

Technical Application Note #5

This Technical Application Note describes modifications, duplexing and tuning instructions to the Motorola Mitrek™ 406 - 420 MHz mobile radio. The following instructions are individually described:

- General Modifications
- Transmitter Modifications
- Receiver Modifications
- 429 MHz Receiver Tuning Instructions

The various modifications described in this Technical Application Note are primarily intended as modifications to the radio for usage as a link radio in the 420 MHz amateur radio band service.

We would like to thank the following individuals for their assistance in developing these modifications:

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This Technical Application Note #5 is available in electronic form, in its entirety including the diagrams and pictures, that can be read with the Adobe Acrobat Reader application. To obtain an electronic copy of this document, send an e-mail message to Ken Robbins, WA6PYJ, at ken@cactus-intertie.org and request an electronic copy of **Technical Application Note #5 - Modifications to the Motorola Mitrek™ 406 - 420 MHz Mobile Radio**.

Conversion for the Motorola Mitrek™ 406 - 420 MHz 30 watt mobile radio for Amateur radio 420 MHz link service.

The Cactus Radio Club, Inc. uses the Motorola Mitrek 406 - 420 MHz, 30-watt version mobile radio as a standard narrowband or wideband link transmitter and narrowband link receiver. The small size and high reliability make this radio an ideal mountaintop 420 MHz link radio. The Cactus Radio Club mounts the radio on a 3 1/2 inch rack panel for mounting in cabinets. There are several modifications that need to be made to the Motorola Mitrek series radio to make them suitable for reliable mountain top link operation. Since the Mitrek is a "single board" radio, it is not recommended this radio be used as a duplexed radio on mountain top sites. The reason for this is, when duplexed, this radio has low level spurs of sufficient power to cause interference to other radios at the site, and be heard many miles away. The 420 version of the Mitrek is different from the 450 version in that the 450 version does not exhibit the spurs when duplexed. The 420 radio should only be used as a transmitter or a receiver at mountain top sites. However, both the transmitter and receiver modifications can be made to each radio. Only install one channel element in a radio, either a transmit or receive, never both. By modifying both the transmitter and receiver and leaving one idle, you will have effectively provided a spare radio at the site if either the operating transmitter or receiver fails. By simply swapping channel elements you will be back on the air in a minimum amount of time.

These instructions have been divided into three (3) sections. The "General Modifications" are those modifications that are needed whether the radio will be used as a transmitter or a receiver. The next two (2) sections are "Transmitter" and "Receiver" specific modifications.

General Modifications

Remove the antenna relay switch from the front panel with long nose pliers. Save the special threaded front panel nut on the antenna relay "N" connector, it will be reused with the new crimp "N" connector. Clip or unsolder the black and red power wires from the relay to the circuit board at the circuit board. Cut the transmitter and receiver coax cable at the antenna relay. The double shielded coax from the antenna relay is routed back to the receiver helical preselector and the transmitter exciter harmonic filter. The double shielded coax is soldered to one (1) grounding clip at the casting as it leaves the receiver and three (3) grounding clips as it passes along the receiver helical preselector. Mark the position of each of these clips so they can be put back in the same position after removing them. With the radio right side up, pull out, as far as possible, the two (2) coax cables and the three (3) grounding clips. Unsolder the receiver coax from the chassis clips and save the four clips. Turn the radio upside down and remove the bottom plate. Locate the small rectangular metal shield that covers the coax connection points into the receiver helical preselector. Remove the one philips screw and remove the shield. Unsolder the receiver coax cable and slide it up out of its slot. Unsolder the flange from the cable and save it, it will be reused. Pull the transmitter coax cable up through the bottom of the radio and fold it out of the way. Using a very large soldering iron, reflow the solder at each of the twelve (12) helical coil connections on the casting. Use only silver solder for the reflowing process.

Transmitter

The most convenient place to mount the transmitter connector is at the normal radio antenna connector position at the front of the radio. However this is also the most critical position and requires a great deal of care during the installation to ensure maximum shielding for the receiver. The second place is in the small open area between the receiver helical preselector casting and the radio side casting. This offers the most isolation and shielding, but also requires the most work since the helical casting must be removed to install the cable and connector. This position also allows the antenna connector position at the front of the radio to be used for the receiver.

Transmitter Output Connector at the Normal Antenna Connector Position

Parts Needed:

"N" bulkhead jack crimp connector for RG-223, AMP P/N 225393-1

Miniature double shielded coax cable, approximately 12 inches, RG-223 (Single shielded coax cable may be used in this installation if the radio will never be used as a receiver)

The transmitter harmonic filter will need to be removed in order to replace the coax cable. The harmonic filter is located on the right side of the radio (as viewed from the bottom) and is held in place with two screws. Before removing the filter, you must unsolder the RF feed from the top of the P.A. board. The solder location of the RF feed point is right next to CR901. After unsoldering the RF feed connection at the P.A., remove the two screws holding the harmonic filter, carefully lift the filter straight up and out, being careful not to bend the RF feed wire from the P.A. Unsolder the coax from the harmonic filter. Using the new piece of coax cable, solder it to the harmonic filter in place of the old coax cable. After soldering the cable in place, do a fit check for the cable routing. The outer insulation jacket may need to be removed up to about two (2) inches from the harmonic filter to make the coax cable fit. Very carefully, reinstall the harmonic filter. Ensure the RF feed to the P.A. sticks through the P.A. board. Replace the two (2) screws to hold the harmonic filter in place and turn the radio over and solder the RF feed onto the P.A. board. Turn the radio back over so it is upside down and route the coax cable along the coax trough and up to the top of the radio through the opening between the helical casting and the side of the radio casting. Route the coax cable through the slot and into the receiver section of the radio. Solder the one (1) grounding clip on the coax cable at the casting slot. Install the "N" bulkhead jack crimp connector in the hole in the front casting of the radio where the antenna relay switch was removed using the special threaded front panel nut that was saved from the antenna relay "N" connector. Assemble the coax cable to the "N" connector. The crimp ring is not used. Solder the coax cable shield braid directly to the shield connection of the connector where the crimp ring would normally go.

Transmitter Output Connector at the Helical Casting

Parts Needed:

"BNC" bulkhead receptacle connector, Amphenol P/N 31-221 (with 1/16" thick mounting nut)

"BNC" connector grounding lug, Amphenol P/N 31-10152

With the radio upside down, unsolder all the connection to the helical casting. There will be four (4) ground straps and six (6) RF connections. Two (2) of the RF connections are the coax cable inputs from the receiver and exciter that are under the small rectangular metal shield attached to the helical casting. Remove the seven (7) mounting screws that hold the helical casting to the radio frame casting. The helical casting should lift straight up and out of the radio. Drill a 3/8" hole through the radio side casting, taking care to center the hole on the receiver side of the radio in the cavity area for the helical casting. The hole will need to be countersunk on the outside of the radio to make the flange of the BNC connector sit flush with the side of the radio. This will give just enough of the connector thread showing inside the radio for the ground lug and the mounting nut. Perform fit checks as hole is being countersunk to ensure the countersink does not go in too far. Mount the connector, with the ground lug in the hole. The ground lug tab should be cut so that approximately 3/8" of the tab extends beyond the mounting nut. The tab should be positioned so it points towards the harmonic filter, with the radio upside down and the connector towards the operator; the tab will be pointing up and to the right at about a 45% angle. Using a pair of side cutters cut off as much of the center conductor of the BNC connector as possible. Using a small file, file down the center conductor of the BNC connector so it is flush with the outer body of the connector. Place the helical casting back in place to ensure it fits and there is clearance for the BNC connector connections.

Remove the helical casting and cut and solder the coax cable from the harmonic filter to the BNC connector. Install the helical casting back in place using the seven (7) mounting screws to hold the

helical casting to the radio frame casting. The helical casting will push against the coax cable shield slightly. Make sure there is clearance for the center conductor connection. Resolder the four (4) ground straps and six (6) RF connections.

Transmitter Power Amplifier Modifications

The Power Amplifier should have two (2) modifications performed. The first modification is to improve the output power stability over temperature. The Mitrek Power Amplifier has a power control voltage circuit that reduces the drive at the first stage of the P.A., Q801, if the P.A. starts drawing too much current. As the P.A. heats up with use, diode CR908, and on some models CR901 is in parallel with CR908, will heat up and will change the current sense bias level which will vary the power control voltage. Remove CR908 and CR901 if installed, and replace CR908 with a jumper. Save the diodes. Locate the exciter section of the radio and find the GREEN WIRE that comes out of the casting next to Q904, which is the power transistor mounted to the side casting. Unsolder the GREEN WIRE from the circuit card. Solder the anode side of CR908 into the same spot that the GREEN WIRE was removed from. Solder the GREEN WIRE to the cathode side of CR908. If there were two (2) diodes that were removed from the P.A. board, solder them together, in opposite directions to each other, anode to cathode, and install them as if they were the one CR908 as described above.

The second modification should be done, as this is a common failure mode. Variable capacitor C800L may arc during operation or during the tuning process. The arcing is very noticeable during the tuning process or can be seen as a dark spot on the Mylar insulator that is installed at the top two (2) plates of the capacitor. If it does arc, the P.A. WILL fail if the variable capacitor is not removed. If arcing has occurred, remove capacitor C800L and replace it with a 10pf, 100 volt, capacitor. Find the best spot for the capacitor by tacking it on the circuit trace in different spots between the C800L and the C800H locations until the maximum output power is obtained. This position will vary with different radios and transmitter frequencies. The capacitor value can also be varied between 2pf and 20pf. Find the best value and the best spot. Solder the capacitor in this spot.

1) RECEIVER COAX CONNECTOR

The choice of connector and coax for the receiver has been found to be the most important step in eliminating any transmitter desense. Miniature 1/8" Teflon semirigid cable (UT-141) has proven to be the best choice. This coax is used with a single hole BNC connector designed for use with a crimping tool. (Tool not required). The shield of the UT-141 should be soldered directly to the shield connection of the BNC connector. There should be absolutely no center conductor exposed at either end of the hardline to act as a source of signal leakage. It is just as important that the hardline be soldered to the grounding clips which were removed from the antenna switch at their original location. Drill a hole through the left side of the chassis to mount the BNC connector. This is done between the aluminum pillar and L102 on the receiver side of the board. The location is about 6 5/16" from the rear end of the heat sink and (with the top cover removed) about 5/8" below the highest part of the side casting. Hole diameter should be drilled to match your Receiver connector. Another successful option to the BNC connector is to fabricate (or buy) a piece of UT-141 with an SMA connector on one end. An 1/8" clearance hole is drilled in the side of the radio in the same location as the BNC connector mentioned above and then SMA to (your connector) adapter is used for receiving. This option is easier but is a trade-off with mechanical strength and cost.

2) REMOVE TWO DIODES

Actually, it's easier to clip one end and lift it from the board. The diodes are CR1 and CR403. See Motorola Mitrek Receiver Picture for general location. This modification unmutes the receive audio.

3) TRANSMITTER AUDIO MODS

When using the radio as a repeater or duplex link, it should pass audio without modification, or to have "flat response". Audio tailoring is then done at the controller of your choice. The Mitrek has very flat audio requiring little work. Flat audio is accomplished by soldering a jumper wire to the interface board at J10 pin 23 directly into pin 4 of channel element F1. The J10/P10 connector is bypassed because it has been found to be the cause of intermittent and high resistance connections. Use a 0.1uf capacitor in series with the wire if the controller does not have a series coupling capacitor. All of the microphone stages must be eliminated by cutting traces.

Most repeater controllers require a negative going signal (to ground) for PTT. The Mitrek provides both a negative and positive PTT logic switching. For negative PTT, place a jumper on the bottom side of the radio at interconnect P10 from pin 1 to pin 25. This connector is located at the front, center of the radio. For positive PTT, tie pin 1 to pin 24.

4) RECEIVER AUDIO MODS

For "flat" receive audio, a connection as close to the quadrature detector output as possible is the goal. The Mitrek does not have sufficient audio out of the quadrature detector to drive Cactus Standard Controllers, so the "Buffered Audio Out" is used. Buffered audio is available at the front panel connector at pin 9, which is labeled "detected audio out". Cactus Standard does not use this output so that a local audio to speaker can be had at the repeater location. To send buffered discriminator audio to your control system, tack solder a wire from pin 1 of U403A through a 0.1 µf capacitor to a solder hole on the interconnect board next to JU3A. See Motorola Mitrek Receiver Picture for location of U403A and JU3A. Cactus keeps the 0.1 µf coupling capacitor near the interconnect board and properly insulated. Use a new high quality capacitor. Change R453, the feedback resistor across U403A from 150K to 51K to provide lower audio output. The resistor value may need to be varied depending on the controller drive requirements.

5) COS

The preferred method of carrier detection is handled by the presence of a signal or noise in the repeater controller. That is, a logic output is obtained from the quadrature detector as in the previous paragraph. The "Micor Squelch Chip" or audio "E" boards both put out logic change when a carrier is detected.

If you are using another controller such as the popular ACC or Hamtronics, etc., you will have to find a logic level change somewhere in the receiver section of the board. That logic level change will have to be conditioned to match the input to your control circuit (i.e., TTL, CMOS, etc.). One point on the board that may meet the requirements is called "Point B" on the schematic. Before deciding on using point B, look at its voltage vs. time vs. input/squelch signal level. You may have to do some special work on this level change make it work with your controller.

To find point "B", first locate the two flange mounted devices fastened at an angle on the left side of the radio case on the receiver side of the board. Point "B" is about 1 3/8" to the right of the center pin of U402, the rear most devices. See the Motorola Mitrek Receiver Picture.

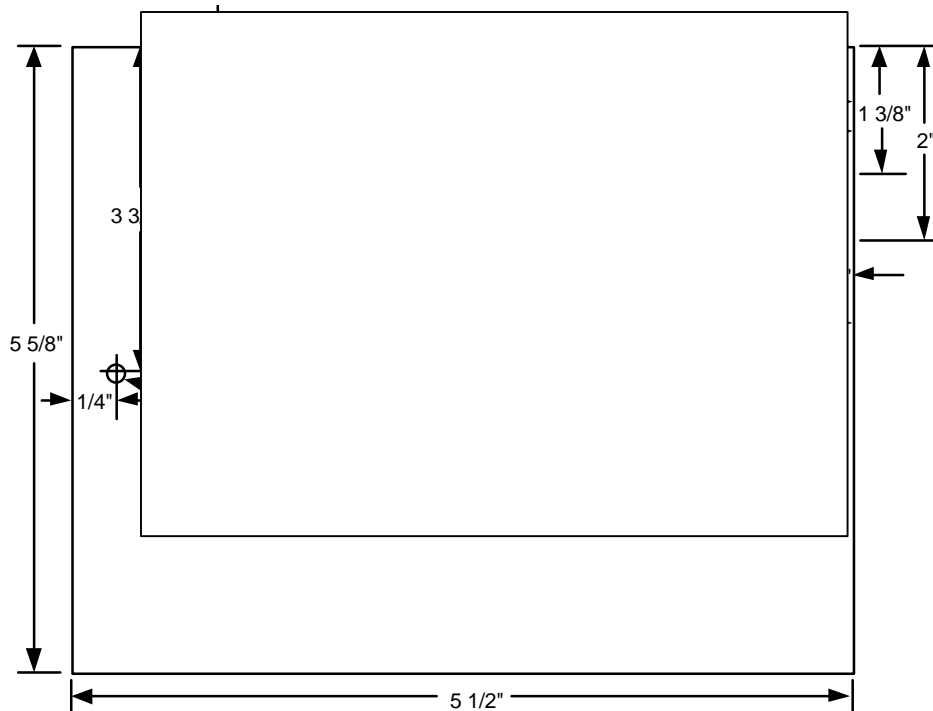
If you have the (uncommon) "Busy Light" circuit option, a lead off of DS106 should be a good source of carrier detect.

6) UNWANTED SPURS

When duplexing the 403-420 MHz version of radio for use in the 420-430 part of the ham band, certain frequency combinations result in the generation of unwanted spurs. Again, using a duplexed 420 MHz Mitrek on a commercial mountain top is not recommended.

Example: Transmitter=421 MHz, Receiver=429 MHz. There are five spurs on both sides of the transmitter frequency which are down only about 50db from the carrier spaced about 1 MHz apart. This is caused by the receiver local oscillator leaking into the transmitter multiplier chain. The following steps should be taken until the spurs are at an acceptable level:

a) Shield the receiver portion of the main board with a thin piece of aluminum as shown below. The rectangular cutout is for the receiver channel element. Use the existing holes in the radio casting for mounting.



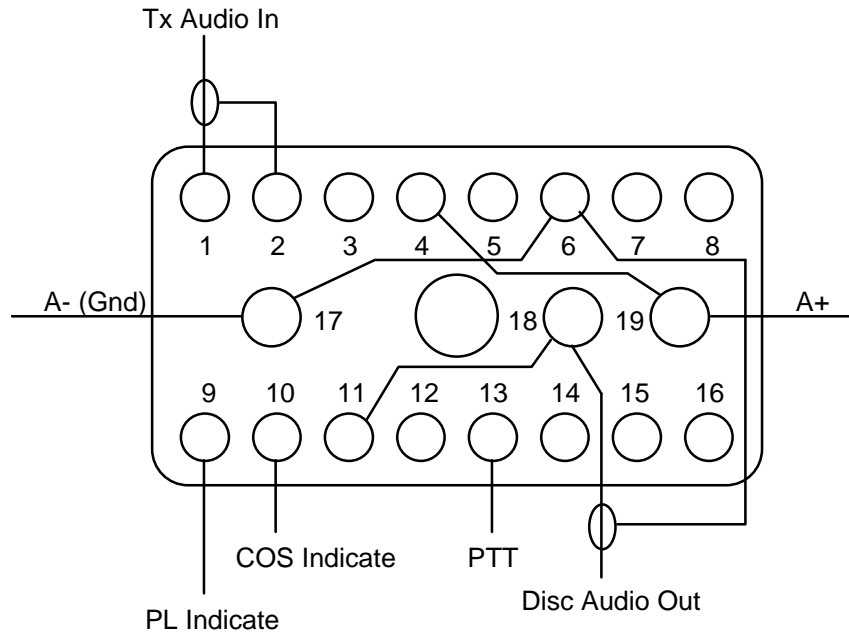
b) Install a 0.1 uf capacitor from the 9.5v channel element supply anyw r the F1 channel element to ground.

c) Ground the injection buffer shield to the preselector by installing finger stock on the inside of the bottom cover. The bottom cover referred to is the cad plated shield, not the painted mounting tray. To do this, part of the inside foam has to be cleaned away, the finger stock is soldered to the inside of the cover and a few fingers have to be removed to make it all fit.

d) Use a cavity at the output of the transmitter.

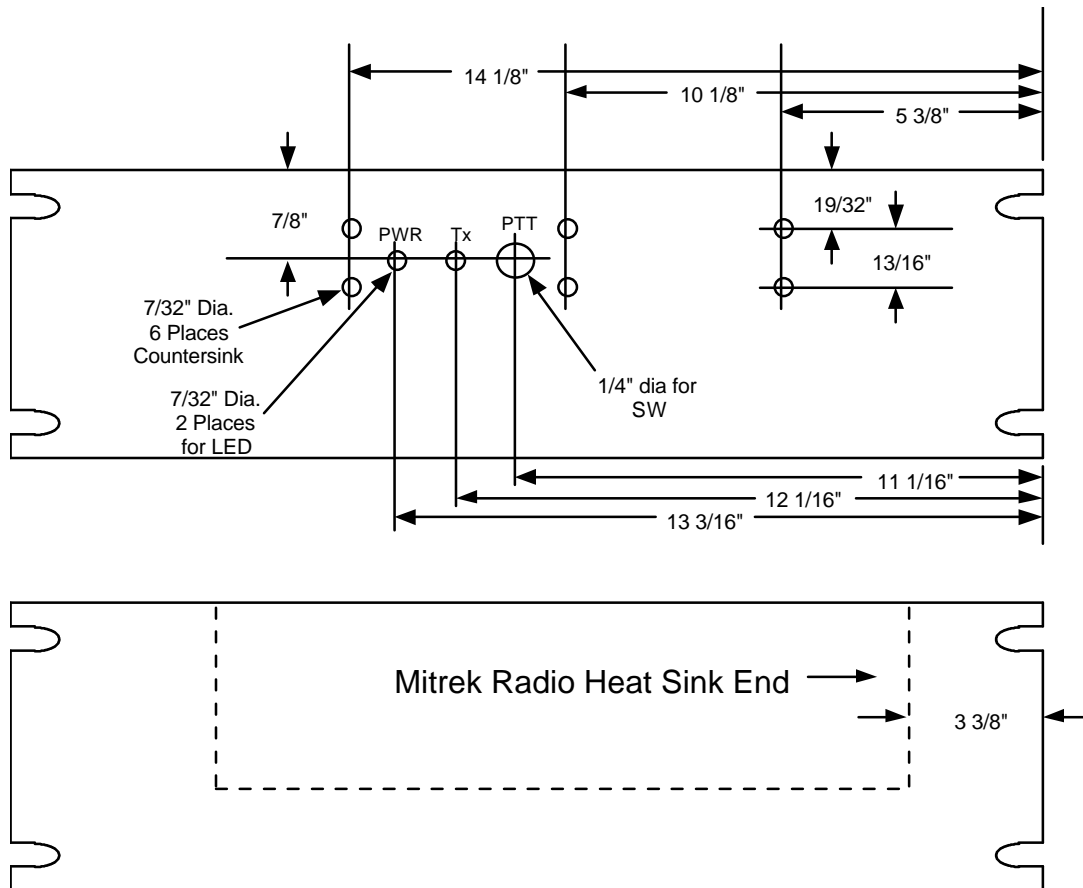
7) FRONT PANEL CONNECTIONS

The Mitrek uses a standard Motrac (yes Motrac) cable connector. This is a widely used connector on several models of Motorola radios, such as Motrac series, Mocom 70 series and Mitrek series radios. The connector wiring is shown below. The diagram shows wiring for both the transmitter and receiver connections. Construct a cable using only the wiring required for the desired modification, either transmitter or receiver.



8) MOUNTING

Construct a standard 19 inch wide by 3 1/2 inch high rack mounting plate as shown below. After the mounting plate is completed, use the mounting plate as the template to mark, drill and tap the six mounting holes for the Mitrek radio. Be sure to leave clearance room for the top and bottom covers of the radio. This requires drilling, using a number 7 (or 13/64") drill and tapping, using a 1/4-20NC tap, the six holes into the right side of the radio as indicated and bolting it to the rack panel. The other holes and features are optional.



For cabinets with limited depth, mount the radio on it's slide tray on a rack panel with the heat sink facing upward.

9) POWER CONSUMPTION

The current drawn from a 30-watt version of the Mitrek should be close to the following. It is not recommended to set the power level of the transmitter lower than 15-watts. Some transmitters become unstable a lower levels.

Power set at approximately 15W = 5.3A
 20W = 6.8A

Receive current = 270ma.

10) POWER SET STABILITY

The Mitrek was designed as an intermittent duty mobile radio. When used as an exciter to an amplifier, it is necessary that the power output does not change appreciably. From ten radios measured, only one varied less than 30% over a time period of one hour. Most of them increased in power from 50% to 100%. Some amplifiers won't like starting at 10-watts of drive which becomes 20-watts an hour later.

The source of instability was found to be the mounting location of CR908. It is located on the P.A. board. As the board heats up, the power output increases. The exact location of this diode is not always where the pictorial diagram in the manual shows it.

Remove the diode, solder a jumper in its place and then wire the diode in series with the green wire that goes to point "E3 on the main board. Point "E" is located in the upper right corner of the transmitter section. See Motorola Mitrek Receiver Picture. The latest Motorola manual shows that this diode has already been relocated to the main board! In a few cases, it has been found that there are two diodes, which are piggybacked at the location of CR908. If so, leave them soldered together and move them both to point "E".

11) COOLING

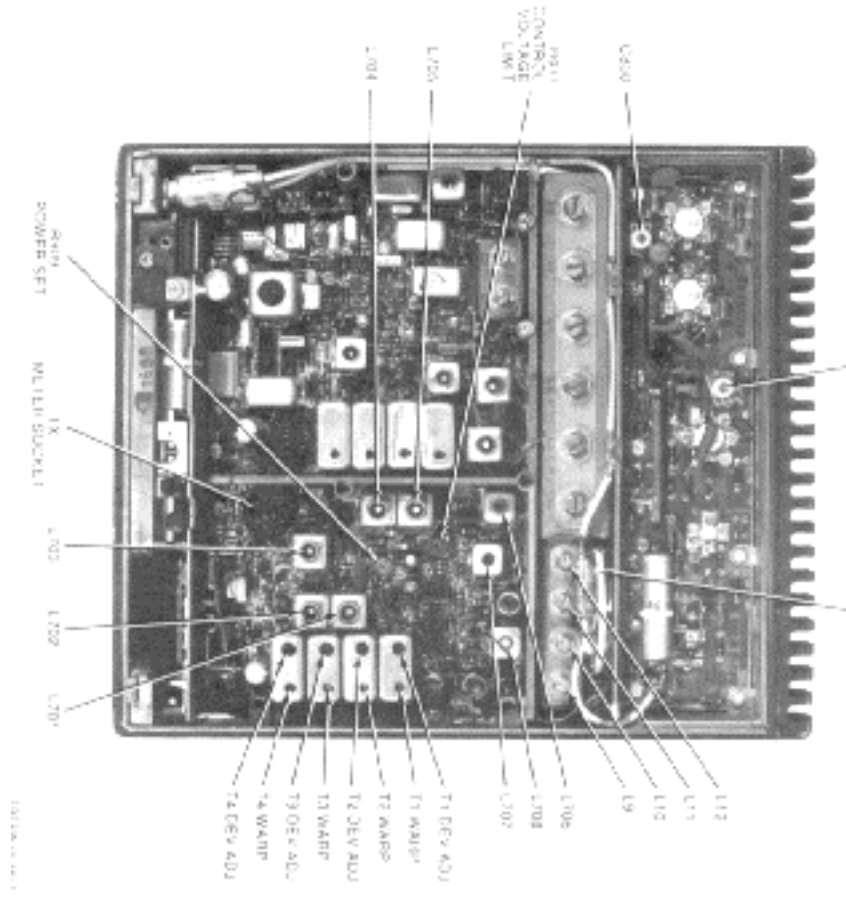
If the 30-watt version is run at 20-watt or less, no additional cooling appears to be necessary except in the very worst environmental locations. The higher power radios will need a fan or more heat sink even if run at very low power due to their inefficiency.

Remember that Motorola does not guarantee the spectral purity specifications of their radios when run at less than 50% of rated power.

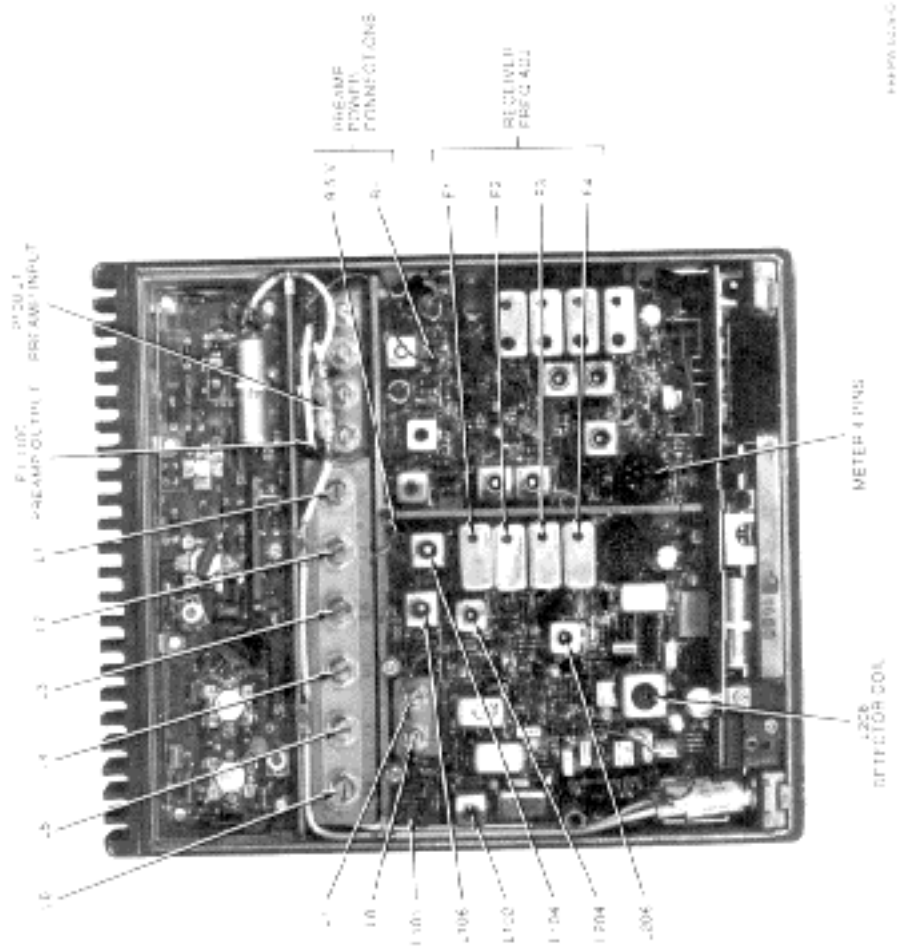
12) CHECK LIST

After completing the modifications and prior to turning the radio on, at least check for the following:

- 1) Check the transmit antenna connector for shorts to ground. If grounded, the transmitter harmonic filter is probably causing the short. Recheck the installation.
- 2) On the underside of the main board, carefully inspect the connection between the exciter output and the P.A.
- 3) While the radio is upside down, check the dozen or so connections where the RF preselector coils are soldered to their casting. It is recommended that the preselector coils be resoldered as a matter course. Use a big iron.
- 4) When keying the modified radio for the first time, place an ammeter in the A+ lead and check against the currents mentioned above.
- 5) Always look at the transmitter on a spectrum analyzer before placing it on a mountaintop.



Motorola Mitrek Transmitter Picture



Motorola Mitrek Receiver Picture

429 MHz Receiver Tuning Procedure

The 406 to 420 MHz MITREK receiver will normally tune as high in frequency as 440.000 MHz, however tuning becomes much more difficult and time consuming. This instruction describes the preset receiver tuning slug positions and the subsequent tuning procedure for a 429.000 MHz receive channel and will make tuning easier for a receiver above 428 MHz.

1. Preset the receiver helical tuning screws, L1 - L6, to 6 mm above the retainer nuts, approximately 6 threads showing.
2. Preset the receiver injection filter helical tuning screws, L7 and L8, to 10 mm above the retainer nuts, approximately 10 threads showing.
3. Preset L104, receive channel element tuned filter and L106, injection amplifier tuned filter, 13 turns below the top of the coil form.
4. Preset L101, the mixer gate coil slug, to the bottom of the coil form.
5. Preset L102, the mixer drain coil slug, 15 turns below the top of the coil form.
6. Preset L204 and L206, IF matching network coils, 8 turns below the top of the coil form.
7. Preset L208, limiter and quadrature detector, to the top of the coil form. Monitor Meter 2 (reverse) and screw coil slug in until Meter 2 first reads 24 microamps. No input signal is required.
8. Inject an on channel, high level signal into the antenna jack. Monitor Meter 1 (reverse), or listen for best quieting signal, and adjust L7 for highest Meter 1 reading. This should happen within approximately 3 turns of the tuning slug in either direction. Be sure to maintain the Meter 1 reading below 40 microamps. Zero the Meter 4, discriminator, with the channel element warping capacitor.
9. While monitoring Meter 1 (reverse), adjust L8 for highest Meter 1 reading. This should happen within approximately 5 turns of the tuning slug in either direction. Be sure to maintain the Meter 1 reading below 40 microamps.
10. While monitoring Meter 1 (reverse), adjust L1 through L6 for highest Meter 1 reading. Be sure to maintain the Meter 1 reading below 40 microamps.
11. While monitoring Meter 6, start with L104 and alternately adjust the injection buffer coil slugs, L104 and L106, 1/2 turn at a time for a peak reading. The preset position may be very close to the final position.
12. While monitoring Meter 1 (reverse), adjust L102, L204 and L206 for a peak reading.