the capacitor that also indicates the negative lead.
- C4,C16 (100 uf): The negative lead (the shorter of the two leads) must be aligned with the PCB. There is a white stripe on the capacitor that also indicates the negative lead.
- Battery connector: Solder the red lead to the "+" hole and the black lead to the "-" hole. Please note that the spacing between the two holds is only 1/10 of an inch. Be careful not to have the red and black wires touching each other, which is easy to do if you are not careful.

Remainder of PCB components

- Install VR1, the on/off switch and RF gain control.
- Install VR2 and VR3, the course and fine-tuning controls.
- Install the battery holder using the two screws that are attached to the holder. The open side of the holder should be facing the center of the PCB.
- Cut a 2" piece of white wire, strip both ends, and solder to the "ANT" hole.
- Cut a 2" piece of blue wire, strip both ends, and solder to the "GND" hole.
- If you intend to use the speaker AND the external speaker/headphone jack, solder the remaining white and blue wires to the SP1 holes and the other end of the wires to the speaker. When a speaker or headphone is plugged into the external speaker jack, the internal speaker will be disconnected.

Back panel

- In order to ensure that the external speaker jack is flush with the PCB, attach J1 (the 3.5mm jack), to the back panel using the nut supplied with J1.
- Attach the back panel to the PCB using the two screws and nuts attached to the back panel. Be sure that the screw head is on the bottom of the PCB to avoid interference with the rubber feet. See the photo of the assembled kit.
- Solder the jack (J1) to the PCB.
- Mount the red binding post in the outside hole in the back panel and the black binding post to the other hole.
- Solder the white wire from the "ANT" hole to the red binding post.
- Solder the blue wire from the "GND" hole to the black binding post.
- Attach the four rubber feet to the four corners of the PCB. The rear feet should be attached to the PCB and not the back panel plate.

Check over your work carefully to make sure the connections are properly soldered, the polarized components are installed in the right direction, and that there is no short between the "+" and "-" connections on the PCB.

Congratulations, assembly is complete!

Initial power-up

Turn the RF gain control fully counter-clockwise to the OFF position.

If the speaker was not soldered to SP1, plug the speaker or headphone into the external speaker jack (J1).

Attach the battery connector to the 9-volt battery and slide the battery into the holder. The battery clip should be facing towards the center of the PCB.

Slowly turn the RF gain control clockwise until a click is felt meaning the receiver is in the ON position.

The green LED should be lit. If it is not, STOP! Immediately turn off the receiver, remove the connector from the battery and troubleshoot the assembly error.

Operation of the unit

Attach a long wire to the red antenna post. Attach the black antenna post to an earth ground, if one is available. See the antenna notes that follow for suggestions for antenna size and placement.

If the receiver is not ON, turn the RF gain potentiometer (VR1) clockwise until the receiver turns on. This control is not a volume control in the usual sense. It controls the sensitivity of the receiver. Start with the RF gain control set fully counter-clockwise and if no signals are found when adjusting the course-tune control, increase the gain by turning the control clockwise.

Set the fine-tune potentiometer (VR3) to the center of its rotation.

Starting at the fully counter-clockwise position, slowly turn the course-tune potentiometer (VR2) until you hear a signal. Because of the wide tuning range, you must turn the control slowly otherwise you may miss the signals.

After detecting a signal or signals, adjust the fine-tuning potentiometer to tune in the signal. This may take some practice especially with voice transmissions.

Tuning CW: Adjust the fine-tuning control for clear tone. During certain times, there may be multiple signals near each other, and the fine-tuning control will help separate them.

Tuning AM: Broadcasts from commercial shortwave stations use AM (Amplitude Modulation). You can tell these are AM transmissions because you can hear a tone along with the voice. Use the fine-tuning control to eliminate the tone, leaving just the voice or music. This is called zero-beating.

Tuning SSB: SSB (Single Side Band) is a special type of AM signal that is used by radio amateurs and other non-broadcast stations. SSB uses power more effectively than AM. When tuning a SSB signal, there will be no tone (carrier), so just fine-tune for the clearest audio.

You may also hear digital communications including radio teletype signals. These signals sound like a warble or signal with two alternating tones. While these signals can be detected with this receiver, decoding them requires additional hardware or software and is beyond the scope of this project.

Theory of operation

The schematic of the receiver is below. It is a designed called a direct-conversion receiver. Direct-conversion receivers are very simple receivers but are capable of good performance at a low cost.

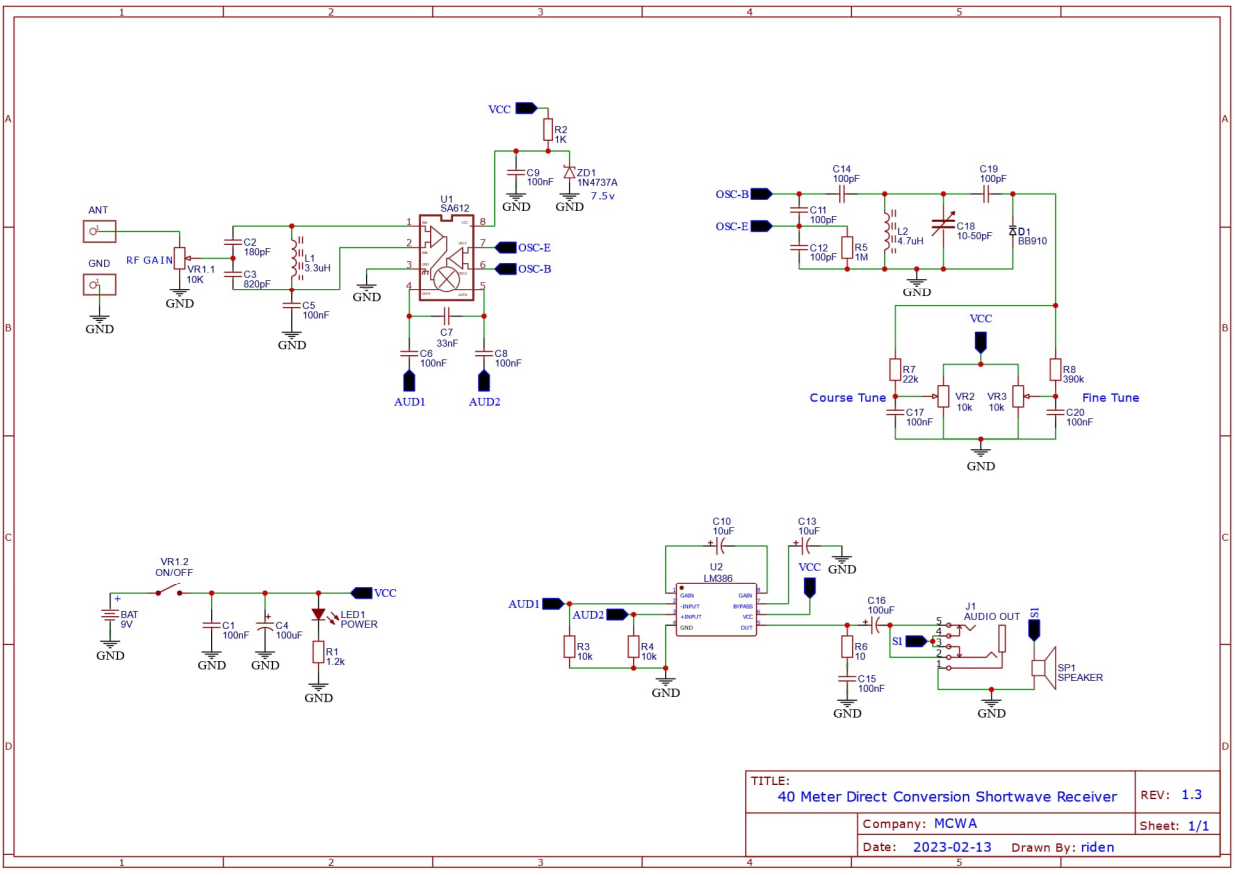
The frequency of the signals that the receiver is listening for is far above the range that we can hear (millions of cycles per second versus 100 – 15000 cycles per second). To be able to hear these signals, a process called mixing is used. The incoming transmission is combined with another signal very close in frequency to the incoming signal. The difference between the two frequencies is then fed into an audio amplifier so they can be heard. You may have heard two singers who are singing two notes that are close, but not exactly the same tone (frequency). You sometimes hear a slight increase and decrease in volume whose rate matches the difference in tone between the two singers. Your ears are mixing the two tones and you are hearing the difference along with the actual tone.

A direct-conversion receiver consists of four basic sections: RF filter, oscillator, mixer, and detector/amplifier.

The RF filter's job is to restrict the frequency of the signals entering the mixer to the desired range. Radio signals (electro-magnetic signals) are all around us. Signals from radio, TV, cell phones, microwaves, the sun, and many more sources surround us. Without some kind of filtering, strong signals outside of the range of desired frequencies can overload the receiver. Capacitors C2 and C2 along with L1 form a tuned circuit that favors signals in the 6.5 to 7.5 MHz range, not letting signals outside of that range to be passed along to the mixer. The RF gain control (VR1) controls the amount of signal applied to the filter providing further overload protection.

The oscillator consists of U1 along with several components that form a type of an oscillator known as a Colpitts oscillator. The base frequency is determined by C11, C12, and L2. The frequency is adjusted further by the varactor diode (a capacitor whose value changes with the amount of voltage applied to it). The course-tune and fine-tune potentiometers control the voltage applied to the varactor, which changes the frequency.

The input signal and the signal from the oscillator is mixed by U1 and the difference between the two signals is sent to U2 for amplification.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R2
1K
C9
100nF
ZD1
1N4737A
7.5v
GND
U1
SA612
ANT
GND
RF GAIN
VR1.1
10K
C2
180pF
C3
820pF
L1
3.3uH
C5
100nF
C7
33nF
C6
100nF
C8
100nF
OSC-E
OSC-B
AUD1
AUD2
C14
100pF
C11
100pF
C12
100pF
R5
1M
L2
4.7uH
C18
10-50pF
D1
BB910
C19
100pF
R7
22k
R8
390k
VR2
10k
VR3
10k
Course Tune
Fine Tune
C17
100nF
C20
100nF
VR1.2
ON/OFF
BAT
9V
C1
100nF
C4
100uF
LED1
POWER
R1
1.2k
U2
LM386
C10
10uF
C13
10uF
R3
10k
R4
10k
C16
100uF
R6
10
C15
100nF
J1
AUDIO OUT
S1
SP1
SPEAKER
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Date: 2023-02-13
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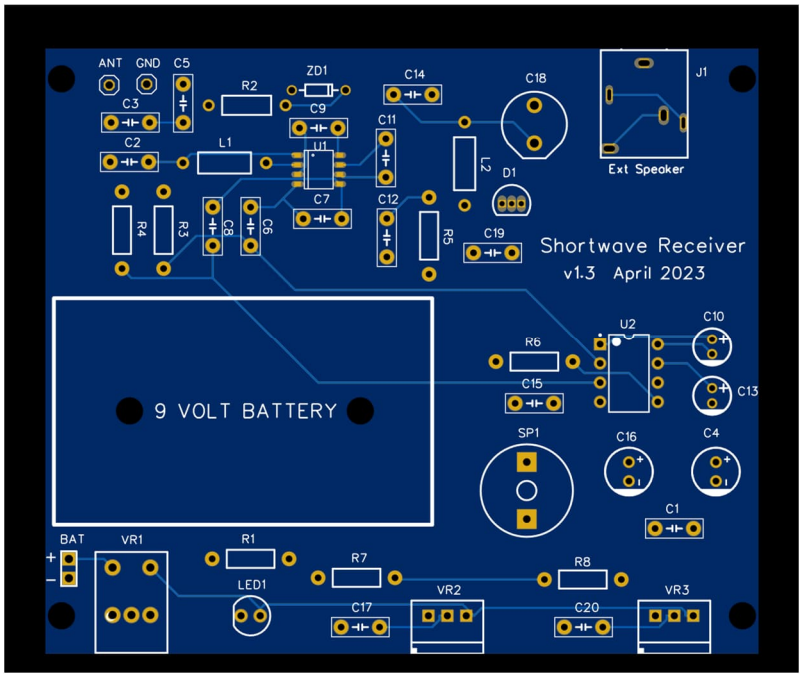
ANT
GND
C5
C3
R2
ZD1
C14
C18
J1
Ext Speaker
C2
L1
C9
C11
L2
D1
C7
C12
R4
R3
C8
C6
R5
C19
Shortwave Receiver
v1.3 April 2023
9 VOLT BATTERY
U2
R6
C10
C15
C13
SP1
C16
C4
C1
BAT
VR1
R1
R7
R8
LED1
VR2
VR3
C17
C20

Limitations and areas for improvement

Even though this is a sensitive receiver, there are a few shortcomings to this design. Fortunately, they can be addressed and addressing them will provide opportunities for experimentation and learning.

Frequency stability: This is probably the biggest issue. The oscillator used in this receiver will change frequency slightly during operation, which requires adjusting the fine-tuning control. Because of the wide frequency range that the oscillator needs to cover, frequency drift can be substantial, especially if the ambient temperature changes.

More advanced receiver designs employ an oscillator whose frequency is stable and doesn't drift. It is entirely possible to incorporate such an oscillator into the receiver. Depending upon the design, it will involve adding additional components which will be attached to the existing receiver board. This is a fertile area of exploration and is a topic in our upcoming Tips and Errata document.

Voltage regulation: This is another factor that impacts frequency stability. As the battery becomes depleted, the voltage changes, which then causes the frequency to change. Increasing the volume increases the drain on the battery, which could lead to a warbling sound as the voltage to the varactor changes. In retrospect, a voltage regulator should have been employed on the varactor control line as it was for U1. If running solely on battery power, an improvement would be to modify the PCB so the course-tuning and fine-tuning potentiometers are fed from the regulated voltage from ZD1 instead of VCC (voltage source).

Another approach would be to use a regulated power supply to feed the receiver. The receiver was designed to be powered by an input voltage from 9 volts to 15 volts. Powering the receiver from an external regulated power supply would solve the problem.

The easiest way to test this is to connect an external power supply between 9-16 volts to the 9-volt battery connector.

IMPORTANT: If you use another 9-volt connector to plug into the original connector, remember that the positive and negative wires are REVERSED. In other words, red is normally positive, and back is negative. By piggybacking two connectors, the second connector's wires are reversed (black is positive and red is negative). DO NOT FORGET THIS OR YOU WILL DAMAGE THE RECEIVER.

Tuning range: If the course-tune or fine-tune is too "sensitive" and doesn't provide enough range of control, the resistors from them to the varactor can be adjusted for a narrower range of voltages.

While it is unlikely to be needed, the variable capacitor (C18) can be carefully adjusted by a small screwdriver (preferably insulated or non-metallic) to shift the range of the receiver. Adjusting C18 will have no impact on how the course-tune and fine-tune controls work.

Automatic Gain Control (AGC): AGC is used to keep the audio level consistent between strong signals and weak signals. Without AGC, listening to a weak signal when a strong signal suddenly appears will cause a dramatic, and often startling, increase in volume.

The original design had an AGC circuit, but it was accidentally dropped from the final design when experimenting with different audio amplifier solutions. Adding AGC will involve adding a few external components and connecting it to the existing receiver. There are a few AGC designs that will be discussed in the upcoming Tips and Errata document.

Although any sufficiently long wire will work well with this receiver, the optimum length for this frequency range is a wire approximately 63 feet long connected to the red terminal. Another length of wire approximately 63 feet long connected to the black terminal or connect the black terminal to a good earth ground.

The wire can be horizontal, vertical, or even run at a slope. Each orientation has advantages and disadvantages. Experiment and see what works best for you. And remember, be safe and avoid power lines.

We welcome your comments and suggestions for improvements for this project. You can contact us at info@mcwa.org. Please visit the project's website from time to time for updates to the project and its Tips and Errata document.

If you are interested in learning more about amateur radio or attending one of our events, you can let us know by sending us an email at info@mcwa.org and we will keep you in the loop.