DR-1(X) Repeater Modifications

Modifications to improve the health and longevity of the repeater

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These are unofficial modifications of the DR-1/DR-1X repeater. There are several objectives:

1. The changes are reversible. In other words, you can undo the changes and nobody's the wiser.
2. Permit reliable, continuous operation under harsher conditions with the potential for power outputs greater than 20 watts.
3. Potential repeater performance improvements.
4. Assist with implementing additional capabilities.

These are not official modifications and they are not sanctioned by Yaesu. I have no clue what they do to warranty status, but I believe Yaesu service would not be unhappy if these were installed in a professional manner. (Poor workmanship on anything will void the warranty - as it should.)

Bottom line - YOU DO THIS AT YOUR OWN RISK!

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Modifications

The following modifications are described (in approximate order of importance):

1. Insert a 10 amp fuse in series with the Tx power supply. (Prevents changing a minor repair to a very expensive repair.)
2. Increase cooling to the Tx. (Reduces the probability of a Tx failure.)
3. Reduce the power supply voltage to 12.8 V. (Reduces the probability of a Tx failure.)
4. Rewire the internal fan so that it does not take power from the Tx. (Reduces noise on the carrier and thus improves Bit Error Rate (BER).)
5. Remove the aluminum foil covering the connectors between the Tx and internal fan. (Reduces the probability of internally generated interference and desense.)
6. Tighten screws. (General maintenance. Reduces the probability of internally generated interference and desense.)
7. Instructions for adjust the Tx power output. This requires an FTM-400 front panel. There is high risk in this procedure and it is not recommended for those without years of service experience. You may want to vary the Tx output to meet the needs of an external Power Amplifier (PA). Running the repeater below 20 watts using an external amplifier is highly recommended.
8. Recommendations for using an external PA.
9. Recommendations for emergency power or battery backup operation.

Fuse the Tx <- A MUST DO!

The DR-1 power supply is capable of 25 amps output - plenty of reserve! There is a failure mode where the output goes to zero, but the input current rises to about 16 amps since the transmitter is being driven to full output (around 70 watts). If this state continues, the Tx board will get fried and probably need replacement. If power is removed quickly, the repair is then pretty simple. This is a good insurance policy, especially if your repeater is out of warranty!

Place a 10A automotive type fuse between then the power distribution board and the Tx module. This can be done with a male/female set of power connectors so that no permanent change is made to the repeater.

BTW, FTM-100 and 400 owners, this applies to you as well. Make sure all your radios have a maximum 10 amp fuse!

Fan Noise Modification

Normally the rear fan turns on when a temperature sensor on the power distribution board goes above 70F - which is almost always. The units had the internal fan wired to the transmitter. This caused electrical fan noise to FM the transmitter. The problem was corrected in later units by wiring the fan directly to the power supply.

This modification causes the transmitter fan control circuit to turn both fans on and off. This is accomplished by building a switching circuit that uses power from the main Tx power bus to power the fans when enabled by the transmitter.

This modification can be made reversible by using two fans that you supply rather than the fans installed in the unit. Otherwise you can cut into the fan wiring to make the necessary electrical connections.

Figure 1 shows the modification to add the Tx fuse and the power tap-off for the fans.

Figure 1 Tx Fuse Installation and Fan modification
TBD

Reduce Supply Voltage

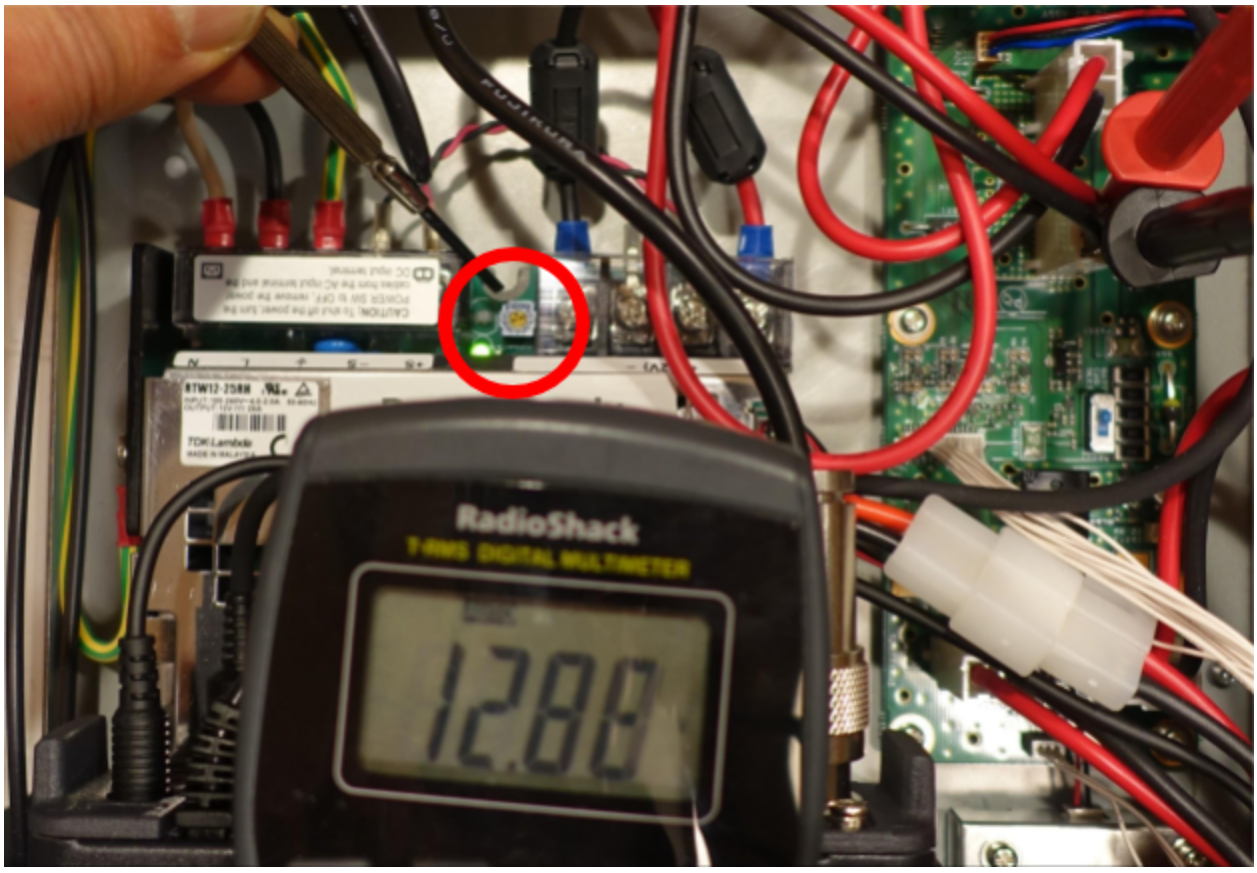
The transmitter is fully capable of putting out 50 watts at 12V measured at the transmitter. As the voltage goes up, the current stays the same thus increasing heat dissipation in the transmitter. This isn't a big issue since the majority of this heat is carried away by the more-than-adequate heat sinks on the Tx.

The voltage is normally set to 13.8. The recommendation is to lower it to 12.8. This still provides the transmitter with more than 12 V and it is high enough that the power fail sense circuitry (which triggers at about 12.2 V) won't be tripped.

The radio does not need more than 12 VDC. If your situation permits, I recommend using 12.0 VDC measured at the Tx under load.

BTW, hint to FTM-100 and 400 operators, this applies to you as well.

Figure 1 Power Supply Adjustment and Measurement Points



Additional Tx Cooling

Background

Too much heat is bad for electronics. For example, semiconductors will generally have their life increased by a factor of 2 for every 10C reduction in temperature. Some parts can get hot - such as wire-wound inductors, they are wire after all. Moving plastic parts can be very sensitive to temperature since heat will cause

outgassing and may deform the part over time. The objective of this modification is to substantially reduce the temperature of Tx components that are highly sensitive to heat.

Before we move on, it needs to be said that the DR-1 does have excellent cooling. The main fan on the rear is temperature controlled (turns on above 70F) and can move a lot of air. In addition to that, an internal fan forces air into the Tx compartment where the real-panel fan pulls it through and removes it.

Air enters the DR-1 from the left side and the left rear. This air flows through and around the powersupply and around the Rx. It then flows past the front panel PCBs and enters the Tx compartment via the internal fan. The air then cools the heatsink and the exterior of the Tx before exiting out of the rear panel. This is an excellent design. Tests show that the PA is kept well within its thermal operating limits when operated at 50 watts out continuously.

What isn't being cooled are the temperature-sensitive components inside of the Tx. There is no airflow through the Tx internals and there isn't enough volume for convection currents to form.

Time for a little physics. There are three basic ways to cool something off:

1. Radiation - The object (such as the plate of a vacuum tube) is hot enough that it radiates the heat in the form of infrared radiation. This is only effective if the temperature is much higher than the environment it is radiating to. Radiation is of little value in keeping a solid-state transmitter cool.
2. Conduction - The object's heat is removed by conduction through some material. Some materials are better at conducting heat than others. Copper is very good, stainless steel is very bad. Plastic is a poor choice. Most modern devices are cooled via conduction through their leads to the copper in the PCB they're attached to. Some devices, such as the PA transistor, is cooled both through the leads and through a low thermal resistance surface in contact with the heat sink. The PA's driver is cooled via conduction through the PCB (which is mostly copper underneath the device) and down to the heatsink.
3. Airflow - Even a very small amount of air moving over a hot object can dramatically reduce its temperature. Sometimes this is done with convection - where the rising hot air sets up a "smoke stack" effect that causes cold air to enter at the bottom, heat up by cooling the device, and the hot air exits at the top. In other cases this is done with forced air movement over the object to be cooled.

Back to the transmitter. It's very likely the most heat sensitive components in the Tx are the four relays. They are made of plastic, so they don't conduct heat well. They have several small leads, so they don't conduct much heat. Three of the relays handle RF power - so they are likely to heat up due to IR losses and mismatch. Unfortunately these relays are in a hot environment (an operating transmitter), internally produce a reasonable amount of heat, and are more sensitive to heat since the inner workings use precision plastic parts.

During Rx all relays are in their de-energized state. VHF Tx energizes one relay. UHF Tx energizes three relays. More power is lost in the relays used by UHF than VHF. This modification can drop the relay temperature by as much as 80 F.

Tx Cooling Modification

The objective of the modification is to force air through the Tx internals thus using forced air flow to further cool the components. This is done by exposing the Tx components to the air stream and forcing a substantial amount of air to flow under the Tx where the components are located.

This modification removes shielding from the Tx which invalidates the FCC type acceptance. Yaesu cannot do this, but our licenses permit us to do this. To date this modification has been performed on three repeaters with no observed interference issues.

1. Completely remove the Tx from the Tx compartment. (See Figure 3)
2. Disconnect all connectors (this makes the job easier).
3. Remove the cover (4-screws, save them and the cover in a safe place). (See Figure 4)
4. Remove the plastic front panel (2-screws, likewise save the screws and panel).
5. Reinstall the transmitter.
6. Re-attach the connectors.
7. Replace the foam air dam with the correct left/right orientation. (See Figure 5)
8. Block airflow below the air dam on the left and right sides.
9. Block four of the vertical fins on the left side of the heatsink and two on the right side. (Most of the heat is sourced near the middle of the heat sink.) (See Figure 6)
10. Verify the foam dam placement and install the DR-1 cover. (Note that this solution is less effective if the repeater is operated with the cover removed.)

Figure 3 Tx and Cover Removal

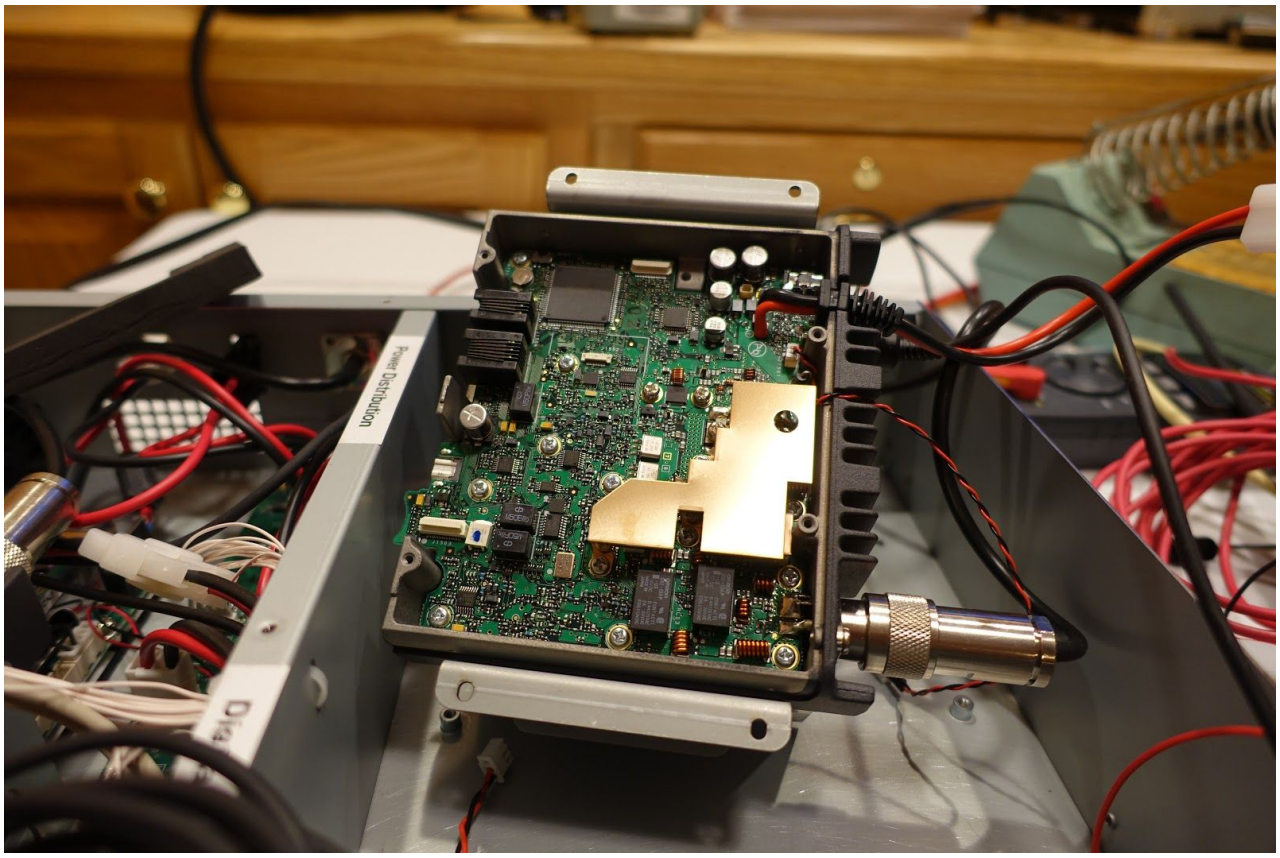
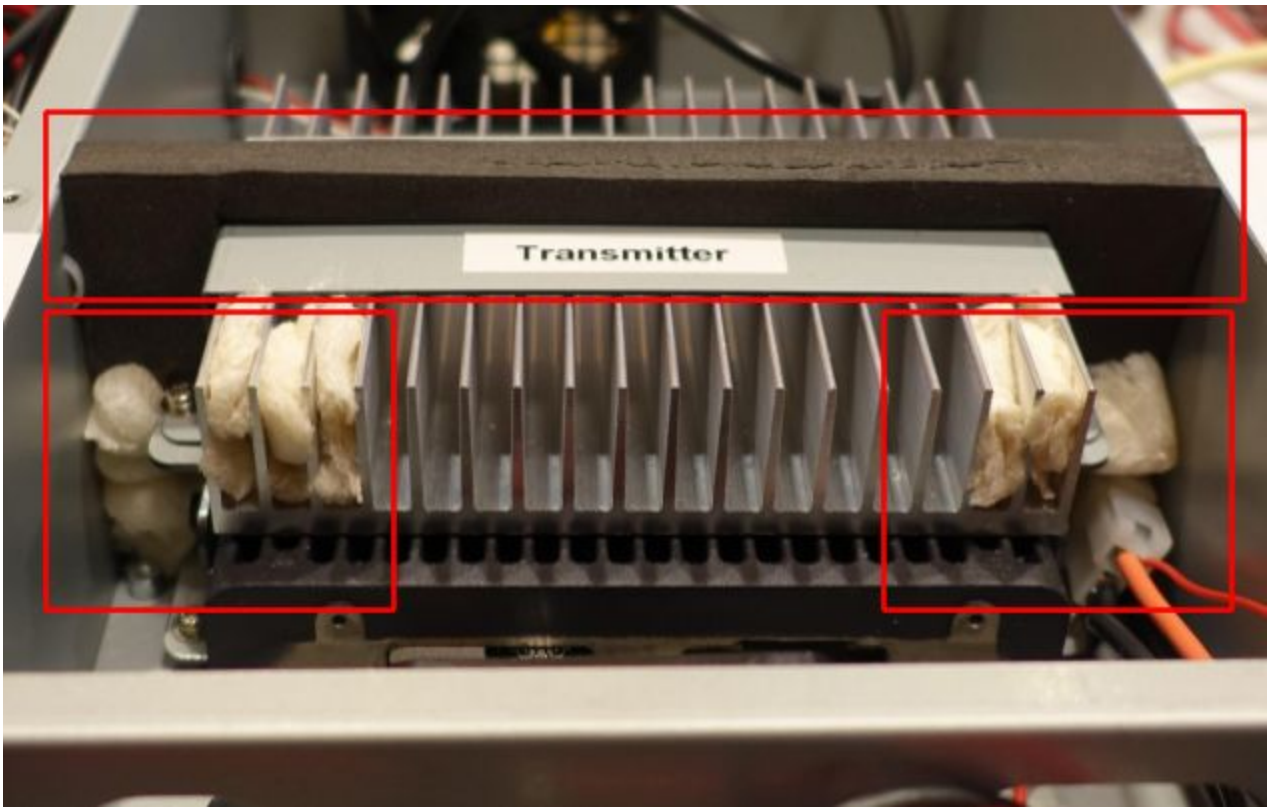


Figure 5 Air Dam Placement



Temperature Monitoring (Optional)

The monitoring of several important parameters can help identify problems and pending issues. One such parameter is temperature. Consider mounting temperature sensors inside the DR-1. It is recommended to monitor the ambient temperature (air intake), and the Tx PA heatsink. This can be done with a remote monitoring system, which is beyond the scope of this article. Another method is to purchase a wired indoor/outdoor thermometer, such as those sold at Walmart or online at Amazon. Place the “outdoor” sensor between the pink thermal pad and the body of the Tx near the middle and about 1” in from the rear (some disassembly of the sensor may be required to make it fit). The ambient is just the “indoor” reading. If the thermometer saves the min and max, you can record these values every time you check the repeater. The difference in temperatures ($Outdoor_{Max}$ - $Indoor_{Max}$ and $Outdoor_{Min}$ - $Indoor_{Min}$) should remain relatively constant for the same Tx output power. You can also monitor the instantaneous temperature to see how the temperature changes as a function of Tx time and power.

Figure 7 Placement of temperature sensor

Figure 8 Sensor layered between radio heatsink and thermal conduction pad

Output Power Adjustment

So 20 watts out just isn't enough. Not surprising since the DR-1 has an excellent receiver. It is possible to adjust the output power, but first the cautions.

YOU CAN REALLY SCREW UP THE REPEATER IF YOU DON'T DO THIS RIGHT! There are things you can do that you cannot undo unless you have a fully equipped RF lab, which I'm guessing you don't have. Therefore:
IF YOU DON'T KNOW WHAT IT IS, DON'T TOUCH IT.

One more caution. THE REPEATER WAS DESIGNED FOR OUTPUTS FROM 5 TO 50 WATTS. ADJUSTING THE OUTPUT OUTSIDE OF THIS RANGE MAY CAUSE THE TRANSMITTER TO BECOME UNSTABLE, GENERATE SPURIOUS EMISSIONS OR FAIL. If you don't know why I said this then you don't know enough to attempt adjustments outside of this range.

You need an FTM-400 to perform this procedure which, as a Fusion repeater owner/operator, I'm sure you have. You will also need a good RF wattmeter suitable for use at 146 and/or 446 MHz and a suitable dummy load rated to 50 watts or more at 250 and/or 500 MHz or higher. Most hams have neither of these. How do you know your wattmeter and dummy load are good? If the wattmeter costs at least $170 then it may be okay. A good one will be 2-3 times that price. The dummy load will be $70 or more used, and will have a label stating its operating frequency range and power limits. Both should use N connectors. (There's a reason the repeater uses N connectors.) If you don't have this equipment, STOP. Find someone who does.

40 watts gives you a 3 dB improvement over 20. So it seems like a power output of 35-40 would be reasonable. I decided to play it safe and adjust the power output to 35 watts.

Setup

1. Make sure the repeater is powered off.
2. Connect the FTM-400 control head to the 4-pin control port of the Tx.
3. Connect the FTM-400's microphone to the 6-pin microphone jack of the Tx.
4. If you didn't just automatically remove the top cover after Step 1, STOP LET SOMEONE ELSE DO THIS!
5. Connect the Tx output to the wattmeter which is in turn connected to the dummy load.
6. Turn the repeater on and verify that the wattmeter displays 20 watts +/- 5 watts in the Mid power position. If it does not, STOP. DO NOT CONTINUE. YOUR WATTMETER IS NOT WORKING CORRECTLY.

Calibration Setup

1. Press and hold the DX and DISP keys while turning the repeater power on. (Do not turn the power off for the remainder of this procedure.) Continue to hold these buttons until the screen shows the main display. (See Figure 9). The transceiver should now be in the Transceive Mode (vs. Repeater Mode).
2. Press and hold the POWER/LOCK button until the Tx shuts off (2 seconds).
3. Press and hold the F(MW) and GM keys while pressing POWER/LOCK to turn the Tx on.
4. Press POWER/LOCK to LOCK the Tx (See Figure 10).
5. Using the microphone, enter the sequence 0, 3, 4, 0, 3, 4. If you do this correctly there will be an acknowledgement beep when you enter the final '4'.
6. Press the POWER/LOCK to unlock the Tx.

Calibration

In this procedure we'll adjust the HIGH power setting to 35 watts.

THIS IS WHERE THE FUN STARTS. YOU NOW HAVE THE POWER TO SCREW THE REPEATER UP! THERE ARE ONLY TWO BUTTONS YOU SHOULD TOUCH ON THE MIC FROM NOW ON - P1 and P2.

1. Set the 'A' band frequency to your repeater's output frequency.
2. Press the F(MW) key. Cycle through the menus (if necessary) and set the Tx power to HIGH. Press F(MW) again to return to the main screen.
3. Observe the 'B' side of the Tx. Press P1 on the microphone until the display says "Adj 02 PWR" (See Figure 9).
4. Write down the displayed hex value. If you wish to return to the factory setting, you will need to enter this value at this step.
5. Key the Tx and adjust the 'B' knob until the wattmeter reads 35 watts. Make a note of this new value.
6. When complete, turn the repeater's power off.
7. Disconnect the microphone from the Tx.
8. Disconnect the FTM-400 control head from the Tx.
9. Reconnect the DR-1(X) front panel to the Tx.
10. Reboot the repeater and verify 35 watts output on the repeater's Tx frequency.

Figure 9 Tx Transceive Mode

Figure 10

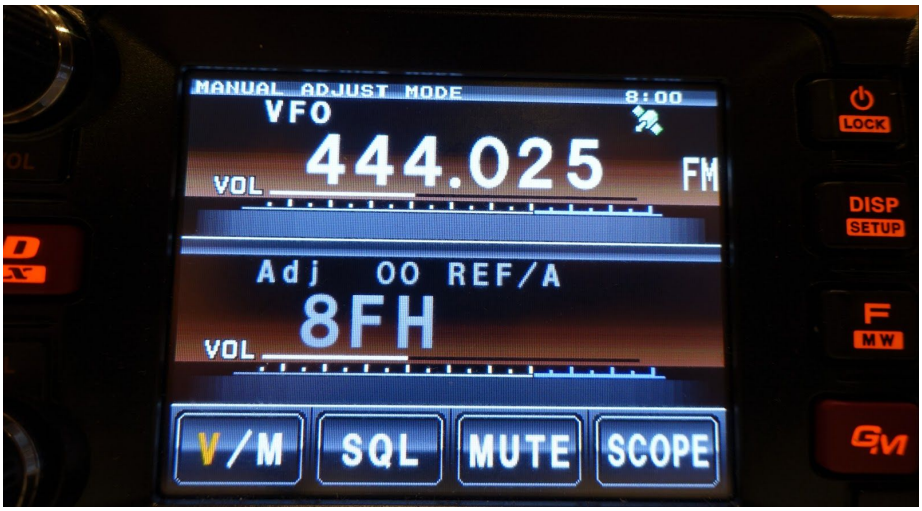
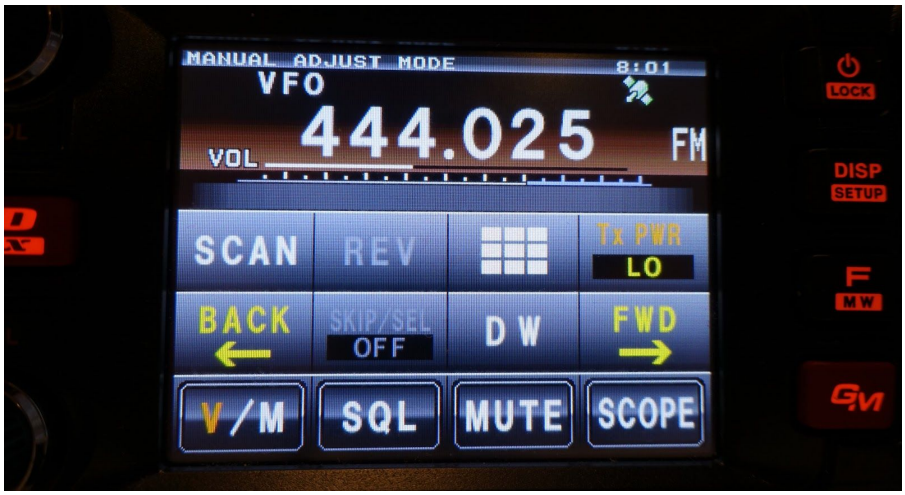


Figure 11 Tx Power Adjustment

Figure 12



Fan Modification

The fan modification eliminates modulation of the Tx caused by the fan motor. The objective of this modification is to change the source of power of the fan to the main power bus, rather than taking it from the Tx internals.

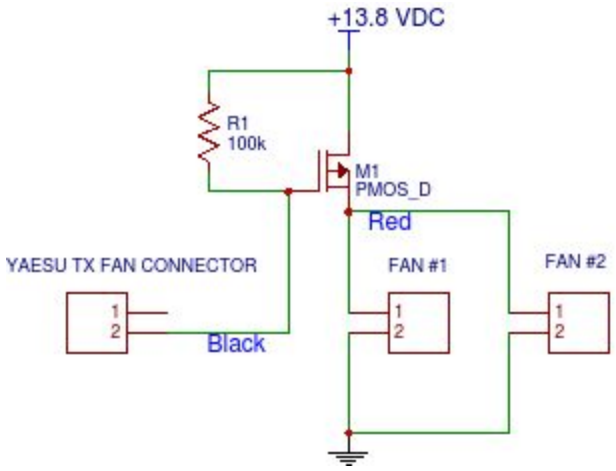
This can be done in one of two ways: Just wire the fan to run continuously (easy); or include the Tx's ability to switch the fan on and off. I don't think there's a problem leaving the fan running continuously. After all, the rear panel fan will typically run continuously in most repeater environments.

I do recommend installing an internal temperature sensor (see above) since an unusual temperature reading can indicate a fan failure (bad). The fans should last for 5-7 years. I would recommend proactive replacement at 3 years since they are an important component of keeping the Tx cool.

If you wish to run the fan continuously, the best way to get power is to tap into the previously installed fuse connections. You'll need to either use a different internal fan (so the connector is not damaged) or cut the leads on the fan, leaving enough slack after the connector so you could reconnect it again.

If you want the Tx to switch the fan, you'll need to build a circuit that controls the fan. A sample circuit is shown in Figure 12.

Figure 12 Fan Control Circuit



Fan Control Parts List

Designator	Description	Digikey Part #
R1	100k, ¼ watt resistor	
M1	P-Channel MOSFEET	
FAN CONNECTOR		
FAN CONNECTOR PIN		
FAN #1		

FAN #2		
-	Red hook-up wire	
-	Black hook-up wire	

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