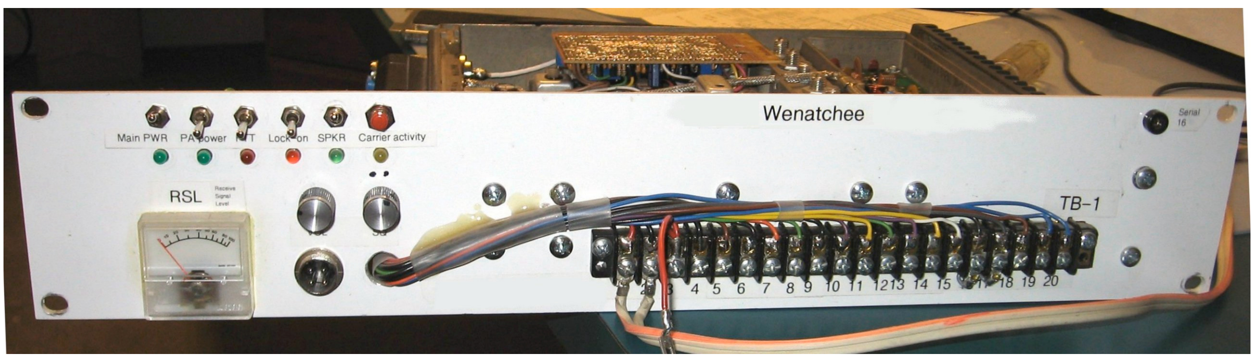
Motorola Mitrek conversion to repeater or link
by Karl Shoemaker

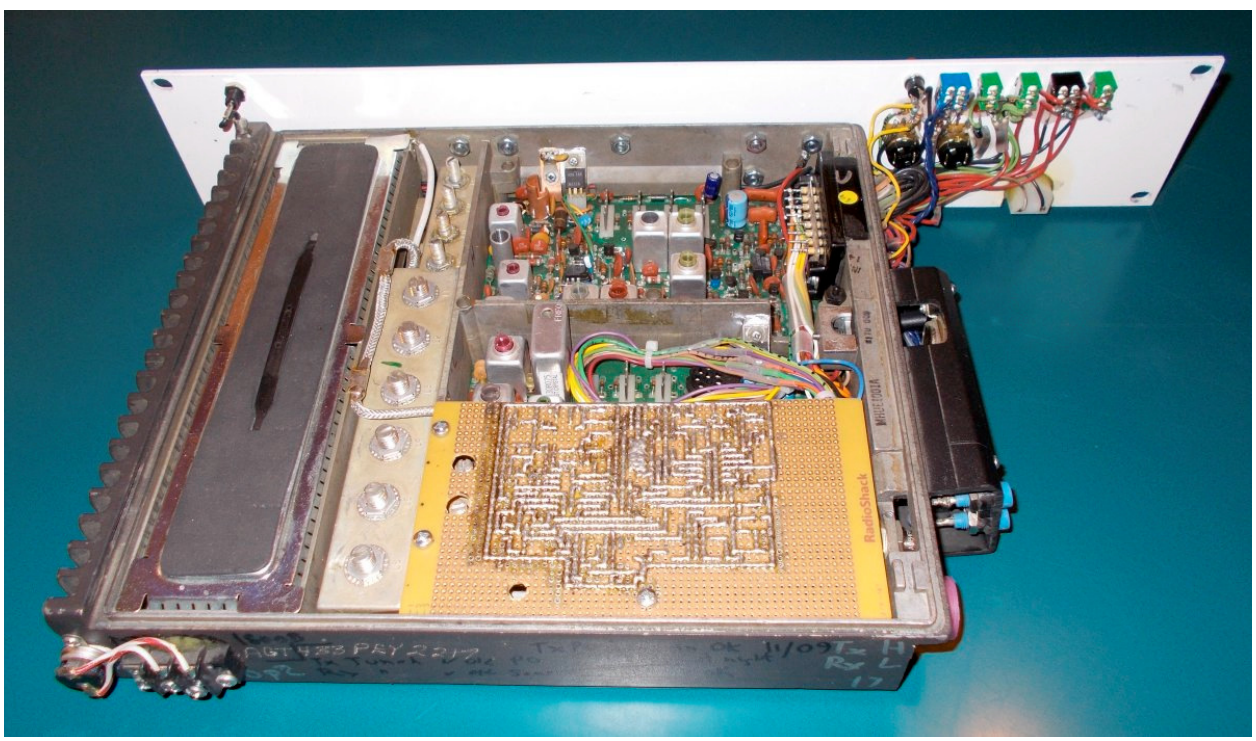
Introduction:

This document is written to include interested people in serious construction of a quality product. Its rather technical however, if you have a basic electronics background with some repeater building experience this should not be an issue. Some of it's dry reading however, you need to spend time on this to better understand advanced circuits, later on. Understanding schematic drawings is required. If you are new at the repeater operation you might want to seek experienced help. Allow plenty of time to construct each unit, especially the first one. No free technical support is available however, some printed documents are available on an occasional bases, for a modest cost for P & H. The project is designed for amateur radio (not commercial) and is open for discussing, changes and improvements without notice. Should you feel qualified you are welcome to deviate from the Author's design. Images in this document may be used to illustrate a point only and may have been taken at different stages of research and development therefore, may not show the end "product" in some cases.

Overview:

For this project the Motorola Mitrek mobile in the 70-cm amateur band is used. This project is for support for SRG's system. It can be interfaced with external repeater equipment. From OEM specifications, no performance or reliability degradation was observed from the modifications discussed in this document. Shown here is a completed unit.





Acronyms, Definitions, semantics and Theory basics for Telecommunications:

Some of this material may not be popular reading for hobbyist however, is necessary to maintain a complete understanding of the project at hand. To be very clear on this philosophy, we will start with the basics. Humans wish to communicate since the cave-man days with grunts. A few million years later with smoke signals. A hundred years or so ago with wired telegraph (1800's) and wireless telegraph (1900's). In the 20^{th} century voice finally was realized. In the 21^{st} century better sounding, analog voice, then data and digital voice was realized. Only analog communications/transmission for Land Mobile Radio (LMR) will be covered in this document.

Radio systems send intelligence (voice, data, etc.) by modulating the originating transmitter and decoding (detecting) this modulation at the far end receiver back to something usable to be understood. How well this is understood depends greatly on how well the system is set up. Just about anyone can "throw" a system together to make it work, somewhat.

Amateur radio can develop the art of radio and improving operating practices in this area. This can set a good example for others, including the commercial industry, to what some amateur radio systems are capable of doing and to provide public service communications in time of need. This includes the technical side, to produce a high performance repeater and/or link.

A "repeater" is a generic term for user's signals to be received (input) and retransmitted (output). This greatly increases radio coverage, for a single-site, conventional repeater. Extended (user) coverage can be realized by linking several repeaters together. Further user coverage can be realized with a voter system and simulcasting as well in analog systems.

Most radio systems in the VHF, UHF (and microwave) are line-of-site for the radio paths. On the ground a path has limited range because of obstructions which attenuate signals. From high (remote) sites greatly increase this because most of the obstructions are gone.

A "link" is a one-way transport method for repeater support, such as the remote receivers on a voting system. For example, a repeater's (input) receiver may need to be "downlinked" to a central control point, such as a voter or connection to the outside world (telephone, internet, etc.). From this control point the system output can be "uplinked" back up to a high transmitter (output) for the users to enjoy wide coverage of such a system. In this case would be a multiple site repeater (system of links, etc.) In conclusion, three factors improve a conventional analog radio system:

- Repeater; to "relay" user signals.
- High location; get away from obstructions.
- Voter system; easy user access, especially with portable-low power subscriber units (users).

A typical (commercial) system uses the audio portion 300Hz~3KHz for repeaters and links. With several links this produces "tinny" and distorted audio. In some cases squelch and signaling circuits produce signals that are annoying and fatiguing to listen to. Because of user tolerance and ignorance this sets a (bad) precedence of what a system is expected to be. This document covering system performance will be somewhat different. The Author's design and specifications call for a better way, and is practiced in all SRG projects such as this one. For example, "flat" audio, better squelch and other signaling practices are utilized. This keeps a large system nice to listen and operate and may set examples for other groups to improve their systems. It also calls for good technical management.

For one, technician organization and discipline is necessary. Plan on what you want to do for a system design and stick to it. Force yourself to keep good practices. One good practice is to establish level references. Some call these "benchmarks" or "baselines". While old methods used linear (microvolts, watts, etc) units of measure, design of this project and document uses logarithmic units. Once accustomed, it's easier to see the entire picture this way, when designing a system or checking system performance and keeps the guesswork out of troubleshooting a subtle level problem. References can be expressed with a few acronyms.

Note: In this document, any font in blue indicates a guess and/or not verified at the time of publication.

Test Tone Level and Test Level Point:

Test Tone Level (TTL) is referenced to tone that modulates a channel or path 100%. For a testing or aligning a LMR transmitter, receiver or path this would be a 1 KHz (1004 Hz for telephone work) for a FM (frequency modulation) system. Test Level Point (TLP) refers to a measurement point (normally on equipment) in reference to TTL. TLP provides easy reference to any parts of the system for measurement and alignment. 0 dbm is referenced to 1 milliwatt at 600 ohms. A 6-dB drop in (voltage) level would reduce the modulation in half, and so on.

Levels are stated in transmit-receive (Tx-Rx) order. Therefore, an audio (Voice Frequency) "drop" TLP of 0/0 would mean a Tx TLP of 0-dbm, Rx TLP of 0-dbm. For example, a transmitter AF input with a TLP of 0 dbm, with a TTL of 0 dbm tone input, would fully modulate the system. If the far end receiver was set up the same, its output would be a 0-dbm tone as well.

Absolute levels are specific-measured (operating) levels, not to be confused with TTLs. Sometimes operating levels are not at TTL. In this case, a level would be so many db "down" from TTL, or just called "xx down". For example, CTCSS (sub-audible) tones normally are 18 db down. (1/8 deviation from voice, or 18 db down from maximum voice and/or TTL).

To avoid technician confusion two sets of numbers are sometime used in diagrams and on the physical equipment's ports or I/O connections. Non-parenthesis figures are (absolute/actual) fixed operating levels, and as mentioned before, may be at different levels from the TTLs. Figures in parenthesis are the TLPs, which is explained below.

Levels below 0 dbm are negative, while above are positive. Take this into consideration when working with system gains or losses. Normally, the negative levels have a minus in front of the number, while positive (optionally) have a plus sign. This is also true for absolute levels (as opposed to TTLs). This method is used for most any AC frequency (audio or RF). For example, many transmitters run a +42 dbm while most receivers' sensitivity run a -117 dbm for 20 dB quieting.

Other terms:

RF or AF ports at the **T**op **O**f **R**ack are considered "TOR". This is all equipment in/on the station's cabinet or rack. External equipment from TOR is later figured for a system performance (losses or gains). This may be RF lines, a combiner system or tower antenna(s). TOR levels are referred in the order of the transmitter and receiver (Tx and Rx, respectively).

Single digit numbers of "1" and "0" in brackets (" [ ] "), are not to be confused with TLPs. In this case these 1s and 0s identify the logic state of a gate, or other TTL/CMOS I/O driver circuit, and so forth. Another aid to avoid confusion between logic states and a TLP is that the latter normally would have a " + " or " - " before the number (as earlier mentioned). For example, a TLP of -14.8 is the audio input controlled by a logic gate of [1], being a normal logic "high". One last word on the logic state; The brackets indicate a state in normal standby/no activity condition. As a side note, "TTL" mentioned above has nothing to do with "TTL logic", a type of IC series.

Most "TIMM"s and AC voltmeter scales are in "dbm". When measuring across a circuit you may need to have the meter in bridge mode, being medium impedance as not to load down what you are measuring. In such cases a more accurate term of level would be "dBu". Having said this, dbm reading in bridge mode is still understood by most, for a specific (absolute) level measurement using log10 based numbers.

The term "COR" came from the old tube days of "Carrier Operated Relay" whereas, a tube receiver had a point, when its squelch opened, a tube (switch/valve) drew current through a relay's coil, to give some contact closure, to key the associated repeater's transmitter. Repeater stations in the early years were called "Relays" whereas, the station would "relay" a signal rather than "repeat" a signal.

As the solid state technology came in the later 1960's the COR term stayed with repeater operation. In addition, most modern equipment no longer had a mechanical "relay" used. Perhaps a more accurate term would be "Carried Operated Squelch" , "Carrier Operated System" (COS) or CAS in the case of the older GE receivers.

Both terms are correct and this gets down to semantics or content of a discussion:

- Modern technology used in the LMR field by amateurs and professionals alike.
- Recent repeater product terminology and it's manuals.
- To avoid reader confusion; since they may expect the term of "COR".

After careful consideration it was decided to stay with the term "COR". Therefore, this and other SRG documentation will reflect this decision.

"CS" will be reserved to describe "Carrier Squelch" as a receiver's mode of operation, verses "TS", "PL" or "CTCSS" to describe a "Tone Squelch", "Private Line" or "Continuous Tone Coded Squelch System".

"SDI" means Signaling Decode Indicator (or Input). It's also similar to a CTCSS line out of a tone decoder. "HUB" means Hang Up Box. Motorola's uses a "closed loop" for mobiles and base station control. "AND squelch" means it takes both carrier + tone to activate a COR board, transmitter or system. AND squelch is also referred as a variable sensitivity squelch whereas, the squelch setting affects activity threshold. An "OR" squelch does not; whereas, it "bypasses" whatever squelch setting, using only tone to keep it active (once the squelch is open on startup reception). More is discussed, later in this document.

Operational Note: Tone "protection" (CTCSS) is only to avoid a squelch from opening undesirable signals. Ignoring RFI does little or nothing to correct it from competing with weak, desirable signals. Hence, the words "protection" in this context is almost a misnomer and does not "fix" the RFI problem.

Push To Talk:

The term "PTT" came from a button on a radio's microphone. For this documentation PTT will describe an active going "low" for DC functions, such as transmitter keying ("PTT Input"). It also will describe a receiver's COR line driving a NPN transistor, with the open collector being "Receiver PTT Out", or just "PTT Out". "PTT 1" will describe this function however, with a buffer, such as the output of the cor/af board, which changes state for user signal change of status. This function would be used for audio switching, such as auto-patch audio routing. "PTT 2" will describe a buffered, and "hangtime/tail" output of the cor/af board, to keep a repeater's transmitter keyed up (AKA tail) for normal back-and-forth conversations of the users of such system(s). One or both types of PTTs may be time-out controlled.

PM/FM: (for a transmitter)

Frequency modulation is the common way to send intelligence in the LMR analog world. FM is also referred to "deviation" (of the carrier, at an audio rate). There are two ways to frequency modulate a transmitter, phase modulation (PM), AKA indirect, or (direct or true) FM (frequency modulation). PM is the easiest design with good frequency stability however, lacks audio response. PM has "natural" pre-emphasis which works well for LMR standard. On the other hand, (direct) FM has much better response (flat audio) at the cost of more complex engineering to keep stability. Also, FM needs additional pre-emphasis. With modern synthesized/PLL transmitters this is major consideration. However, later technology-design has allowed direct FM to perform well in LMR systems.

The MI (modulation Index) for a PM signal is always changing, especially for voice traffic. MI is mentioned because FM causes side bands to be created above and below the carrier and takes up bandwidth on a particular frequency, or sometimes called a "channel". Modulation and deviation are the same results when talking about FM. Maximum deviation of 5 KHz means 5 KHz above the center frequency and 5 KHz below the center frequency, making a total bandwidth of 10 KHz possibly including side bands.

Radio technologies have different bandwidth standards (for maximum deviation) such as:

- FM radio broadcast of 75 KHz
- TV (analog) aural of 25 KHz
- Legacy cellular of 12.5 KHz
- Legacy commercial/government (LMR) VHF-UHF of 5 KHz (and most amateur).
- Current commercial LMR of 2.5 KHz
- Point-point microwave using (legacy) frequency division multiplexing about 5 MHz, in many cases.

While its good to be aware of these different bandwidth standards only amateur radio standards will be covered in this document. Crowded parts of the U.S. and abroad may use the “narrow band” standard of +- 2.5 KHz. It’s believed the reasoning behind the narrow band is less adjacent channel interference at the cost of lower performance in some cases. The Pacific Northwest VHF bands are still blessed with the 5 +- KHz standard and is the standard for SRG projects such as this one.

A quartz crystal is normally used to control the frequency of an oscillator. A variable capacitor across the crystal can fine-adjust the frequency in the form of “warping” it. The fundamental crystal frequency will be converted by multiplying its frequency to obtain the (final) operating frequency. For example, a typical LMR VHF transmitter would be 12 times; or a tripler, driving another doubler, driving a final doubler. (Fc=12 MHz x 3 x 2 x 2 =144 MHz). It’s then amplified to a usable level for transmitting over the air.

Transistors and diodes have a P-N junction inside the case. The former can be used as an amplifier or switch with a potential (voltage) applied to create current flowing in the forward direction (against the schematic diagram arrow).

They also can be used as a variable capacitor. The P-N junction on either device has a “space” in the middle in the form of capacitance called the “depletion zone”. By applying a DC (reverse) voltage across this zone will affect it. This is also called “bias” across the zone. More reverse bias results in more space, thus, causing less capacitance. In a RF circuit this can mean higher frequency, in general.

By applying “intelligence” in the form of audio (AC/voice) across the zone will cause the RF circuit to change in frequency at the same rate, thus, creating frequency modulation. The bias is set up for a fixed value to keep the voice operating in the linear range of this device. This will create good symmetry (waveform) on a frequency modulated RF carrier. This is especially true (no pun) for true/direct FM.

Special diodes are made for this purpose, called a varactor diode or “veri-cap”. They come in various specs, for capacitor ranging 5 ~ 100 pf. Typical is 10 ~ 13 pf for LMR.

Most PM transmitters have the veri-cap diode in series with the crystal causing a phase difference on the fundamental frequency, while most FM transmitters have the diode in parallel to the crystal causing a (direct) frequency change on the fundamental frequency. For FM transmitters, most have the anode to (common) ground.

FM is also used for compensation against frequency drift from temperature changes of an oscillator circuit. In some cases a transmitter uses both PM and FM for audio and compensation, respectively, or two stages of FM, for both reasons as well. Sometimes both circuits are contained (with the crystal) in one module, as in the case of the GE Mastr-II transmitter’s “ICOM”. This way the channel device (element) can be set up (compensated) for each crystal for best performance.

Frequency multiplication also multiples the modulation of the fundamental frequency. Since this arraignment multiples the crystal frequency 12 times it won’t take much capacitance change to obtain 5 KHz modulation (deviation) or temperature/frequency compensation, at the operating frequency.

Flat audio – The long explanation:

As previously discussed, most stock/conventional two-way radios are designed for single path operation, with it's own pre-emphasis, deviation limiting (clipping) and receiver de-emphasis, and "forgiving" squelch operation. Each time a repeated signal occurs some reduction in signal quality happens. For multiple links (long haul) these stock radios can add gross problems, such as excessive distortion, audio frequency response being very poor and very long squelch bursts. All these conditions will cause a system to operate badly and be rather annoying and fatiguing to listen to. Fortunately, these conditions can be corrected.

Some of the problem is human ignorance, interpretation, perception and semantics when discussing audio processing (or not). To fully understand proper audio will take some careful thinking. The other point to keep in mind is the frequency range specification, such as 300 Hz ~ 3 KHz response for a conventional voice circuit, (which some would call “flat”) or 20 Hz ~ 5 KHz (which is more “flat”) or somewhere in between. Perhaps a better explanation to clear up this argument would be to call the latter “extended flat audio” (EFA). Also, there are ways to modify a PM transmitter to FM (true) as part of a flat system. Now, let’s go over some audio processing methods:

There are two types of audio frequency processing when it comes to FM radio equipment; which is conventional (emphasized) and flat (modified or specially designed). One of the standards for FM operation is to improve reception (audio) quality by improving the signal to noise ratio. Consider these two factors:

- Signal; meaning, the intelligence quality of voice or analog data reception.
- Noise, meaning noises from all other sources of this type of communication circuit.

Most of the noise is in the high end of a standard communication channel of 300 Hz ~ 3 KHz; also known as a voice channel. Therefore, by processing the high end of the voice channel can improve audio reception quality. This is normally done by emphasizing (increasing the level) of the high end at the originating source audio by 6 db per octave and de-emphasizing (decreasing the level) of the high end of the far end audio at the same slope.

This is a similar method to “Dolby B” technology used in stereo/hi-fi sound recordings for music listening; except its not companded (compression during recording and expansion during playback). For LMR, the far end listener will experience apparent noise reduction; thus, better S/N ratio. This method is for simplex operation and is done only in the subscriber units. While this may work for a single path, repeaters and multiple links will need further understanding to produce a quality audio path.

Repeater stations:

One could use the audio from the speaker of a receiver feeding a mic. input of a transmitter. Since amateur systems can be modified without violation of type acceptance better points can be used. For example, the (flat) DPL (channel element) input is used in the case of Motorola LMR equipment. For the receiver the discriminator output is used. All receiver's discriminators should have great low-end response however, (due to IF filtering restraints) the top end always rolls off too soon. There is also the impedance-loading and level issues to deal with in some receivers. This and other SRG documents address this.

Most amateurs refer to “flat audio” with methods for the equipment. The key point is both parts have to be the same type conditioning. A repeater station with a flat receiver driving a flat transmitter will result in a flat audio path going through that type of repeater. On the other hand, a repeater station with a properly de-emphasized receiver driving a properly emphasized transmitter will also result in a flat path through that type of repeater. For this discussion we using standard voice channel of 300Hz ~ 3KHz. A flat repeater means the path will be transparent and not alter the audio frequency response. While some conventional station curves may have a sufficient for a single path voice transmission, most are not precise enough to be called “flat”; hence, the misunderstanding. The other key point to remember is that the term “flat” should refer to path/circuit performance and not the method to obtain this.

One exception:

If a repeater is truly flat for subscriber Tx to Rx path (reception) there is one exception for processing within the repeater station for “drop and insert” applications. In the case of flat equipment being used, there is a special situation where pre and de-emphasis is used in addition, to properly interface with non-radio equipment, such as a controller, voice synthesizer or the PTSN (Public Switched Telephone Network), AKA a phone patch. These sources are flat in origination therefore, need emphasizing to properly interface with subscriber (user) radios for a compatible audio frequency response curve.

Deviation limiting or clipping:

Each time you limit deviation for each link in series will add more distortion. An alternative is passively repeating the audio 1:1. If you do have to limit, only do so at one point, such as the system's controller, user signals or system output transmitter (user receive). Another option would be to set the system limit at 6 KHz and let the system user's transmitters limit at 5 KHz deviation, to avoid (double) audio distortion. Passive mode requires system management and user responsibility with your adjacent “channel” neighbors. This may require some enforcement on the owner's part. There are ways to "punish" or filter over deviated (and modulated) users however, is beyond the scope of this document.

Squelch operation:

For squelch modifications, some theory is needed to be discussed. FM receivers have large IF gain. At the discriminator there is plenty of noise available during signal absence. This noise can be filtered above the standard voice channel near 8-10 KHz, amplified, rectified and DC amplified to usable DC levels. The higher audio frequency range is chosen so normal traffic (voice) won't affect the squelch operation. This is known as a noise operated squelch, used in the LMR-FM analog world. A signal into the receiver that is stronger than the noise will "quite" the discriminator audio output, which changes the DC levels in the squelch circuit and turns on the audio amplifier to drive the local speaker for listening. A squelch circuit can also be used to key an associated transmitter; thus, making a repeater.

Sub-audible tone:

Some FM systems use CTCSS (Continuous Tone Coded Squelch System). A carrier operated squelch can work together with a tone to make either an "AND" or "OR" squelch. Companies produce repeater controllers and use this acronym in many cases. Other types of signaling (digital, etc.) can also be used to control a circuit or System. Therefore, the general term used for SRG equipment is "SDI", for Signaling Decode Indication (or input). Other terms include "PL" "TPL" "CG" for various brands of equipment.

"AND" squelch means it takes both a valid carrier and valid tone decode to activate the squelch. "OR" squelch means a valid tone decode will keep the squelch open regardless of the carrier squelch setting; thus, bypassing the squelch setting. An OR squelch is not desirable for amateur use because of the (annoying) long burst of noise that occurs after the input signal stops. AND squelch is best for amateur to avoid this burst. "OR" squelch, "reverse burst" (squelch tail eliminator) and other theory of operation is discussed in another document on the SRG web site in greater detail.

Stock radio receivers have (carrier) squelch constants (time for squelch to close and mute the audio path) designed for both fixed (base station) and mobile (moving station) signals therefore, are a fairly long (200 msec.) time for squelch closure. This is noticed by a burst of noise at the end of a received transmission. For a single site this is tolerable however, for multiple links (hops) this can quickly add up to something annoying to listen to. It also slows down switching paths, causing user collisions. For links, this problem can be corrected by lowering the R/C constants in the squelch circuits; thus, shortening the squelch burst. However, if they are too low the circuits will be unstable therefore, require some careful selection, which is discussed in other documents concerning link receivers, on the SRG web site.

Links are not intended to receive mobile (moving) signals. Therefore, this squelch modification will be transparent to fixed (links) station use, which should be full quieting, strong signals. Only multiple "clicks" would be heard with this modification. The remote user (input) receivers will still have stock squelch components therefore, will provide for moving (mobile) signal changes, plus, "cover up" the multiple link clicks. The result will sound like a simple, small, single site System.

For flat audio processing there's a "cor/af board" design (by the Author) to work with most FM receivers. This board is "fixed" with soldered wires (or screws, such as the RF-IF board in the receiver). A "card" is removed simply by pulling it out, such as with the Spectra-Tac shelf. If the cor board is mounted on a card then the entire piece becomes a "card" thus, "cor card" (or module as the OEM manual calls them).

Other definitions, acronyms and other "shortcuts" are for practical reading and document space. For example, names may be truncated only after the **full name** is established. This avoids reader misunderstandings. For example, the parts list shows several manufacturers in truncated form, such as, Mouser Electronics (a major parts supplier) and may be later referred to as "Mouser" or "ME", etc.

Spokane Repeater Group:

The Author is the founder of SRG, which is a non-profit organization for the development of equipment, operation and enhancement for the benefit of other amateur radio operators doing Public Service (emergency traffic) and other hobby type discussions. http://www.srgclub.org

The project:

The Motorola Mitrek UHF radio makes a nice repeater. The radio modifications make a rack mounted full duplex (4-wire) link radio too. If using the Canadian version (previously from C.W. Wolf Comm.), which comes with the higher clearance top cover, so you can use this area for addition control boards, such as the COR/AF or (future designed) 4wire link board, designed by the Author. Either board has its own documentation, as a separate project however, the former will be mentioned several times in this documentation, known as "cor board". Final design called for the normal "flat" cover, however.

The receiver is like the Micor, in frequency response, making it rather flat audio at the discriminator area for "amateur" use. SRG specifications call for something better. The top end response can be extended to meet this requirement. The Mitrek "plus" version adds more IF filtering; thus, more selectivity. The Mitrek doesn't have the Micor silent squelch. If you wish to get a shorter squelch burst for a link and cor drop out time, similar to the Micor, you will need to change some of the squelch time constant capacitors.

There are three cor points, and depending on what cor point you use will determine how many caps, you will need to change out. Some of the OEM wiring points are changed per the Author's specifications. When studying the OEM drawings keep this in mind.

The radio will duplex without any desense to itself and if necessary, will work with only a band-reject duplexer. With the optional preamp this may still be true in most cases if careful construction is used. Most link applications use the T34 while stand-alone repeaters use the T44 or T54JJA while running the PA down 3 dB from spec, say, around +42 dbm. (That's about 18w @ 50 ohms, for math challenged people). Reduced power will save the output transistors from IR heat and help prevent failure. However, some of the heat will still transfer to the outside heat sink. Therefore, it also helps to run a fan across the sink. It's best to control the fan with a mounted heat-sensing switch on the heat sink area. Use a 12-volt fan for safety sake. You should have the top, bottom, and PA covers normally installed, except for testing and aligning. The transmitter uses channel elements which have a direct F.M. input (DPL input) already, so you don't have to modify the radio for F.M.

Some of the stock circuitry is discussed, then options and modifications/solutions are discussed as well. This gives the builder the ability to make informed decisions on the project. All these subjects, plus more, are discussed later in detail to provide you with the information to make the radio into a repeater or link. If you want a flat audio repeater or link this is a good one to use.

Mechanical modifications

The radio is to be mounted horizontally, on a 2 RU (3 1/2") 19" rack panel with several #10 screws into the radio's right side. It's offset to provide panel space for the local controls. This position was chosen to provide easy access to the top and bottom of the radio while on the rack or (temporarily) pulled for maintenance. The front panel will need to be drilled out with several holes.

The old mobile mounting plate and accessory group are discarded. The inner bottom (dust) cover and top cover are still used. The radio’s old front now becomes the unit's "left" side and the radio's old left side becomes the unit's "rear". The antenna connectors are now on the unit's "left" side to allow close (rear) clearance in small cabinets. There's an interface board inside the radio (for audio and PTT functions) which is removed. More on that later. Additionally, (external) I/O functions run through the stock control cable connector (P1) at the front of the radio, then to TB1, a terminal strip, on the panel which provides spade lug type connections. The screws will accept a #2 phillips or straight blade screw driver. It's designed to hold a # 8 spade lugs, although, a #6 will work if that's all you have on hand. To mount TB1 you will need to drill and tap 2 holes. Suggestion tap size is 8-32. You should also put some glue on the backside of TB1. Most of the maintenance components such as local speaker, "S" meter and local mic are on the panel. The local volume and squelch controls are either on the panel or inside the radio. The latter arrangement discourages "sticky fingers" (unauthorized persons) at the site playing around with the equipment that's not locked. This makes up a nice compact, self-contained unit. All you add is DC power and some R.F. connections.

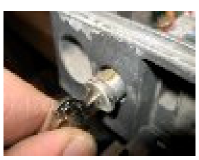
The SRG version ("A") has a handy feature of a panel mounted AGC meter (Non technical amateurs would call it an "S meter"). After plotting an AGC curve on the finished product, the RSL (Received Signal

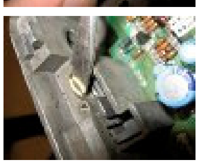
Level) can be determined from the far end station. It's also useful for tuning the front end, checking path, antenna alignment, RFI searching or even tuning the Rx side of a band pass cavity. This meter takes the place of a test set, using the "M-1" function, plus can be calibrated in a more meaningful scale, logarithmically speaking, and provide a 0-to-full scale reading. Because of the panle size the meter needs to be small, and more importantly, have a small hole required for mounting to keep the structural integrity of the panel itself.

Several radios were modified (at one time) for a more efficient "production" type operation, since there were several plans for the radios, to serve different proposes. Therefore, some of the pictures will show many of the same parts being worked on. Remember, that some of the pictures may not pertain to certain options. Several versions have been built, such as a 2-channel scanning repeater a stand-alone repeater and transceiver operation for packet stations/nodes. This next section is for duplex mode, or repeater operation. For simplex-transceiver mode, you can skip ahead to that section.

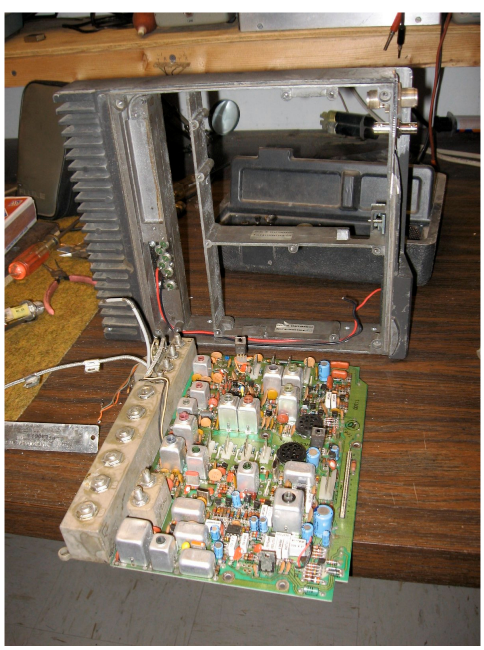
<u>The RF I/O connections</u>

This section discusses the coaxial RF connections for the radio for duplex operation. If you are configuring this radio for simplex operation some of this section won't apply. If you need an overall view go forward to the section of "Configurations" for clarification. Then return to this section for relevant information. For the radio to properly duplex you need separate Tx and Rx RF ports (connectors) for the coax runs to the duplexer (or two antennas). Both connections go out the "side" of the newly arranged unit. The first major modification is the mechanical/chassis. For DUPLEX radio option, you need to remove the T-R relay, 2135 core/tumbler and handle parts. These and the mobile mounting plate are discarded.





The next challenge is to provide for a proper mounting area for both RF connections (Tx & Rx). Since the chassis is aluminum, it's practical to use a reciprocating saw to cut away certain portions, to allow proper surfaces to be fabricated for proper mounting of

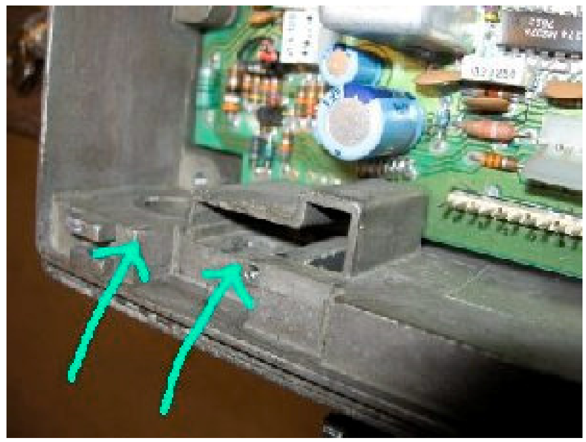


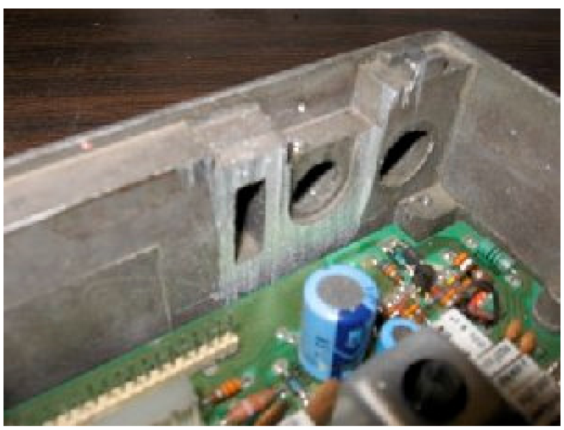
connectors. You can perform the cutting with or without the radio electronics mounted to the chassis. It's recommended the latter to prevent metal contamination. First, unscrew all the main board screws, unsolder the wires at the feed through caps in the rear, and lift out the main board and RF front-end chassis. There may be some miscellaneous straps to unsolder as well. By clamping the radio (using the rear PA heat sink area) in a vice you can perform this critical task.

If you choose to leave the board in, and take very special care, you can run the blade between the chassis and board. You need to cover the main board with something such as 1" foam to protect it from the aluminum "dust". Cut the one side, over to the far edge, then stop. The pictures show which way the cut was made, by observing the surfaces where the metal was. Any slight debris can be blown away with an air nozzle. In early (prototype) versions the cutting was done this way. The next picture points out the areas of this task, cutting it and afterwards, with the board in place.

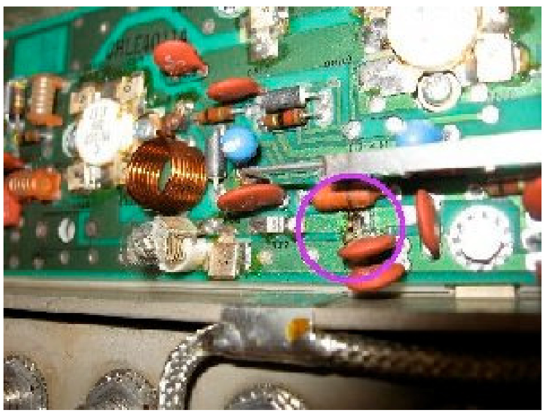
Another difficult area is cutting the front of the (aluminum) chassis straight, to eliminate the sloping front, which is a bad angle for the receiver port to mount, with the nut on the outside of the chassis. There is a supplement document on this task, in greater detail available on SRG’s web site.

After you get the proper and flat mounting "front" for the RF connectors, select your type of connectors for the transmitter and receiver ports. By using different connector types it's improbable to connect the coax cables backwards, thus preventing radio damage.



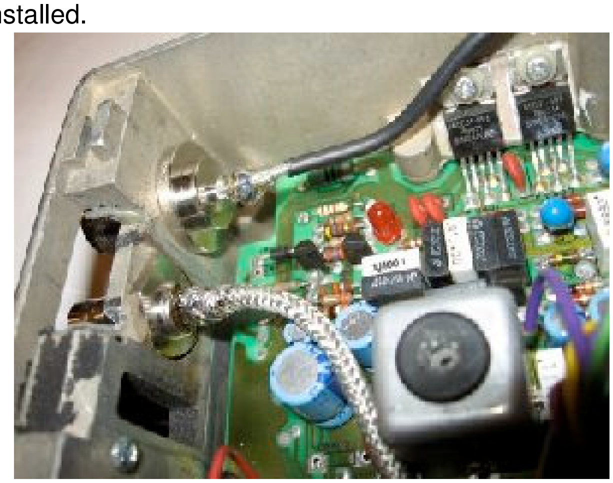


Some pictures of the power amp (PA) section. On the right is the exciter tuning coils, L9 through L12. This is a problamatic area of tuning the radio. Refer to the OEM manual for clarification if needed.



Here’s some detail on the output area and where you need to unsolder the wiring going the filter mounted on the bottom of the chassis.

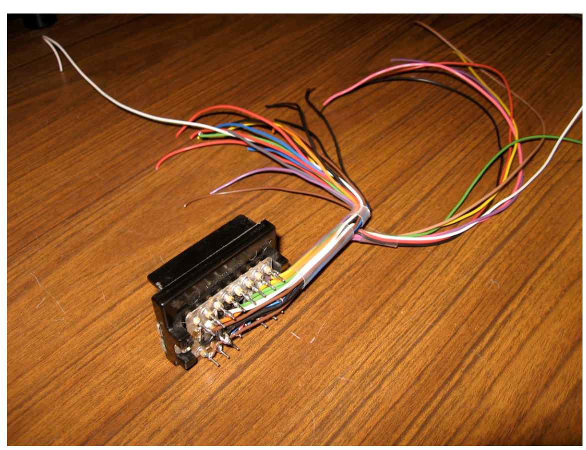
This is with the completed antenna connectors (ports) installed.



Transmit and receive ports:

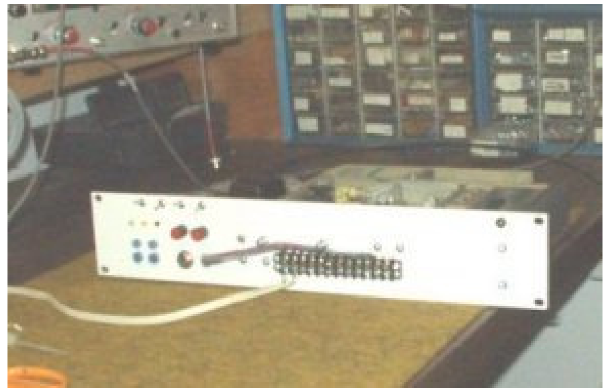
For the transmit port a type N connector was selected. For the receive a BNC type was selected (chassis mount). The selected type will need its mount modified to seat into the inside surface of the chassis. File down the edges and round the bottom half of the connector, then mount and tighten with the supplied washer and nut. More information on this subject can be found on SRG's web site, which covers sources, part number and lot of details on installation.

The interconnect board can be intermittent at times, mainly from the pins not making contact. To increase reliability it was discarded, but the P1 (control cable connector) was re-used, because of the nice feed-thru caps for RFI filtering. Connections from the main board to P1 were made with new wires, color-coded per a spreadsheet on SRG's web site. Because of this discarded board, there will be some other components to replace, which are discussed, later, under "Radio Mods". First, P1 needs to be removed. It's real tough to get out, so by removing the big diode across the PA leads, then sucking out most of the solder for all 19 pins. A torch could be used, by "hitting" all the pins at once and working the connector out, unharmed. One can't say the same for the board, but it's to be discarded.



The last parts to be saved are the speaker output caps. If in doubt of their age you may consider installing new capacitors. The first radio built for version A used radial caps, however, axial was ordered for future radios. Both have advantages. With all the stock lined up the Author's ready to assemble the first parts of the newly modified radio..........

Here's what the empty eyelets on the main board (P10) look like.



There are other people's version of prepping the radio which leaves the interconnect board in service. If you choose to do this you will need to "exercise" the contacts periodically. For expensive trips to remote sites you make take that into consideration if making this choice.

Here's with most of the panel controls installed. Version B is shown in this picture.

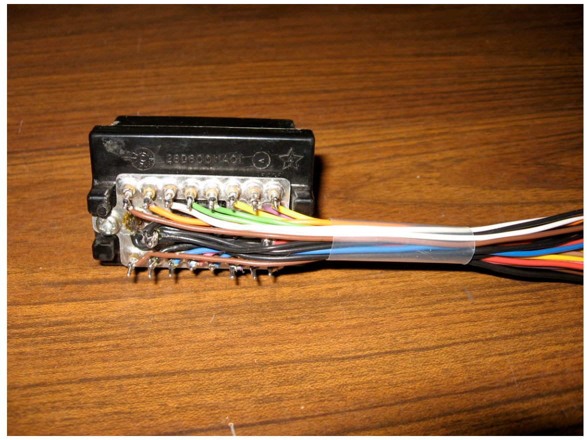
Wiring

For either mode (repeater or link) you will need to install some "lost" parts from the interconnect board being removed. C1, C2 and R4, are for the speaker output circuit. (R4 goes across the caps). The best place the author found to mount them is to glue on the inside chassis, just behind the escutcheon. Also, C3 is for DC blocking of the detected audio for the volume and squelch pots. The negative lead goes towards the pots. The final version has C3 soldered to the squelch pot tab, feeding both pots. (for note: the later cor board version has its own DC blocking cap.)

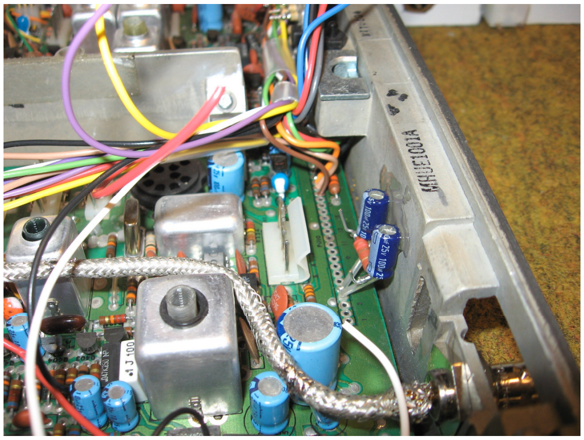
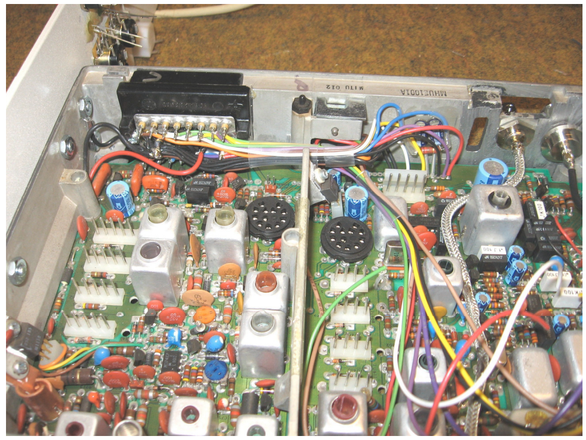
The P1 wiring harness is made up separately then installed in the radio for further hook-up. The pictures show the P1 and some of the wiring installed. A good way to do this is hold the P1 in a "jig" such as a little vice and solder all the colored wires on at one time. You will have plenty of them going to the right, towards the middle of the radio. Installing some clear heat shrink around the bundle keeps it manageable, while still being able to trace wires, should the need arise.

P1 Power leads

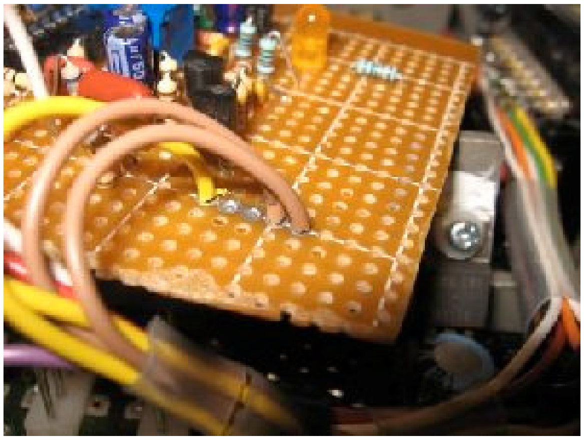
For clarification, the red and black wires, power and grounds, pins 19 and 17,respectively, are discussed here; For the red leads, will be a total of four; three going to the main board's P10 and one for the cor board. (not to be confused with the large red lead for the PA, on pin 18, discussed later). For the black leads, will be total of seven; three going to the main board's P10 and one for the cor board. One short jumper to the P1 ground ring and one jumper to the chassis (with a soldered ring) plus one more for the PA's "A-". (not to be confused with an additional black wire for the mike "low" which goes to P1, pin 2). Even though these runs are fairly short with little potential differences the Author decided to follow OEM wiring as much as practical. Take all of this into account when applying the heat shrink to the bundle.



The left shows where the new speaker coupling caps can be installed, in this case, radial leads were used. Right shows the overall view of the new wiring.

The prototype cor board was built with the tan color type with no silk screening. A silver felt pen marked the holes for easy location for the wiring. The right picture identifies the PTT red LED location.

A local speaker is real handy and having it part of the one-piece unit is even more convenient. Some (new) surplus front mount Radius type speaker housing were found at (now defunct) Hosfelt electronics. With drilling a couple of 1/8” holes and mounting it with 4-40 screws and standoff, make a pretty nice local speaker.

Production of the local speaker assemblies.........

After the speaker assemblies were installed it was decided a good way for part connections would be to mount the tie points and other parts, such as the load resistor inside the speaker housing. The load resistor is a 4.7 ohm, 2 or 3 watt value. The left, showing wiring and the right the complete and mounted speaker housing for good wire management. Overall view of the nearly complete wiring inside the prototype radio. The panel wiring is yet to be done.

Radio Modifications

Modifications made inside the radio are documented on a copy of the transmitter and receiver schematic diagram, usually penciled in. This is a good time to discuss some of the functions of transceiver switching. In order for the receiver to be protected during transmit, the receiver is disabled, or, "turned-off" during transmit. This can be accomplished a couple ways. For the Mitrek, both the receiver crystal (entire channel element) and the speaker amplifier are turned off during transmit. Most of the other receiver circuits are left on during transmit. The transmitter is "turned-on" by turning on Q701 in the early stages, (along with pin 2 of the transmit channel element) plus a few other power control circuits. The transmitter P.A. is "hot" all the time. Since the P.A. is a class-C device there's no power out during receive. It's important for the receiver to "recover" (turn back on) as quickly as possible. This is usually controlled with values of capacitors on these "control lines". No modifications are recommended at this point; these functions are mentioned in the event your version B has a receiver "recover" problem, such as sometimes noticed with high speed (9600 bps) packet operation.

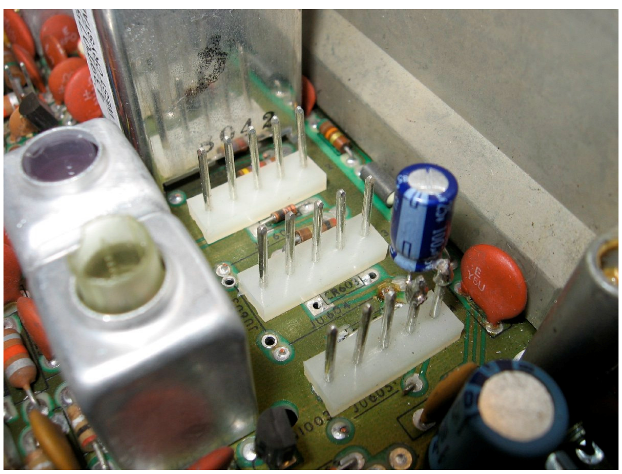
Transmit section

Flat audio

The Tx AF TLP was based on the channel element's "IDC" set at maximum (which no longer functions as a deviation limiter). As previously discussed the Tx audio input TLP can be either set up for that or 0 dbm as well. Otherwise, if you choose to leave the Tx TLP a little higher (ie. +5 dbm) thus, producing some headroom for minor level adjustment (using the IDC pot) this will allow for little differences in crystal characteristics.

The stock PL buss connects all the CE's pin-4 to modulate the transmitter. Therefore, the channel element positions will be isolated, since they will be used for various new functions. The procedure for isolation is covered further into this document, under the "Configurations" and "Transceive, Duplex Repeater, Duplex Link, and scanning Link" sections. This section covers the transmit audio input which uses the F4 line.

The transmit audio needs to be flat in frequency response, by using the PL input. Only the F4 position is used for this, via P10-21. To do this remove CR604 and install a jumper in its place. Solder a 100uf/25v coupling capacitor across pins 4 and 5 of the F4 Tx position, with the positive lead on pin 4. This is to block the DC on the line from the outside, while maintaining the good low-end response. Since the associated diode CR604 was permanently removed, this new cap will be called "C604".




Not shown in these pictures is the addition .1 uf caps on pins 1 to 3 of both the Tx and Rx CEs as discussed on the next page.

If you are building out version "B" for packet this section will apply. For version "B" C604 should be in the 4.7 uf area or less, because of data waveform's eye pattern gets distorted with high coupling. There is a separate document for packet on SRG's web site.

Otherwise, the following applies to either version:

You can lower the Tx AF input TLP to about 0 dbm for the UHF radio. Some older TNCs, such as the MFJ-1270C, do not have enough drive level, plus, they get loaded down too easily, (higher impedance). To accomplish this, change R513 from 200 ohm to 10K ohm in the UHF radio. It's located between Tx CE2 and CE3 positions. To avoid confusion the VHF version stock is a 560 ohm. In the UHF stock version it's a 200 ohm. Next, change R515 from 360 ohm to 6.8K ohm. It's located near Q503 and Q504. Another twist, in the VHF radio, it's a "L515" choke. Remove it and install a resistor in its place. We will now call it "R515". (In the UHF radio it's already called R515 , so just change the value as mentioned above). The next paragraph talks about the TLP for the UHF radio.

This does not increase the sensitivity of the modulator, in fact, does the opposite, however, this is not the point. The point is, by changing some resistors on the output section raises the impedance, thus, reducing loading to the external device (TNC, link source, etc.) therefore, effectively lowering the Tx AF TLP. The channel element's deviation pot adjustment could be left at maximum. With a 0 dbm input tone should give you about 6.5 KHz deviation. A better way is to set the Tx AF input for a standard, such a TLP of 0 dbm. This will give you enough headroom for crystal variances to run it at 5 KHz deviation.

FM NOTE: (for packet)

For the VHF radio has one-third less multiplication, resulting in one-third the deviation at the operating frequency. The modulator needs three times the amount of deviation to make the operating frequency deviation of 5 KHz. Therefore, the TLP will be 3 times higher; or about 9.5 db higher. Take this into consideration when using the cor board or other controller-line driver for your repeater or link.

This will also lower the sensitivity for the local mic audio, however, has low impact, since the local mic is used only for testing. The only exception to this would be in the case of using the mic input for TNC input. If this is the case, make the "R515" (the old L515) a 1K ohm, plus, change out C503, C504 from .047uf to .22uf. Also, change R501 from 560 ohms to 4.7K. These three parts changes will allow (weak) TNCs to modulate the transmitter, sufficiently for packet operation, say, around 3 KHz deviation, bringing the Mic TLP in the -30 range. This will also raise the TLP back up for the flat Tx AF in, but this is only normally used for 9600 bps operation. Since most VHF packet is 1200 and pre-emphasized, using the mic input has priority design over the flat AF input path. The latter is normally only used for higher speed operation, such as 9600 baud on UHF. Obviously, if you need to use 1200 bps/pre-emphasized on UHF and need the extra sensitivity, then set it up the transmitter modulation changes like the VHF radio, as just described.

The point is, prioritize which audio input you need to use and modify it, if you need more level sensitivity. Yes, you could add an IC amplifier for better control of the TLPs, however, the Author chooses to keep it "simple" by working with the OEM circuits and modifying them as needed.

Another note: From a packet radio site , (TAPR.ORG) recommends: for some RFI protection on the 9.5v line; install a .1 uf disc capacitor on Tx #4 channel element pins 1 and 3. If you are building out version "A" these changes are not required however, recommended.

<u>Netting circuit:</u>

As you probably found out, many manufacturers (OEM) of two-way radios sometime do strange things to make a circuit work. Motorola is no exception. The Mitrek power control and receiver netting circuits are strange and poor in design. We'll first cover the latter circuit, which was built in the early 1978 radios, but left out in the latter, 1981 radios. Two service manuals numbers reflect this:

- # 68P81037E75-A of the 1978 period used the transmitter netting circuit. This consisted of P905, E5, and CR903 .
- # 68P81045E75-A of the 1981 period, omitted this circuit.

The idea was to short pins of P4 to turn on a mulivibrator circuit to give "M4" of the receiver to net its channel element on frequency. Then, you could short P905 which would put "9.5" to the "Tx SW 9.5 line via CR903. P905 also does the same thing as the P4 function. With the two circuits on you could net the transmit frequency to the receiver's. This, of course, only worked if they were on the same frequency. For duplex/repeater pairs this method is almost useless.

The transmitter netting function can be disabled by removing CR903, so no voltage gets to the Tx sw 9.5 line during receive mode with the PA power off. One more point on this; the VHF version does not seem to use this CR903; at least, the version of radios and manuals available to the Author at time of the research. If this is the case, the VHF radios don't have the problem; only the UHF early versions which SRG uses in the system. This modification won't be an impact alignment because the receiver frequency alignment can be accomplished by sweeping the front end with a signal generator (preferred method).

Power Control circuit:

The power control circuitry probably is the most troublesome area of the radio and very hard to improve with modifications. To understand some of its functions we will discuss what the Author has discovered.

U901's input on pin 2 goes lower to increase the power out. Input going lower causes the output on pin 6 to increase and further conduct Q903, which increases conduction of Q904 to increase the control voltage to tripler, Q704 and the PA control voltage input as well. The stock radio should have the nominal 12v (A+) because of the power control circuitry. For repeater operation it should be set 1-2 db down from that.

Suggestive A+ for the PA (only) is 13.0 volts minimum. As with most semiconductors (being that name) the part that's not conducting in the form of resistance gives off heat when current is drawn. This is the classic case of a transmitter running at rated input voltage and output power. In noting the transmitter efficiency that's rather low, the typical figures are: at 13.1 v DC supply it should draw 6 amps. That's 78.6 watts of power on the DC side. For the AC side, AKA RF, +44 dbm converts to 25.119 watts, at 50 ohms. That works out to 31.958% or just about 32%, efficiency.

Anything lower than 12v to the PA section may cause unstable operation in some older radios. For example, one SRG site with the KPS-20 supply shares the 10v for this and another radio, which pulls it down to around 11v; the radio won't work at that voltage. Of course, the other solution is two supplies, one for the 2-meter transmitter and other for this radio, running at the recommend voltage of 12v nominal at the expense of heat losses.

You can lower R913 or shunt the E9 line to ground. Either will cause U901 pin 6 to increase. However, full control won't be realized. If you do this then accidentally run the radio at the (OEM) 12v you cannot turn down the power and that will damage the PA if used in repeater (high duty cycle) service.

A simpler way is to disable half of the circuit, by removing CR902. This disables half of the circuit including the temperature and level sensing, the "orange" pot (R909), but not the blue one, still giving you manual adjustment of the power level you wish to run with a DC supply of 10~14v on the PA power (big wire). This addresses the issues:

- You should be able to lower the PA voltage to 10 (to reduce heat loss).
- You still have smooth control to set the power you choose to run (+40 ~ +42 dbm at Tx port).
- Easier Tx tuning is now realized.
- The PA section runs cooler (Author's design still calls for a FCU).
- The leakage issue is solved (explained below).

Another thought: If the technician does not read this document, but finds the orange pot is inactive will be a clue that something is different with the radio and should seek information.

Another couple weird ones: The OEM diagram calls for R910 to be a 22K however, some of the radios have a 39K. This was corrected to 22K. Also, there's a 91K resistor tacked on the board's bottom and is not documented on the diagram. It connects Tx 9.5 to the top of R911 pot, causing higher voltage range into pin 2 of U901 presumably, for better power control range. This was left as is. Also, the drawing shows R913 as a 9.1K however, most radios have a 10K (which is close enough).

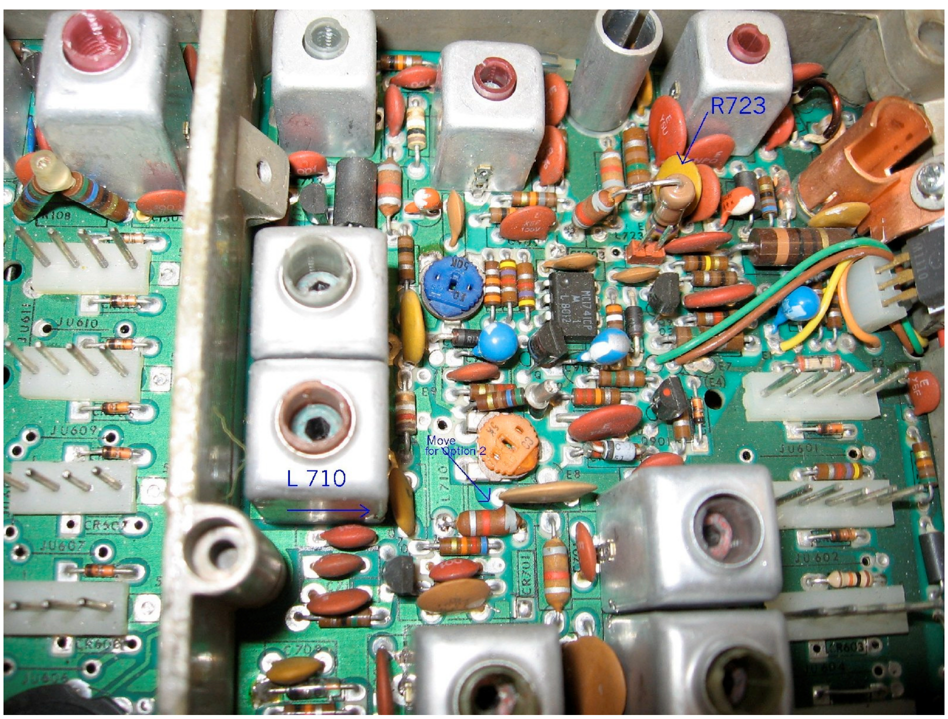
Leakage issue:

As it's understood, part of the power control circuit, U901, was designed to "see" 12v power (voltage) at the PA, during receive and transmit modes. The normal path for the "big red lead" ("A+" 12v+) for the P.A. is from pin 19 (OEM) of J1, then to a red lead in the radio (next to the chassis) that goes through C884 in the PA section. However, this circuit has a secondary path. At the J1 connector, pin 19 (OEM) also runs through the interconnect board. "A+" is applied to pin 17 (OEM), of P10 on the main board. This runs to the power control circuitry, through L901, JU905 and the surrounding components of Q902. With the "A+" applied, Q902 barely has enough bias to keep it turned off.

In the event the big read lead fuse is blown the transmitter may be active (very low power level). This happens from Q902 leaking some voltage, going through (believed to be) CR902, and CR903, which turns on the netting circuit (as previously described). While this condition may not damage the front end of the receiver, the condition will be that the receiver will be "hearing" a local signal all the time. This is obvious in simplex operation and was observed on the bench with one of the radios. This condition could exist until discovered at the remote site. Of course, if the radio was set up for repeater (duplex) or cross frequency mode this problem would not be so easy to find. Even though the interconnect board is to be removed (for this project) and certain runs and connections are bypassed or otherwise modified this condition still can exist.

The (new) separate PA power switch on the front panel is handy for testing; "transmitting" locally without output power. However, it will cause the same condition as just described. For duplex operation this is not a problem. With the (new) green LED PA is a nice addition. However, with the switch off it will "glow" a little for the same reason (CR908, R802, R801 or R804 feeds about ½ voltage to it) This could be distraction/misleading to the radio's condition if you don't know this. One cure is to add a 1K resistor across that green LED to dissipate the leakage, thus, keeping it off when the switch is off.

With some radios Q703 runs a little to hot. To correct this, install a 2-watt resistor in series of the junction of L724 and L723. This now will be called "R723". This lowers the output so be careful on the value of R723. Experiment between 18 and 47 ohms; to a point it runs cooler but still provides good output. Note it's on the "cold" (DC) side of the RF filter, L723. Also, R706 may need to be installed, if not already (normally for the low range radios) in. Now, retune the transmitter especially, the affected circuits, which includes L705, L706 and exciter filter L9~L12. If you can; check for a clean signal on a spectrum analyzer. Then `set the power out for repeater operation.

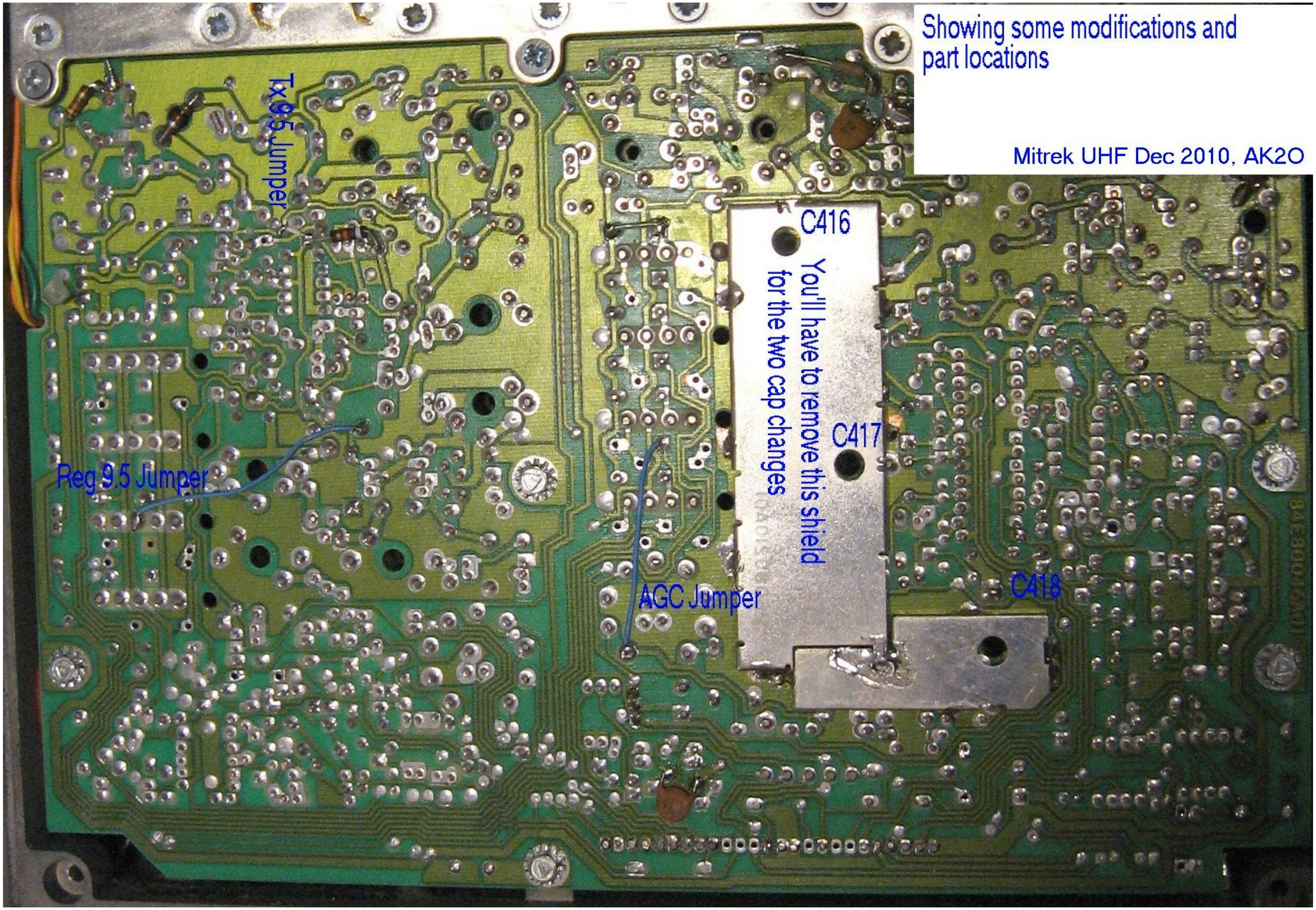


In this image you can also see just below R732, where CR903 has been removed (that was the leaky PA circuit described earlier).

There should be a (modified) schematic drawing about this modification elsewhere in this manual.

Showing some modifications and part locations

Mitrek UHF Dec 2010, AK2O



Channel elements:

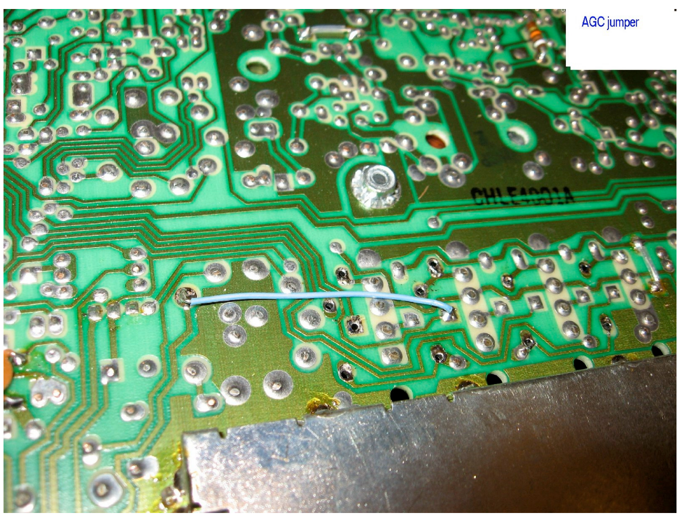
The radio needs to stay on one frequency and is controlled by “channel elements”. The radio uses one each for the transmitter and receiver. Each element is metal encased with several components. This discussion is about the quartz crystal in each. The output of the channel elements (Tx or Rx) is three times the crystal frequency. Therefore:

The transmitter formula is Fc x 36 = Fo; meaning, 3 x 2 x 2 x 3 =36 (CE, 2 doublers and 1 tripler).
The receiver formula is Fc x 9 + 10.7 MHz = Fo   (1 tripler on the low side injection).
Whereas, “Fc” means crystal frequency. “Fo” means operating frequency.

It the past SRG would send in the old channel element for the vender to replace the crystal and also compensate the element against temperature changes causing frequency drift. ICM and West crystal were the main venders however, closed around 2016. Most of the other crystal companies no long compensate elements either. There may be a procedure developed by SRG in the future (as time permits) to perform you own compensation. So far, only a few venders still make the basic crystal.

Being a mobile, frequency stability should be good enough for most repeater projects. You may note that a new crystal will drift around during the first part of the aging process. Receiver elements run all the time; the transmitter does not during standby. Therefore, it will take much longer for the Tx frequency to settle down. An option is to run the Tx element all the time as well. This will require modifying the 9.5v lines for the early stages of the transmitter section. There is a separate document to address this.

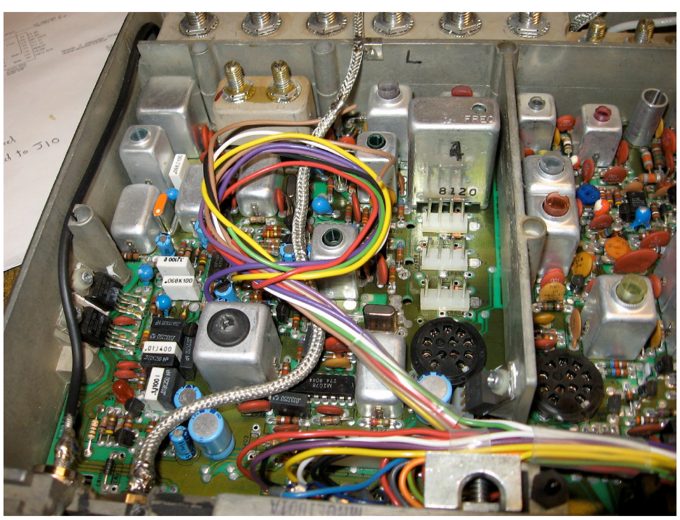
In the event you don't have any elements (or crystal) to check or tune the radio there's an alternative using a signal generator as a local oscillator described in separate document as well.



Receiver section

The OEM Rx audio output TLP is spec at about a +2.5 dbm. This is at the "detected audio output" from pin 9 of P10. For amateur standards this point is fairly flat. Further improvement for frequency response can be provide by using the (separate) cor board designed by the Author. If you wanted to standardize Tx and Rx levels, such as 0/0, you could install a simple pad on this output, before it gets to the external equipment. A good place to perform this might be on the inside of the I/O connector, J1 pins.

"AGC" meter



The F3 CE position is used for the M1/AGC meter function. The M1 function is picked up from the junction of R222 and C233, then processed externally with the cor board's built-in limiter DC amplifier, then goes back out through J1 to dive an external (panel mounted) meter to indicate the receiver's limiter. To accomplish this jumper J1001, pin 1 to a run going to P10, pin 20. There's a handy eyelet for this modification. Details on this circuit can be found on the cor board documentation found on SRG’s web site. Even though some other board versions will work with this radio, 6.xx is the intended one to use. In the lower picture the wires are tucked away for later, for when the COR audio board is to be installed.

COR points

As previously discussed, when a signal enters a FM receiver, it quiets the receiver, which activates the noise operated squelch. This squelch has several circuits to handle this condition, which also provide several voltage points that changes DC level. There is a choice of using one of the three cor points, "L", "E" OR "H", all which are controlled by the panel squelch pot, of the point at which the local speaker and repeater squelch gate opens. (In the Micor repeater the squelch gate has it's own noise amp and switch for independent opening point). One of these points can drive a high impedance DC buffer/amplifier. The cor board has a DC comparator to perform this function. In order for this buffer to sense carrier activity, a reference voltage (bias) need to be adjusted on a one-time basis, depending on which squelch point is used. COR points of L, E and H; each have their own characteristics. Earlier mentioned was the cor board and the versions, depending on what configuration you are doing. Refer to the cor board documentation about polarity of the cor input buffer. It's found on SRG's web site.

- "L" is a negative going active point (less positive). Being a DC "analog" point, it sits about 1.8 volts positive with the squelch closed, but near the threshold. As a signal quiets the receiver, this point goes less positive, to .04 volts with a full quieting signal. (Never goes negative). This point is DC analog, therefore, you have a "quieting" choice where the cor will change logic state on the control board. This might be handy to set the cor and local speaker activity points differently. This arrangement is similar to the "repeater squelch gate" used in the Micor station repeater. If using this point, set cor board bias at un-squelch, at desired level of quieting, but less than the cor standby voltage, but more than the active low voltage. It's at the junction of R410 and R411 and the base of Q405.

- "**E**" is a negative going active point (less positive). Being an almost completely logical point, it sits about 2**.**8 volts squelched and 0**.**16 un squelched. It's at the squelch switch and used for the stock consolette interface board's carrier indicator. The advantage is time and "stock" proven for reliability. If using this point, set the bias for a + **.**924 volts. Point "E" is at the junction of R430 and C418 and at collector of Q406.

- "H" is a "low" in standby (squelch closed) and goes positive on squelch open. Being a logical point, it sits about zero squelched and 6 volts unsquelched. Point "E" drives the input of U401, which is acting as a DC comparator to switch on the audio. Point "H" is pin 4 of U401, which is one side of the balanced audio output to drive the local speaker. The advantage is this active high point will drive any cor/circuits you might already have in mind, and is simple to set up. The disadvantage being audio is riding with the cor voltage, so if you crank up the local volume too high, the cor/PTT function will drop out erratically. If using this point set the bias around 4 volts (lower than the cor active voltage).

For a (single) conventional repeater skip this section and leave the squelch constant caps "stock". For links, as previously mentioned, the squelch time constant can be shortened (5-10 times as less) to get away from (linked) additive long bursts. Depending on which cor point is used, will determine how many caps are needed to change to a lower value. You have the option of performing all the cap changes to allow cor pick off changes in the future. All the SRG link radios are intended for long haul links therefore, most or all the changes are performed. The images showing the cap areas will help you locate them. Most of the new capacitors are yellow or blue, being a tantalum type.

For the short squelch constant change the following capacitors:

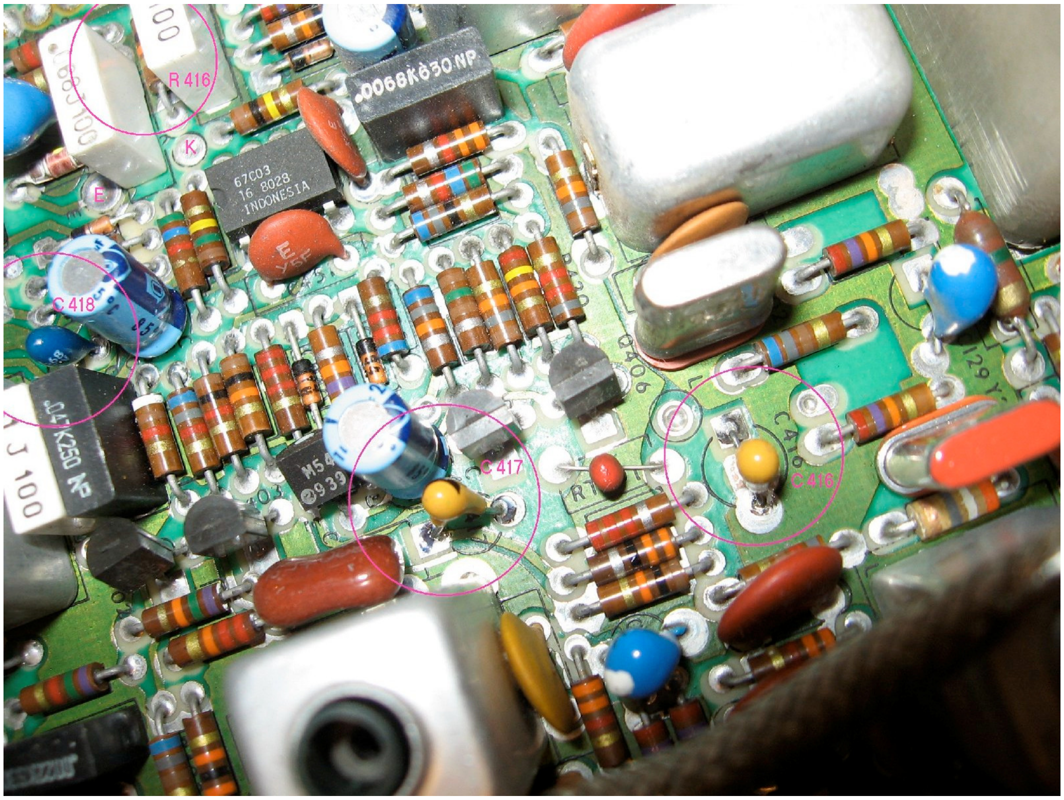
- For cor "L" method change C416 from 15uf to 1uf and change C417 from 4**.**7uf to 2**.**2uf only if there is no potential of interference or other unstable conditions.

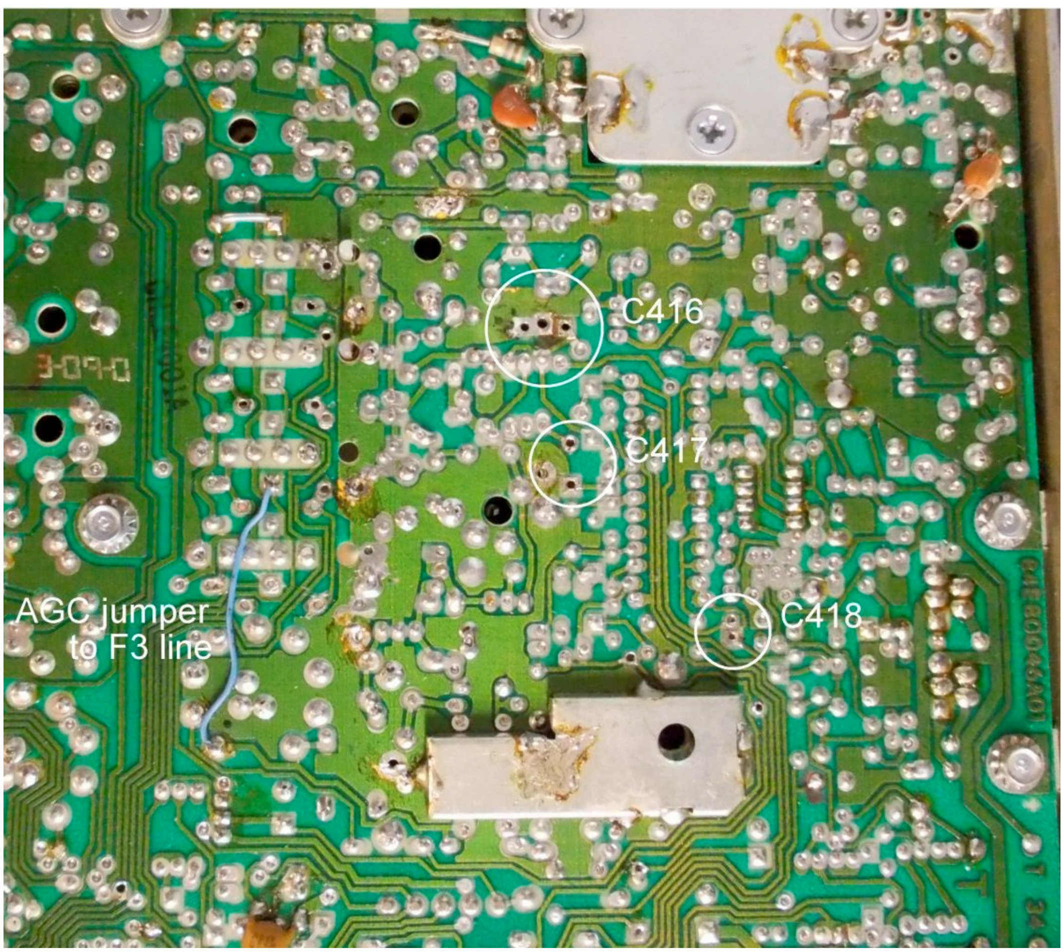
- For cor **"E"** method, perform the first changes, plus, change C418 from 10uf to **.**68 uf. (**.**47~**.**1uf will work with proper testing/checking)

- For cor "H" method, perform the first two changes, plus, change C427 from 15uf to 4**.**7 uf.

The "**E**" point is used for all SRG projects.

The following images show where these caps are locate on the main board. Also, note the location of R416; another modification to lower the receiver's audio output section.






Q 101
Inside
L 8
L 7
L 104
L 204
U 403
R 416
C427
L 206
L 208
C 432

As previously mentioned, the cor board version 6.x is used for this radio, for interface to outside equipment. It mounts, upside down (components down) in place of the stock PL deck, with a slight twist. It does not mount on the interconnect board because that was removed as part of the modifications. Also, the stock screws for the front connector, P1, and the PL deck may be hard to find especially if your radio is a carrier squelch model. The OEM manual showed them to be M3.5 x 0.6 mm (pitch) x 6 mm screws. Most local hardware stores will not carry them. .At first, # 6-40 (not a typo) machine screw with Pozi drive head was found. Even though that may work, the Author preferred to keep them stock. After considerable research on the web, an equivalent screw was found a few years ago for about $5 for a box of 100 on Mc Master Carr's site. The PL radios had threads in the mounting holes however, the carrier squelch ones may not therefore, a tap was located to thread the holes.

<u>Other issues</u>

As you are aware this radio was originally designed as a mobile. That's means a transceiver , running half duplex, AKA, transmit or receive, but not both at the same time. Most of the modifications discussed in this document converts the radio nicely into a repeater and/or link radio able to run in full duplex mode. One minor issue concerning the B+ line should be noted. The receiver's audio output amplifiers, U401 and 402 are capable of driving an external speaker very loudly with several watts of audio power. When the volume control is cranked up this audio will "ride" on the B+ line. If there are other radios or devices sharing the input power will be affected by this audio on the DC line. This is mostly observed as a "noise" on the other devices, while the radio's squelch is left open. Another symptom is "crosstalk" where is the receive audio from the radio is heard on another radio (channels) that share the same DC power source. This can cause additional time troubleshooting if it's a problem on your system. One easy cure is leaving the receiver's volume down low, or off. This is a good (courtesy) practice, anyway, for a station at a site with other tenants there. One small modification is to change the value of R416 from the 10K to 47K for the audio preamplifier, U403B. This will reduce the TLP at point "K" 11 1/2 dB. The image above (cor points) show the caps, but also this resistor change location. The range of the volume control is too high to begin with so this won't be an operational factor.

Another (minor) issue was found in 2014. With the newly routed Rx coax it was observed (with serial 16) a slight increase of receiver noise happen sometimes when the transmitter was keyed. Upon further investigation it was found not to be the PA or the latter stages but the early stages or the CE it self. This was proven by leaving the PA power switch off, keying the radio and pulling the Tx CE out. While this does not appear to affect the radio's performance, an increase of noise (at the discriminator) will "change" the squelch setting. For example, if you have the squelch right at the threshold (not recommend for normal service) there will be a popping sound because of the shortened constant (capacitor changes). When the transmitter is keyed the popping will stop, indicating more noise going to the squelch circuits. As you may recall (from earlier reading) this is a noise squelch system whereas, opens with less noise (quieting) to the squelch circuits. It was also observed placement of the Rx coax has affect on this condition. As you might have guessed, the RF from the Tx CE (and a stage or two, depending on which "StabOption" you use) is getting into the receiver for a small degree. Last note; this condition does not appear to cause Tx-Rx desense. Take this into consideration if performing the Tx stability option in a separate document found on the SRG web site.

There was a minor inconsistency in the OEM manual. It's about the dropping resistors for the volume and squelch. The documentation, here, by the Author, is correct for this application and will work fine. More information on this subject can be found on SRG's web site.

Using the OEM manual's schematic, remember to align the receiver properly once you obtain the proper (compensated) re-crystaled channel element for the operating frequency you plan to use. A tip for adjusting the receiver; assuming the IF is properly tuned; you can "sweep" the receiver to get the channel element on frequency. Inject an on-frequency RF modulated signal with a 1 KHz tone, of 7 KHz of deviation. This will be at the clipping point of the IF. Increase the RF level to the point of no clipping. Typically this will be around a -103 dbm. The "sound" of the tone will mostly clear up from the "raspy" sound at this point. Then "rock" the warping device in the channel element back and forth for the clearest tone. Once set, you can re-check the frequency by rocking (no pun intended) the signal generator's frequency back and forth as well.

Radio Versions

A:
Made for SRG; The mic connector is a 4-pin, two coupling capacitors to route the local speaker lines to the outside local speaker, and an AGC meter is mounted on the front panel. It's anticipated future versions for SRG will only be built and will be version "A". As side-note earlier versions before 2000 such as the Spokane link (repeater) have different arrangements, such as a separate control head. This version uses the cor board versions 5.x or 6.x This version is a duplex radio and is obsolete.

B:
Made for I.E.VHF R.A.; A.K.A. the VHF club; The mic connector is an 8-pin, 2 pin jacks and 2 banana jacks are mounted on the front panel for the local speaker monitor for testing. The meter is left out; the pins mount where the meter would be on version A. Also, for packet the T-R relay is left in and operational, because this version is built for packet simplex operation. There were five radios build (serial 1~5) for the VHF Club in this version around 2004 for a very specific use of 2 packet radios for two different sites, plus a fifth one for central control for them and a BBS. This type of quality design and attention was a bit overdone for the club for their needs. Therefore, it's anticipated these will be the last of this version, although the readers are welcome to produce more. To be clear, it’s is a simplex radio.

Configurations

In addition, the old frequency select lines for F3 and F4 will be modified to for new functions of M1 and transmit audio, respectively. However, they will need to be isolated from the channel element matrix. To do this several jumpers will need to be removed, as discussed below. There are about four configurations for this unit depending on the intended purpose. Even though SRG's main configuration is "Link" the other ones may be useful for the reader therefore, are discussed.

The versions can be configured different ways. Being that a morse code IDer may be the main component of a repeater that is not addressed with this project, you may want to take that into consideration when choosing the configuration. Otherwise, in some cases, most basic functions can be used, such as timers and controls. Referring to the interconnect diagram has many I/O functions on TB-1. A few of them are dual purpose, depending on which configuration you wish for the unit. Consideration was made not to interfere with the cor board's functions either, nor a TB-1 function conflicting with another configuration.

Transceive, Duplex Repeater, Duplex Link, or Scanning Link:

For Transceive (SIMPLEX) or half-duplex link configuration you will need all the (stock) receiver mute/channel element functions enabled by leaving in CR1, CR2 and CR403 on the main board in. Since the interconnect board will be removed (loosing CR2, etc), you will need to run a jumper from P10-7 and P10-14, so the receiver audio amplifier will mute during transmit. (It was mentioned here so you understand what will be affected by leaving out the board). The OEM circuit used a diode, however, because of the simplicity of the modifications, a jumper will be fine. You will be leaving the T-R relay alone as stock. In the receiver section remove JU606, JU607, JU608, JU609, JU610, CR607 and CR608. In the transmitter section remove JU601, JU602, JU603, JU604, JU605, CR603 and CR604.

For the cor board, SDI or CON 2 won't be a function in this case. Terminal 17 could be used for a rudimentary CON 1; if so leave JU611 in for single frequency operation. Or terminal 17 could be used for control of F1; if so leave JU611 out for the same reason. Transceiver is used for packet operation. To note: As previously mentioned, TAPR.ORG recommends: for some RFI protection on the 9.5v line; install a .1 uf disc cap. on #4 channel element pins 1 and 3 for both the Tx & Rx side.

For Repeater configuration you will need all receiver circuits operating all the time for duplex operation therefore, the receiver mute functions need to be disabled. Since the interconnect board will be left out that covers the removal of CR2 on that board, as well. (not to be confused with the second "CR2" described, below). For this configuration do not jumper P10-7 to 14. There's also a receiver channel element off/mute function plus a secondary function of "M4" test. The "M4" circuit is explained on the receiver schematic. It's a poor solution to Rx frequency netting. Also, the mute function goes the way of

Q3 and Q1 of the "M4" circuit. Neither will be used and can be disable by leaving out CR1 and CR2 on the main board.

One last mute circuit needs to be disable by leaving out CR403 on the main board. Also, in the PTT circuit, optionally, change R1012 to 1K and install a red LED in the holes where the relay wires were. This is handy as a transmit indicator. In the receiver section remove JU606, JU607, JU608, JU609, JU610, CR607 and CR608. In the transmitter section remove JU601, JU602, JU603, JU604, JU605, CR603 and CR604.

Use the cor board for this configuration for internal control and timing. Also, if you are also using the stock PL deck, you may be using the mode function on terminal 13. You also may be using CON 1 and CON 2 on terminals 17 and 18, respectively. If so, leave JU611 in, for single frequency operation. JU611 is located around channel element #1 in the receiver section.

For (duplex) link configuration you will need all receiver circuits operating all the time for duplex operation therefore, the receiver mute functions need to be disabled. Since the interconnect board will be left out that covers the removal of CR2 on that board, as well. (not to be confused with the second "CR2" described, below). For this configuration do not jumper P10-7 to 14. There's also a receiver channel element off/mute function plus a secondary function of "M4" test. The "M4" circuit is explained on the receiver schematic. It's a poor solution to Rx frequency netting. Also, the mute function goes the way of Q3 and Q1 of the "M4" circuit. Neither will be used and can be disable by leaving out CR1 and CR2 on the main board. One last mute circuit needs to be disable by leaving out CR403 on the main board. The antenna port modifications were covered, earlier. Also, in the PTT circuit, optionally, change R1012 to 1K and install a red led in the holes where the relay wires were. This is handy as a transmit indicator. In the receiver section remove JU606, JU607, JU608, JU609, JU610, CR607 and CR608. In the transmitter section remove JU601, JU602, JU603, JU604, JU605, CR603 and CR604.

For Scanning Link configuration you will need all receiver circuits operating all the time for duplex operation therefore, the receiver mute functions need to be disabled. Since the interconnect board will be left out that covers the removal of CR2 on that board, as well. (not to be confused with the second "CR2" described, below). For this configuration do not jumper P10-7 to 14. There's also a receiver channel element off/mute function plus a secondary function of "M4" test. The "M4" circuit is explained on the receiver schematic. It's a poor solution to Rx frequency netting. Also, the mute function goes the way of Q3 and Q1 of the "M4" circuit. Neither will be used and can be disable by leaving out CR1 and CR2 on the main board. One last mute circuit needs to be disable by leaving out CR403 on the main board. Also, in the PTT circuit, optionally, change R1012 to 1K and install a red led in the holes where the relay wires were. This is handy as a transmit indicator. In the receiver section remove JU606, JU607, JU608, JU609, JU610, CR607 and CR608. In the transmitter section remove JU601, JU602, JU603, JU604, JU605, CR603 and CR604.

For the cor board, in this case you won't be using CON 1, CON 2 on terminals 17, and 18 respectively. Most likely a link will be carrier squelch. If not, you could use an external controller and/or decoder. In this case terminal 13 might be a SDI for tone squelch. You need to leave JU611 out. An external "scanner" will control the F1, F2 lines. Ideally this controller could be built to do all three; scanning, control/timing and tone decoder in the case of co-channel RFI). The unit would now be a "control station" for two distance "Hub" repeaters in opposite directions. This configuration will have two control pairs, adjacent channel, especially when using a single duplexer. This is an advantage where a site owner charges per radio.

<u>More on Terminal 13 and tone control</u>

Most of the TB1's connections go to P1, then various point in the radio and cor board. Most of the positions are fixed, dedicated to the radio's functions and I/O. However, a few positions can be changed on a permanent basis. For TB1, previously mention was "robbing" terminals 17 and 18 for other functions, such as CON1 and CON2 respectively, by leaving JU611 in for single frequency operation. Also, terminal 13 is a triple assignment however, only one at a time; which are either SDI, HUB or CON2 (decoder input, hang up box or control-2, respectively). This discussion involves using the cor board version 6.3 of course. Other versions don't work the same as 6.5. You need to remember this, especially if “upgrading” from an older version of radio conversion/modification documentation found on SRG’s web site.

If you choose to use an earlier version the following rules apply:

By default 13 is the SDI. That means using an external or internal tone decoder, it's signal-decode output connects to 13; active going high (relaxed). This can go to either the cor board's SDI or CON2. In the case of using an internal decoder, such as the TS-32, use the "Out-2". If you wish both audio and PTT 1 (out) to be an "AND" squelch, connect it to the CON1. However, in this mode will include any "tail" before the PTT2 is disabled. Or, if you wish to control both Tx and Rx operation by disabling both channel elements leave JU611 out and use the F1 select for this. This would be a rudimentary control even in the case of a scanning repeater. Optionally, you can leave JU611 in for single frequency (pair) operation.

In either case CON2 on terminal 18 is not available for a scanning repeater. Another point to remember is if you want use the F1 line for control, once active, will disable the entire radio because it would disable any audio path for controlling it back to enable. To address all these features you could use an external controller and/or decoder with an independent audio path. For example, a multi-port controller is typically used for a 4 wire, 2~4 way matrix/link station. Such a controller either hand-made or bought can address most of these features for the configurations.

Using an external control for mode change was previously discussed. There is another way, using cor board version 6**.**5. On the board is a "JU4" berg type jumper to change modes locally (at the site). For more information on this jumper seek that version of cor board found on SRG's web site There may be a "catch" to this jumper and is discussed in detail in that document. Obviously, if you feel qualified, you can deviate from the Author's design and wire up a solution for your particular needs.

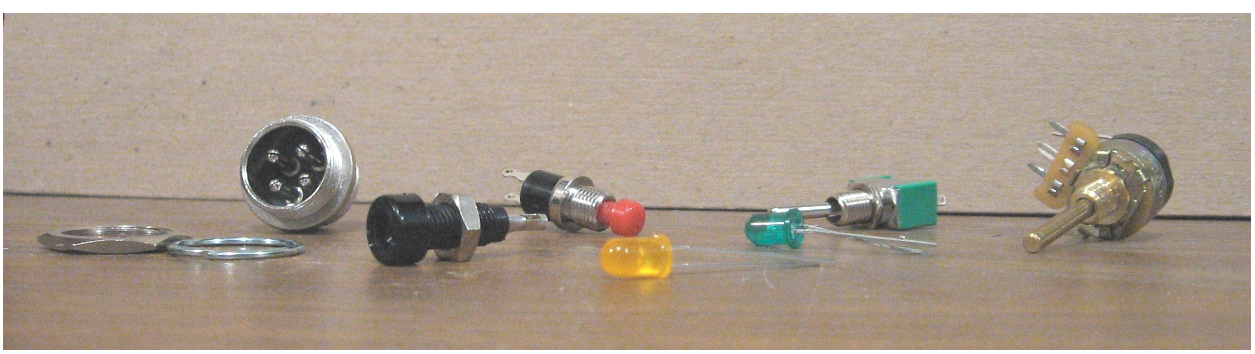
In the event the cor board version is not (yet) available, you could use version 5**.**x by modifying on section of the op-amp for the AGC meter driver. Another option is an external AGC circuit. In this event you would run the M1 lead (via the F3 line) outside the radio to an external device to drive a meter.

Additional information

Tip: When you suck out the solder in the holes they make a handy eyelet location tool. (you can find the open hole on either side of the board for referencing other eyelet locations).

Many of the wire and circuits may appear to be redundant and not needed. Wiring color and functions were selected for most any configuration you may need. Either install them or leave them out. The former is preferable to avoid "tearing" into the harness, management shrink and glue holding the wire. Another possible option is to use the extra wires for another function. This is another reason for the redundant (black) wires for additional grounds were installed in the original design specs by the Author.

As of 2024 I had a need to isolate the PTT line with another radio at the same site. Therefore, install an diode in line of the panels PTT encode switch (center post) and it's green wire (going to TB1 pin 8).



Mitrek modification parts list:

Version specific radios (A or B) may be indicated by colored fields on the web site; they are not visible on this document, however. Optional parts that are grayed (lowlighted) on the schematic diagram are not listed here.

Unless otherwise specified, resistor values are in ohms 1/4 w, 10%, chokes in milli-Henries, caps in Micro-Farads. Color of wires: Black, brown, red, orange, yellow, green, blue, violet, slate, white and pink. Tan was discontinued due to lack of vender-sources
Past list:

QYT	Description:	Values/notes:	Part number:	Approx cost:
1	panel, 19" rack	# 2 RU	PBPA193000B	12.00
1	Meter, panel analog	~200uA,1.6 x 1.6 x1"	MFJ 400-0026A	7.92 + ship
7	Screw, machine 10-32	1/2" for radio	TBD	0.04
2	Screw, machine 4-40	1" ?	TBD	0.04
2	Screw, machine 4-40	3/4"	TBD	0.04
2	Screw, machine 4-40	1/2"	TBD	0.04
2	Screw, machine 8-32	1/2" For TB1	TBD	0.04
9	Nut,hex 10-32	.	TBD	.10
1	Nut,machine,hex	.	TBD	.02
1	Lug, ring #8	For ground	TBD	.02
6	Lug, spade	For I/O connections	TBD	.02
2	Standoff, 4-40 Fem	1"	Speaker mount	.30
1	Terminal strip	20 position,.TB-1	TBD	3.00
1	Jack, pin type	.	TBD	.02
2	Jack banana type	Blue	TBD	.02
1	Jack, mic Pin-4	.	TBD	2.00
1	LED, T1 3/4	Green, diffused	TBD	.10
2	LED, T1 3/4	Red, diffused	TBD	.10
1	LED, T1 3/4	Yellow, diffused	TBD	.10
1	LED, T1 3/4	Green, blinking	TBD	.10
1	LED, T1 3/4	Red, blinking	TBD	.10
4	Resistor, 1K ohm	1/4w	TBD	.02
1	Resistor, 4.7 ohm	1w	TBD	.10
1	Resistor, 220 ohm	1 w	TBD	.05
1	Resistor, 6.8K	.	TBD	.02
1	Resistor, 1/4w	10K	TBD	.02
1	Resistor, 41 ohm	2 w, R723	TBD	.25
2	Capacitor, 100uf/25v	Electric, radial leads	TBD	.30
1	Capacitor, 4.7uf/25v	Electric, radial leads	TBD	.30
2	Capacitor, .22uf/25v	Electric, radial leads	TBD	.30
1	Speaker, with housing	.	TBD	3.00
2	Pot, 25K, LT	1/8" shaft Vol & Sq	TBD	3.00
2	Knob, round	.	TBD	.30
3	Switch, DPDT,	10 amp	TBD	.30
1	Switch, SPDT	3 amp	TBD	.30
1	Switch, thermo	NO, closes 120°	TBD	4.00
1	Connector, RF	Type N female	523-82-5378-RFX	6.00
1	Connector, RF	BNC female	523-31-318-RFX	6.00
6"	Cable, coaxial	RG-415 teflon 50 ohm	TBD	6.00
1	Channel element	With Tx crystal	KXN1089B/86	35.00
1	Channel element	With Rx crystal	KXN1088A	35.00
1	Board, COR	Version 6.3	TBD	.02
24"	Wire, hookup	22 AWG	various colors	5.00
4-ish	Wire, bare	22 AWG	For jumpers	.10
¼ oz	Compound (for RF casting coating) Harger # HAAJC8 (gray in color)			
1-2	Cable tie; Tiewrapes.com # 3M07-N-100 (narrow tie; good for small wire management).			

Other notes:

When tuning the radio, this involves adjusting several metal slugs. To ease the stress on the slugs you can loosen the nuts. First remove the OEM nut sealant which is normally a yellowish-clear “glue” in each of them. When tuning is completed you can re-tighten them to a reasonable amount being careful not to over-do it. It’s best to re-check the tuning (slightly) to confirm tightening the nuts did not move or affect the tuning of the cavities in the radio’s casting.

For the AGC meter, If you use a 100uA movement and use cor board version 6.xx you need to add a 1K shunt resister across the meter. This will help you obtain a decent AGC curve.

For the transmitter filter section is L9~L11, which uses a 10 mm nut.

For the receiver RF section L1~L6 uses a 13 mm nut while the multiplier section L7~L8, uses a 10 mm.

In the drawing of BD-EEPS-27564-O an error was found in 2015; next to U401 (off of pin 4) is labeled “R442” where it should be “R422” instead. The “real” R442 is located between R414 and R429 in another part of the board.

Some screws are the standard phillips head however, for the bottom cover and other screws some are “pozi-drive”. It’s best to use that type of screwdriver for each of them.

If you are making up a power cable it’s suggested to use the red & black wires, AWG 12, stranded. The spade lugs that work are Mouser # 517-1635, made for 16-14 wire so you may have to flare it out prior to soldering. They are made for a #6 screw. Of course, other sizes and part numbers can be used.

Most conventional amateur stations that use this radio (and perhaps these modification) normally run the entire station on one 12v power supply. For the SRG stations are configured differently. For example, the exciter / receiver sections run on conventional 12v while the transmitter’s PA section is on a separate, 10v supply to keep IR losses to a reasonable level. It might be useful to know what the current draws are as shown here.

Mitrek radio study for power figures, both conventional and K-SRG arraignment

Status	DC input in volts		DC draw in amps		Remarks
	Excitor & receiver	PA	Excitor & receiver	PA	
Standby	13.80	13.80	0.33	0.00	Exciter, receiver and PA tied together
Keyed *	13.80	13.80	0.89	6.46	Exciter, receiver and PA tied together
Keyed **	13.80	11.56	0.89	7.60	PA on separate supply
NOTES:	All test are with transmit port out set to +44 (blue and orange pots)				
*	Conventional means typical amateur station with one DC supply powering everything				
**	K-SRG arraignment with separate 12v & 10 v supplies; the latter for the PA only				
	All figures are typical however, may vary for each site				
	The radio needs to be modified (orange pot control disable) for proper				
	operation (power control) at 10v nominal, typically at 11v.				

Other info:

The Author assumes no liability/responsibility in the event of equipment damage from these modifications. The Author designed this project and wrote this document in MS-Word '97. It was then converted to pdf (Portable Document Format) to make it readable to anyone with any operating system on one's computer. This also works out better over browser viewing because of the several variables in people's PCs (resolution, screen and browser type and settings, etc.)

In discussion about FM and using a "vari-cap" to do this there's a nice article on the Wiki:

https://en.wikipedia.org/wiki/Varicap

For more information visit Spokane Repeater Group's web site:

http://www.srgclub.org

Most of the developments and corrections were made in June~August of 2004, with updates in Sept. of 2005, October of 2008, April and May of 2014, Feb of 2015, Oct 2015, Aug 2016, July 2018 and Sept 2018, Feb 2019. April 2019, Oct 2019, Nov 2019, Feb 2022 and June & July of 2022, Oct of 2022, March of 2024 and April of 2024.