

# A Complete X-Band SSB Portable Communications System.

Dave Glawson - WA6CGR



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With surplus solid state microwave equipment becoming more readily available and affordable, systems like the ones described here are now within reach of the microwave experimenter.

The systems described here are based on the M/A-COM 10 GHz Data Link systems that have become available at swap meets and surplus dealers. These units are essentially X-Band transverter systems consisting of an R.F. unit, an L.O. assembly, an I.F. subsystem, a power supply, and a 27" Dish antenna with penny feed.

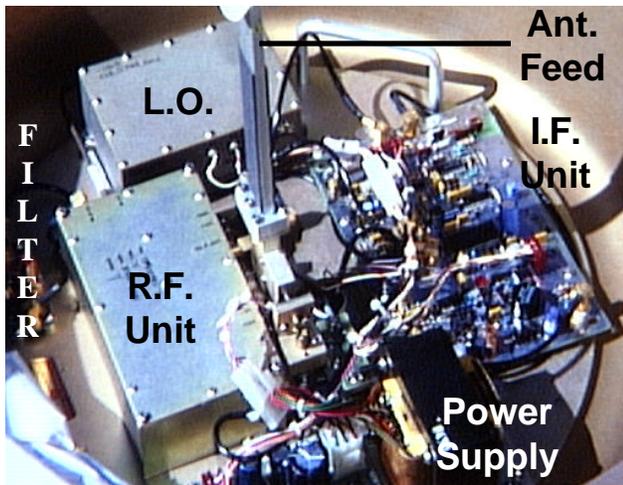


Figure 1.

Figure 1 shows the original M/A-COM system configuration with the radome and antenna reflector removed.

The necessary components for the systems described here are the R.F. unit, the L.O. assembly, and optionally, the antenna structure.

Some of the modifications to the M/A-COM units are described in a set of original documents by

Chuck Swedblom, WA6EXV<sup>1</sup>.

I will describe these modifications and present construction details of a 146 MHz to 28 MHz transverter to utilize an inexpensive 10-meter transceiver as the SSB I.F. system.

As it is necessary to understand the operation of the system, I have provided a block diagram of the existing M/A-COM units as well as a block of the completed system (see figures 43a and 43b).

The L.O. assembly consists of a free running microwave oscillator, a crystal oscillator, amplifier, a multiplier (X102), and a phase lock circuit.

The frequency of the free running x-band oscillator is controlled by a DC ramp signal from a low frequency sweep circuit. In the unlocked state, the X-Band output sweeps across a 50 MHz bandwidth centered at approximately 10.5 GHz.

This signal is then phase locked by a crystal oscillator, amplifier, and multiplier to 102 times the crystal frequency.

The M/A-COM units come with different frequency L.O. crystals, so be sure to carefully check your particular unit for proper determination of the I.F. frequency required.

The original L.O. units also employed the use of an AFC circuit which for stability reasons is removed according to the directions described later.

The output power of the L.O. assembly is approximately 50 mW (+17 dBm).

I have found two different L.O. frequencies in the

units I have converted. The first uses a 103.0794 MHz crystal and the second, a 103.05 MHz crystal. These translate to 10.5141 GHz and 10.5111 GHz respectively.

The original I.F. frequencies used by M/A-COM were 139 MHz for transmit and 70 MHz for receive, however the system is capable of using transmit and receive I.F. frequencies of up to approximately 150 MHz without modification. This lends itself conveniently to using a 2-meter signal as an I.F.

These systems are configured as a high-side injection L.O. system.

Since the common operating frequency of SSB communications at X-Band is 10.368 GHz, we can expect an I.F. frequency of 146.1 MHz when using an L.O. of 10.5141 GHz ( $10.5141 \text{ GHz} - 10.368 \text{ GHz} = 146.1 \text{ MHz}$ ) and an I.F. frequency of 143.1 MHz with an L.O. of 10.5111 GHz.

This also means that the I.F. signal is inverted frequency wise (e.g.  $146.1 \text{ MHz} = 10.368 \text{ GHz}$ ,  $146.0 \text{ MHz} = 10.3681 \text{ GHz}$ ,  $145.9 \text{ MHz} = 10.3682 \text{ GHz}$ , etc.). The sideband signal is reversed also meaning USB at X-Band = LSB at 2-meters.

These systems are capable of being run with low side injection as well (which makes everything come out right side up), but that means ordering an expensive crystal and waiting 6 weeks.

For those of you who would like to do this, I have included the ordering information at the end of this article<sup>2</sup>.

The main R.F. unit consists of a transmit and receive I.F. amplifiers, separate transmit and receive mixers, X-Band power amplifier, filters, and an R.F. sampler as outlined in the block diagram in figure 43a.

I have outlined the approximate signal levels within the block diagram to give an idea of the

signal path and function of the various stages of operation within the unit.

The conversion of the M/A-COM units for amateur use starts by determining the configuration of your particular system.

For example the easiest way to get on the air is to use a 2-meter SSB radio as an I.F. system.

All that is necessary is to modify the oscillator, retune the M/A-COM R.F. unit to 10.368 GHz, add a power supply, compensate for the high power output of your 2-meter radio, add some switching and you're off and running.

Or alternatively you can add some additional circuitry including another high-side conversion to arrive at a 28 - 29.7 MHz I.F. This will result in having the frequency tuning and sidebands in the right direction (eg:  $10.368 \text{ GHz} = 28.0 \text{ MHz}$ ,  $10.3681 \text{ GHz} = 28.1 \text{ MHz}$ , etc.)

Both methods will be described in this article.

The first thing to decide is whether or not to use the original weather proof housing and radome/antenna system. Or to make a more compact unit with the flexibility of utilizing a wide variety of antenna systems and configurations.

The built-in antenna housing is nice and very functional, but is heavy, bulky, and somewhat difficult to manage, although some folks have built some very ruggedized and elaborate systems using the original housing.

I chose to go the more flexible route for a number of reasons.

First, the performance of the system while adequate for doing some contest work, does not lend itself to the easy addition of a pre-amplifier for weak signal work and secondly, I wanted the flexibility of changing the antenna system to suit the requirements (eg: a smaller antenna for quick hill-top contacts, or a larger dish for serious contest or

distance work).

The out of the box performance isn't too bad considering the relatively low cost of the units that I have come across (in the range of \$100 - \$150), but much higher performance can be obtained with a little work and some added expenditures.

Factory tuned units will have a noise figure between 12.5 and 15 dB and a power output at 1 dB compression of 80 - 100 mW.

The expected power output of units that have been fine tuned will be in the range of 180 to 380 mW.

With the addition of a 3 stage GaAs FET pre-amplifier such as the ones designed by Al Ward - WB5LUA<sup>3</sup> (QST-May 1989) and sold in kit form by Down East Microwave<sup>4</sup>, a front panel system level noise figure of 2.3 - 2.5 dB can be realized.

The conversion process begins by removing the radome and dish reflector from the front of the unit (save the hardware if you will be utilizing the existing housing and antenna assembly).

Next remove the R.F. unit and L.O. assembly (see figure 1). The L.O. assembly is attached to the R.F. unit by a short length of .141" semi-rigid

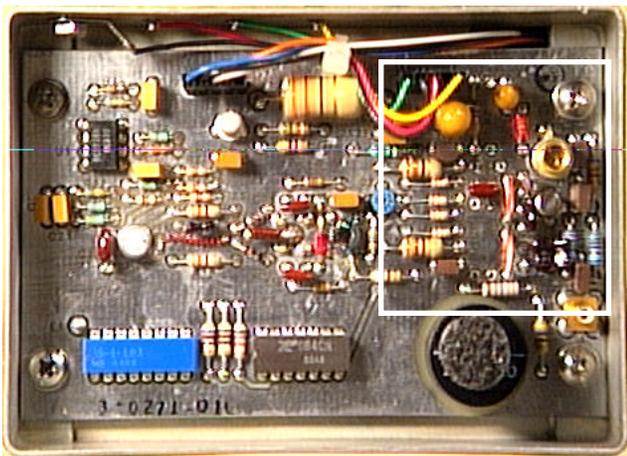


Figure 2.

*This is the oscillator and phase lock section of the L.O. assembly with the cover removed. The area highlighted is where the circuit modifications are. A close-up view of this area is shown in figure 3.*

cable with SMA connectors. These are the primary units of the project.

The I.F. Unit, Power Supply and any remaining units should be removed at this time as well.

Some essential parts in these other modules will be used within this project such as the SBL-1 mixer and the 75 coax assemblies with the special connectors. The components and assemblies that are left over can be used for spare parts or to hold down your garage floor.

In either system configuration the oscillator modification comes first.

Open the top side of the oscillator unit by removing the 14 screws and set them aside. Figure 2 shows the inside of the oscillator assembly.

Note the orientation of and then unplug the connectors J1 and J2 (they are keyed).

Next remove the four screws holding the circuit

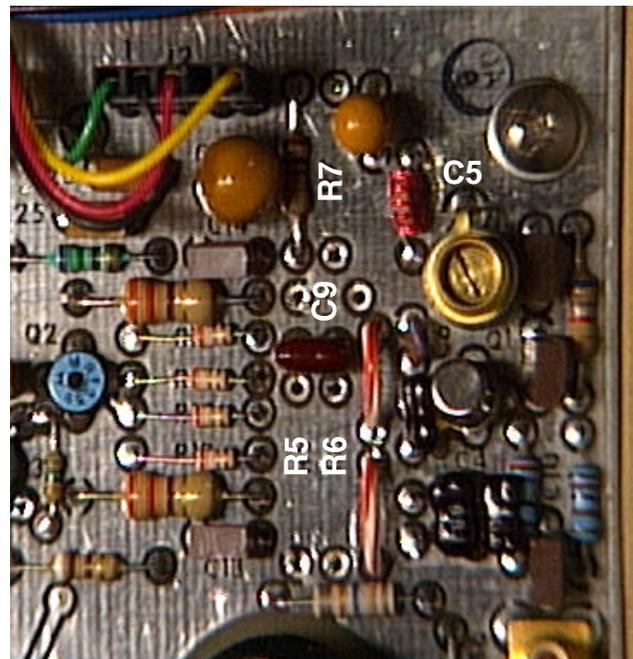


Figure 3.

*This is a close-up view of the modified L.O. assembly. Note that R5, R6, C9, and R7 have been removed and two jumpers have been installed where CR1 and L3 used to be. C5 is adjusted for proper frequency. Refer to the text and figures 4 and 5 for the schematic references.*

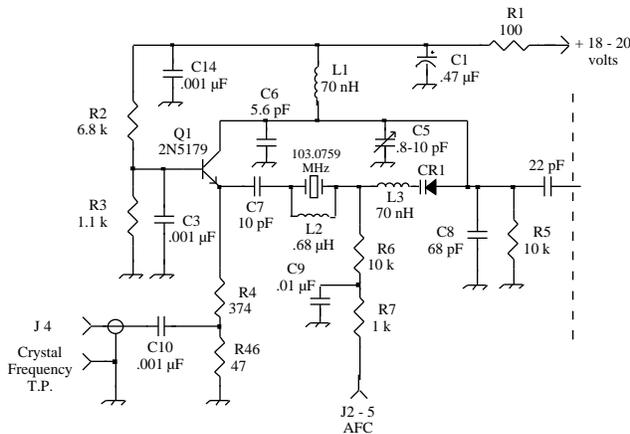


Figure 4.

This is a partial schematic of the original M/A-COM oscillator before modification. CR1 and L3 will be replaced with insulated jumper wires, while R5, R6, R7, and C9 will be removed.

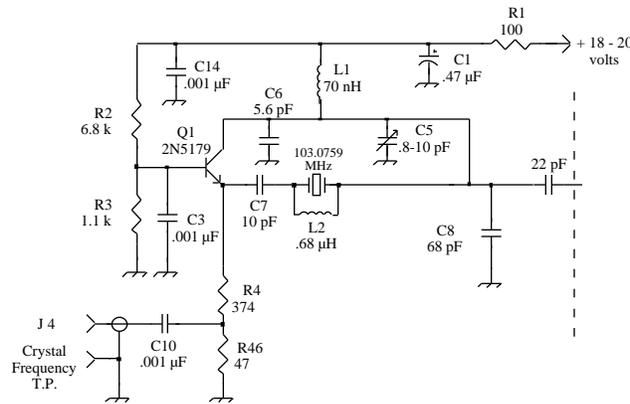


Figure 5.

This is the same partial schematic of the M/A-COM oscillator after modification.

board to the chassis and CAREFULLY lift the circuit board from the chassis. There will be some physical resistance due to the R.F. connector that attaches to the board underneath.

Unsolder and **REMOVE** R5, R6, R7, and C9. See figure 3 for the location of these components.

**REPLACE** CR1 and L3 with insulated jumper wires.

This completes the circuit modification to the oscillator section of the L.O. assembly.

Carefully re-install the oscillator circuit board in the L.O. unit to insure that the connector is properly seated in the receptacle underneath and replace the

four mounting screws. Re-connect the plugs to J1 and J2.

When aligning the oscillator, remember that the unit's output power is in the range of 50 mW or +17 dBm so use an appropriate attenuator between the oscillator and frequency counter.

It is extremely useful to connect an L.E.D. and 2.2 k resistor between the + 20 volt connection of the oscillator and the VCO ALARM output. This L.E.D. indicates a "VCO unlocked" condition. When the L.E.D. is ON, the oscillator is unlocked and is extremely unstable. When the L.E.D. is OFF, the L.O. assembly is operating normally.

Next, connect a frequency counter through a 20 dB attenuator (or whatever value of pad is necessary for your counter) to the L.O. output.

Attach a +18 to +20 volt 0.5A regulated supply to the appropriate feedthroughs on the L.O. assembly (see figure 6), and adjust C5 (see figure 3), for the frequency of operation which is 102 times the crystal frequency.

If the frequency seems extremely unstable and the VCO alarm L.E.D. is on, then carefully adjust R20 until you can get reliable L.O. operation when switching the power supply off and on (ie: the L.E.D. always goes out and the frequency is stable).

Before replacing the top cover on the oscillator assembly, you may want to drill an access hole over C5 in the cover to easily fine tune the oscillator when the project is complete. After drilling a 1/4 " hole over C5, replace the cover of the L.O. assembly.

Refer to Figure 7 for the following discussion of the R.F. unit conversion:

There are several modifications that can be made in the R.F. unit.

The most critical are the adjustments for the two transmit filters and one receive filter.

There are two ways to accomplish this, one is to align the filters in the box, which will be discussed later, and the other is to remove the filters and tune them externally using a network analyzer or equivalent test equipment.

If you are going to utilize a network analyzer or equivalent test equipment to tune the filters, you must first remove the filters and R.F. absorbing material on the filters from the R.F. assembly.

The mounting screws are located in the four cor-



Figure 6.

ners of each filter. Gently remove the R.F. absorbing material that's glued onto the filters as you will need to replace it later, then remove the mounting screws and set them aside. Then carefully unsolder the input and output pins on the filters.

Care must be taken when soldering to the p.c. board as the p.c. traces are easily burned off with too much heat!

M/A-COM has conveniently placed tapped holes (2-56 screws) for 2 or 4 hole SMA connectors on the filter inputs and outputs and at the antenna port.

For connection to your test equipment, you will need two 2-hole or 4-hole SMA connectors with pin sockets to connect to the filters (see figure 11).

Attach the two SMA connectors with pin sockets to the 2-pole transmit filter. Then connect the filter to

your test equipment. You should be able to see a filter response that is similar to that in figure 12. Find the appropriate wrench and hex tool that fit the hex nuts and tuning slugs of the filters.

Start by loosening the hex nuts on the tuning elements and beginning with the filter resonators (see figure 8) "walk" the filter down in frequency to the amateur band. Careful adjustment of the aperture screws is essential as these are very critical and somewhat touchy. After tuning, your filter should be similar to that in figure 13.

Remove the SMA connectors from the 2-pole filter, and re-install the filter and R.F. absorbing material back into the R.F. assembly.

Using the same technique, re-align the 4-pole transmit filter and the 6-pole receive filter referring to figures 8, 14, 15, 9, 16, and 17 respectively. This completes the out-of-box alignment of the filters although small adjustments will usually be required once the unit is completed.

The following alignment procedures will require the replacement of the antenna pin (see figures 10 and 11) with an SMA connector. Hold the antenna pin with a small pair of needle nose pliers and while heating the soldered side of the pin, pull the pin out of the chassis.

As mentioned earlier, be careful when heating the circuit board as the traces will easily burn off with too much heat.

Acquire a 2 or 4 hole SMA connector with an extended center pin (see figure 11). Trim the center pin of the connector so that the teflon insulation is flush with the inside wall of the chassis.

Cut the center pin beyond this point approximately 1/32". This will be the point where the center pin is soldered to the board (see figure 19).

Mount the SMA connector to the chassis with two 2-56 screws and then carefully solder the connec-

tor pin to the antenna circulator.

This connector will allow for the final alignment of the system as well as enabling the system to be used with external pre-amplifiers, coax switches, and coaxial antenna systems. The installed connector

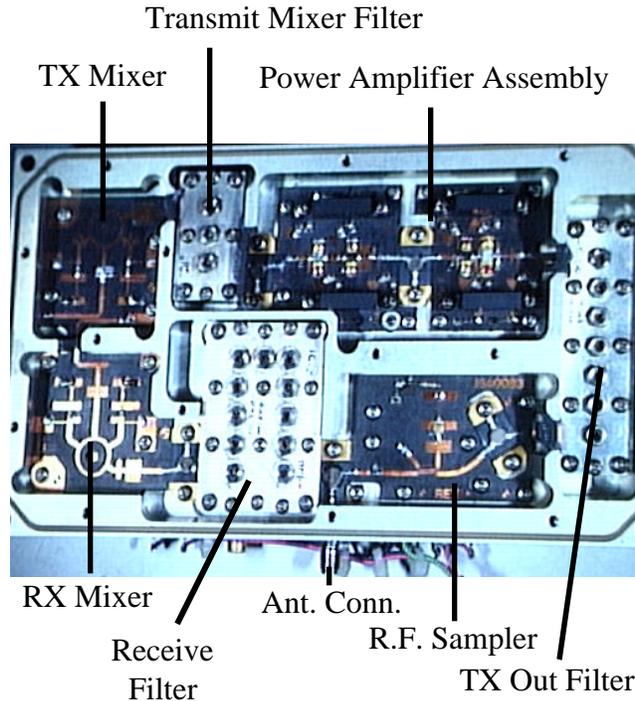


Figure 7.

*This is the bottom side of the R.F. assembly with the cover removed. The first modification to this assembly involves re-tuning the three filters shown.*

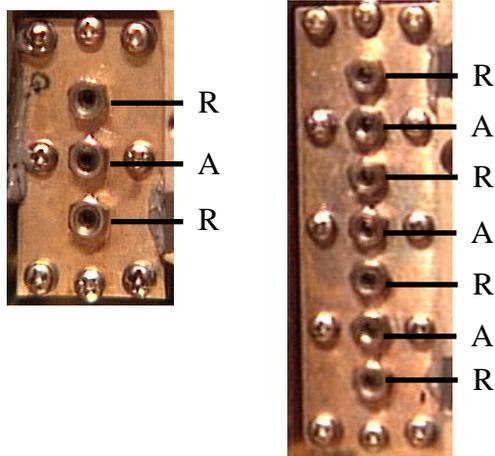


Figure 8.

*The 2-Pole (left) and 4-Pole (right) transmit filters. The screws marked with "R" are the resonators and the ones marked with "A" are the apertures. See text for alignment procedure.*

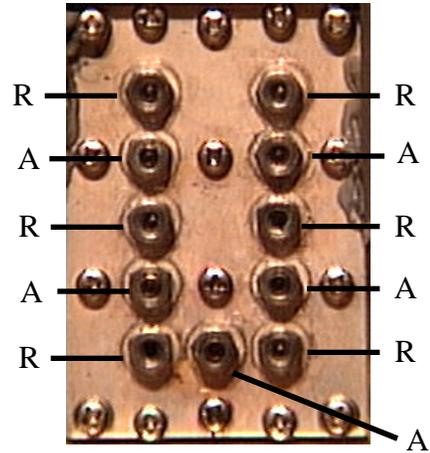


Figure 9.

*The 6-Pole receive filter. Again the screws marked with "R" are the resonators, and the screws marked with "A" are the aperture adjustments. See text for alignment procedure.*

Antenna Circulator    Antenna Connector Pin

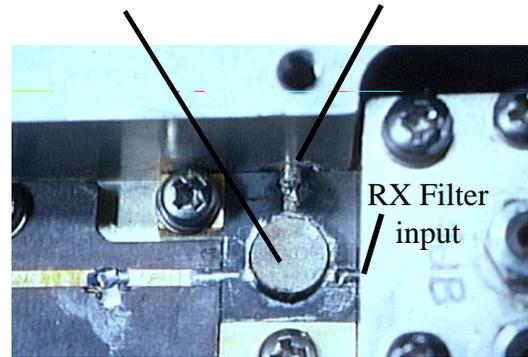


Figure 10.

*The output circulator and connection to the antenna. When soldering to the pins on the antenna connector or the filter connectors, use the lowest temperature possible to avoid burning off the plating on the circuit board.*

is shown in figure 20.

For alignment of the three filters mounted inside the unit, it is necessary to have an adequate signal source for receiver adjustment and a signal generator and power meter for the transmitter alignment.

To align the transmitter filters, connect the L.O. assembly to the R.F. assembly with the .141" semi-rigid cable that was supplied with the unit.

Attach a power meter capable of handling 0.5 watts of power at X-Band to the antenna connector. Use one of the 75 cable assemblies to connect a 146.1 MHz signal generator to the TX I.F. port. You will

need to install a standard 50 ohm connector on the signal generator end of the 75 ohm cable (such as a BNC or SMA connector).

When connecting the power supplies to the R.F. assembly, ALWAYS be certain to connect the -5 volt supply first to avoid damage to the GaAsFET power transistors. In fact it's good practice to always leave the -5 volt supply con-

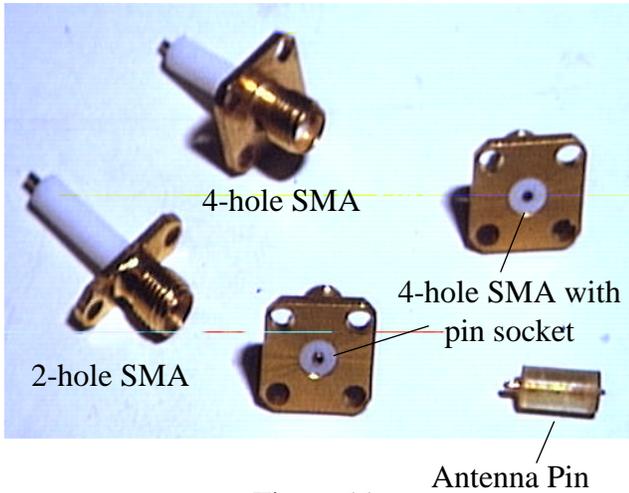


Figure 11.

You can utilize either 2 or 4 hole SMA connectors on the filter connections and the antenna port. The filters require SMA's with a pin socket. The antenna pin shown is removed and replaced by an SMA connector for alignment and for use in coaxial systems.

nected when using or adjusting the system.

Connect a +18 to +20 volt 0.5 A supply to the L.O. assembly. Now connect a -5 volt 100 mA supply to the -5 volt connector and a +12 volt 1 A supply to the +12 volt TX feedthrough on the R.F. assembly (see figure 20).

Before making any adjustments on the transmit filters, loosen the hex nuts and turn each tuning screw 1/2 turn clockwise otherwise you may be tuning the system at the image frequency.

Set the signal generator to 146.1 MHz if your L.O. frequency is 10.5141 GHz or 143.1 MHz if your L.O. is 10.5111 GHz and set the level to -20 dBm.

If everything is functional so far, you should get some R.F. output at this time. Set the range on your power meter to keep the output in the upper half of

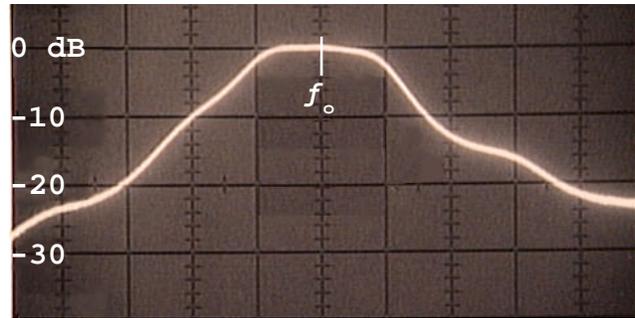


Figure 12.

Network Analyzer Photo of the M/A-COM 2 Pole Transmit Filter at the original frequency. The filter has a 3 dB Bandwidth of 100 MHz centered at 10.650 GHz and a 0.1 dB insertion loss.

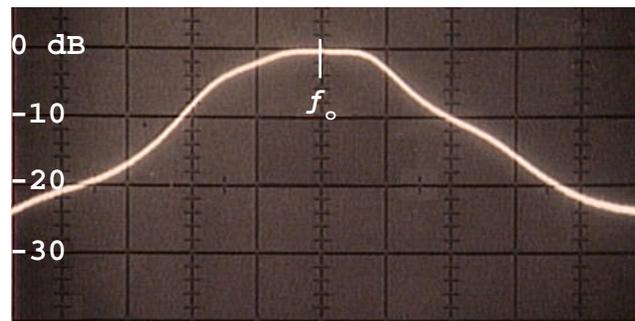


Figure 13.

Network Analyzer Photo of the M/A-COM 2 Pole Transmit Filter tuned to Amateur frequencies. At Amateur frequencies the re-tuned filter has a 3 dB Bandwidth of 80 MHz centered at 10.370 GHz with an insertion loss of 0.1 dB.

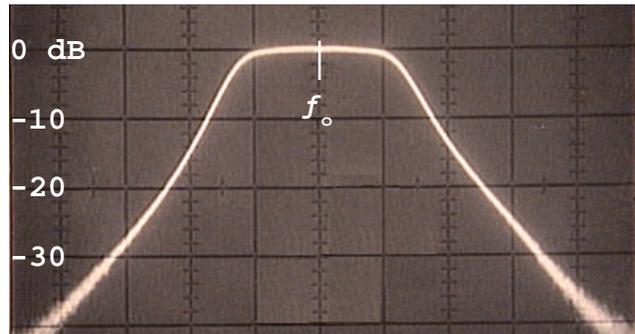


Figure 14.

Network Analyzer Photo of the M/A-COM 4 Pole Transmit Filter at the original frequency. The filter has a 3 dB Bandwidth of 60 MHz centered at 10.650 GHz and a 0.2 dB insertion loss.

your meter. Follow the tuning procedure in the previous section, adjusting the resonators first, and then the aperture screws.

Since the filters are relatively broad, you can tune them for maximum power output without sacrificing SSB performance across the normal 2 MHz

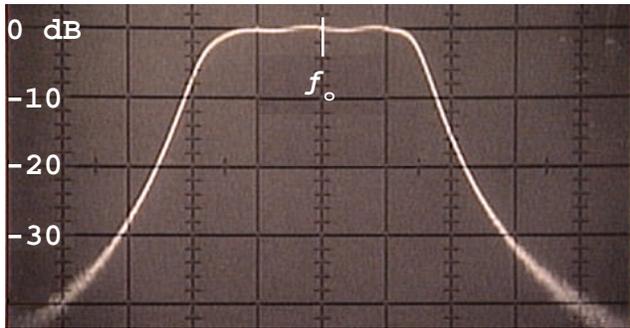


Figure 15.

Network Analyzer Photo of the M/A-COM 4 Pole Transmit Filter tuned to Amateur frequencies. At Amateur frequencies the retuned filter has a 3 dB Bandwidth of 60 MHz centered at 10.380 GHz with an insertion loss of 0.2 dB.

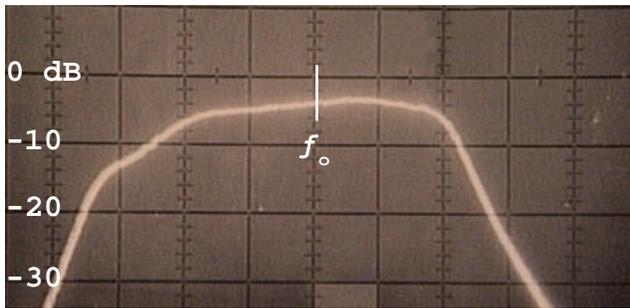


Figure 16.

Network Analyzer Photo of the M/A-COM 6 Pole Receive Filter at the original frequency. The filter has a 3 dB Bandwidth of 50 MHz centered at 10.575 GHz and a 4 dB insertion loss.

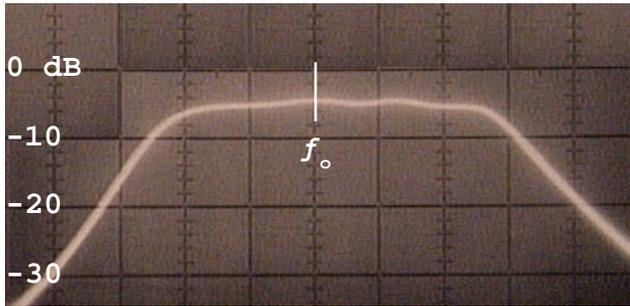


Figure 17.

Network Analyzer Photo of the M/A-COM 6 Pole Receive Filter tuned to Amateur frequencies. At Amateur frequencies the retuned filter has a 3 dB Bandwidth of 50 MHz centered at 10.375 GHz with an insertion loss of 4 dB.

wide 10.368 GHz - 10.370 GHz band.

If you are considering any wide band modes of operation such as high speed data or video, you might want to consider getting help from someone to tune the filters as previously mentioned.

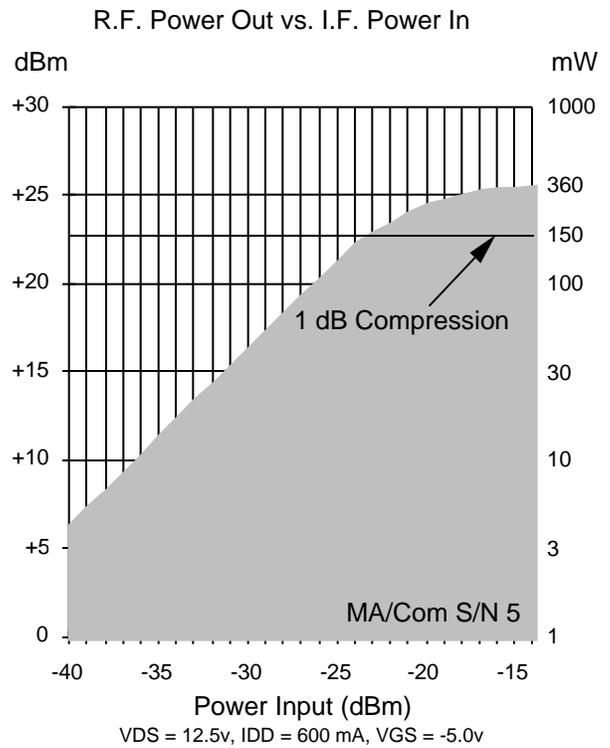


Figure 18.

This diagram shows the performance of one unit. Saturated power output is 360 mW with a 1 dB compression point of 150 mW. Power input is at 146.1 MHz from a 50 generator.

Don't set the output level of the generator any greater than -12 dBm, as the I.F. amplifiers within the R.F. unit are in full saturation at that point, and damage may result if the level is greater than -10 dBm.

After tuning the two transmit filters, you can expect a power output of 80 - 150 mW with -20 dBm I.F. input.

You may also want to adjust L4 on the other side of

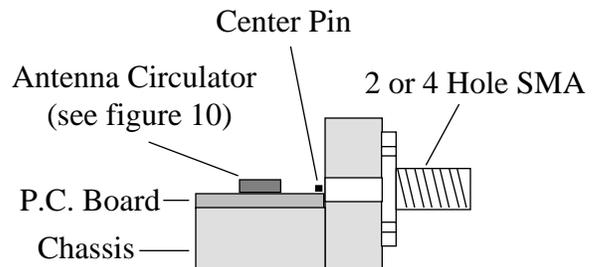


Figure 19.

the R.F. assembly at this point for maximum TX I.F. sensitivity.

After tuning the RX filter, we will come back to the transmitter for fine tuning the X-Band power amplifiers.

For the receiver filter adjustment, remove the TX

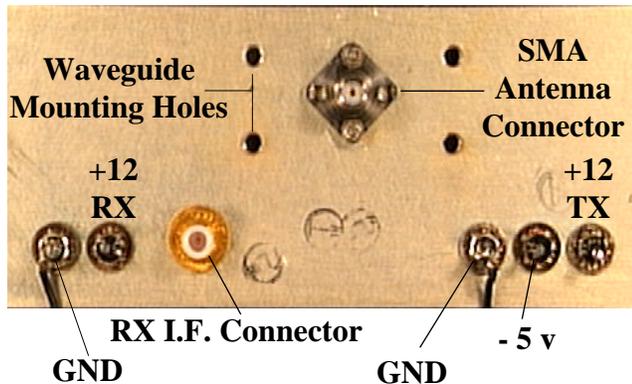


Figure 20.

*The newly installed SMA connector on the R.F. Unit. This allows for alignment of the system and for the addition of coaxial switches, pre-amplifiers, and coaxial antenna systems.*

I.F. cable from the TX I.F. port and the signal generator, as well as the power meter from the antenna port.

Also remove the +12 volt supply from the +12 volt TX feedthrough and connect it to the +12 volt RX feedthrough (see figure 20).

Connect the I.F. cable assembly from above to the RX I.F. OUT connector and attach the 50 Ω end to either a two meter receiver with an S-Meter or to a spectrum analyzer.

Following the procedure above, loosen the hex nuts on the receive filter and turn each tuning screw about 1/2 turn clockwise before alignment to get them "in the ballpark".

Connect an appropriate signal source to the antenna port. This can either be a calibrated signal generator, a friend's X-Band transmitter with appropriate attenuators, or any of several signal sources that can be built from articles in ARRL or

RSGB publications.

Tune the two meter radio to either 146.1 MHz or 143.1 MHz as mentioned above or the spectrum analyzer to the appropriate frequency and adjust the 6-pole receive filter for maximum output.

You may also want to adjust C1 on the other side of the R.F. assembly at this point for maximum output as well.

If you are able to measure the noise figure of the system at this point it should be between 12.5 and 14 dB.

If you tuned the filters outside the R.F. assembly, you might want to "peak" them up at this time to compensate for any variances in the impedances within the R.F. unit.

This completes the "basic" alignment of the R.F. and L.O. assemblies and the units can now either be put into operation or "fine tuned".

Fine tuning involves "tweaking" the microstriplines in the transmitter power amplifier section, so in addition to the equipment needed for the TX filter adjustments, you will need to make a simple "tweaker tool" made of a tooth pick and a 1/16" square piece of copper or brass glued to one end.

To make these GaAsFET tuning adjustments, connect the power meter, signal generator, and power supplies as you had them when tuning the transmit filters and verify that you have R.F. power output.

Adjust the 146.1 MHz signal generator to -15 dBm.

The following adjustments, while simple, are extremely critical. Great care and patience is required so as not to destroy these static-sensitive and expensive GaAsFET transistors.

**PROCEED WITH CAUTION! ALWAYS UTILIZE AN ELECTROSTATIC DISCHARGE (ESD) STRAP ON YOUR WRIST WHILE**

## WORKING WITH THE GaAsFETS!

M/A-COM has provided a means to tune the microwave circuitry. They have provided "tuning tabs" or small etched squares of copper next to the microstripline tuning stubs (see figure 22).

These tabs provide additional capacitance to the tuning stubs. The number of tabs attached with a solder bridge depends on how much capacitance is needed.

To determine how much capacitance is needed, use the toothpick tweaker tool (that I'm sure you have built by now) and by observing figures 21 through 26, hold the metal end of the toothpick near (or touching) the points indicated in the photos.

Start with the gate stub for the final transistor (figure 22). While holding the tweaker on the tuning stub, observe the power meter. If the power increases, then you will need to use at least one tuning tab at that location. If the power goes down, leave that stub alone. The stubs I have shown in the photos are the one's most likely needing to be tuned. Additional stubs or a different combination of stubs may prove the best for your particular unit.

Be careful, but don't be afraid to experiment with all tuning areas in the power amplifier.

Always work with only one stub at a time and remember which one it is!

Determine with the tweaker if the tuning tab is needed, then shut off all power, solder the tab with the smallest soldering iron tip possible, then turn on the power supply to see if you got the desired power increase.

If the power output has gone down after re-connecting the power supply, don't worry, it just means that you might have connected more than one tuning tab or that one tab may be too much capacitance. If that's the case, remove the solder from the tab with some Solder-Wick® and try adding some solder to the stripline itself to "build it up" a little.

When you get to the point where trying the tweaker doesn't produce any more meaningful increases in power output, then you have probably reached the finishing point. Don't try to "squeeze" an additional 1 or 2 mW of output power as the system will probably vary more than that one way or the other when you put the cover on the box.

The R.F. absorbing material that is glued in various spots within the R.F. assembly is there to minimize this effect.

You should have been able by now to increase the power output of your unit at least 3 to 4 dB or a minimum of twice the power output at the 1 dB compression level.

Some units that I have "tweaked" have only improved 2-3 dB while most units have been in the 3-4 dB range.

Figure 18 shows the performance of one of the "hotter" units that I have tuned.

This completes all modifications and adjustments within the R.F. and L.O. assemblies. I will now concentrate on the additions to the units to make them fully operational.

As I mentioned previously, using a two meter SSB radio as an I.F. system is an easy way to get on the air.

The schematic diagram shown in figure 27 shows how this is accomplished. The power output of your particular two meter radio is used to determine the size of heat-sink necessary to absorb that power.

For example, a 2" x 2" x 6" heat sink should be adequate to absorb the power from a 25 watt transmitter.

This method was used by Chris - WB6HGW in his X-Band system.

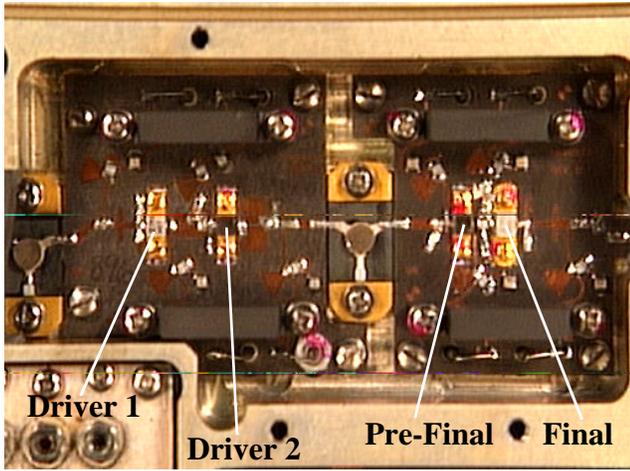


Figure 21.

*This is the transmitter amplifier assembly. Be sure to ground yourself using an Electro Static Discharge (ESD) wrist strap before working in this compartment.*

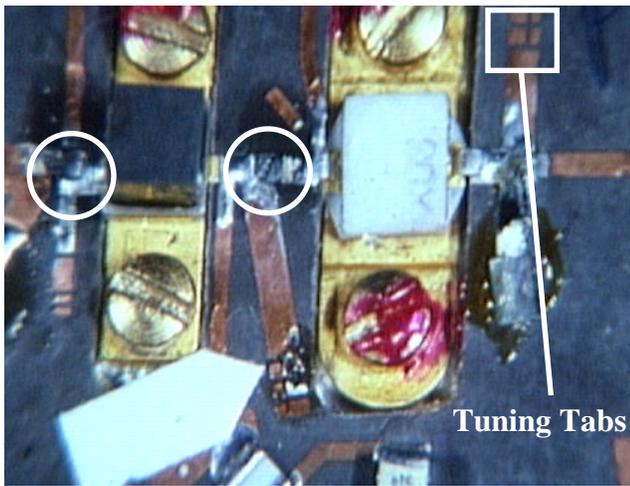


Figure 22.

*The large white pointer in this photo shows where to solder to the "tuning tabs" on the gate of the final GaAsFET. The areas that are circled in these photos are stripline capacitors (see figure 23). These areas should be avoided as the capacitors are easily destroyed by heat or pressure. See text for adjustment procedures. The rectangle shows unused tuning tabs.*

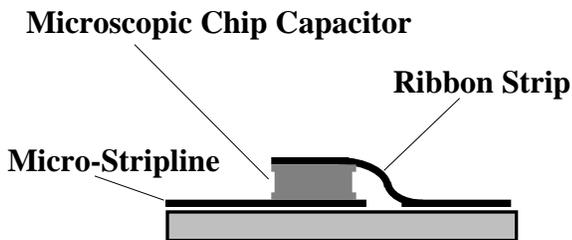


Figure 23.

*This is a side view of the microstripline coupling capacitors contained in the areas circled in white in photos 22, 24, 25, and 26. The capacitors are very fragile and should be avoided.*

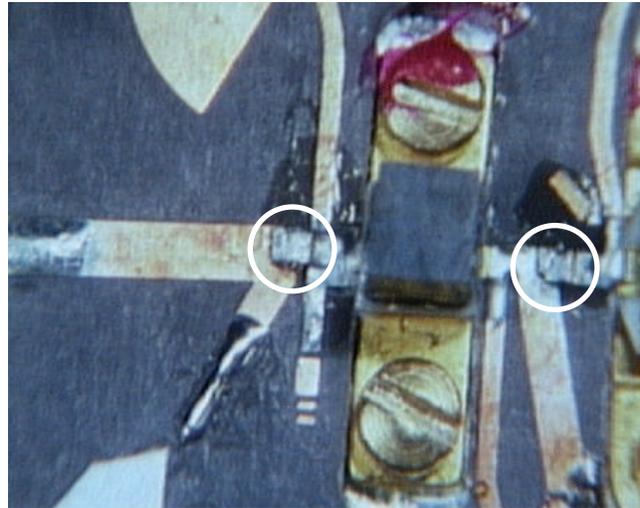


Figure 24.

*The large white pointer in this photo shows where to tune the gate of the pre-final GaAsFET.*

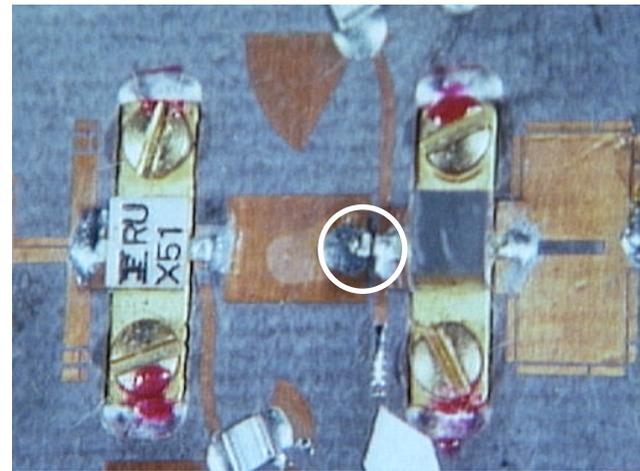


Figure 25.

*The large white pointer in this photo shows where to tune the gate of the driver 2 GaAsFET.*

The circuit can be constructed on a double sided p.c. board mounted on the heat sink. The first component mounted (and the most critical) is the 50  $\Omega$  terminator (see figure 28).

Cut a rectangular hole in the p.c. board the size of the terminator. This is to allow the terminator to be mounted directly to the heat sink (be sure to use heat sink compound on the terminator).

Attach some copper braid or a brass strip from the p.c. board ground plane to the bolts on the terminator.

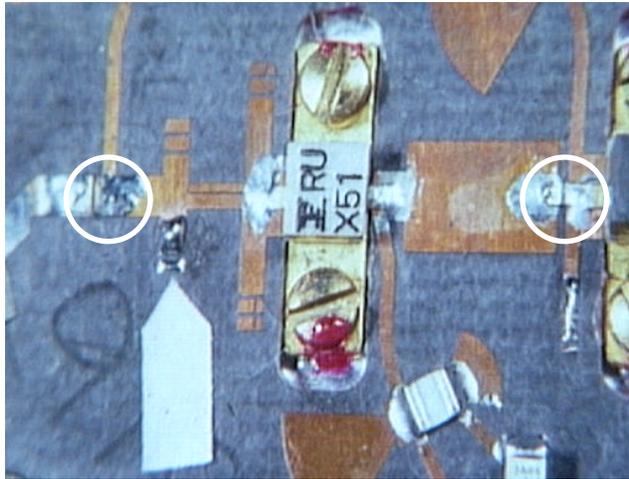
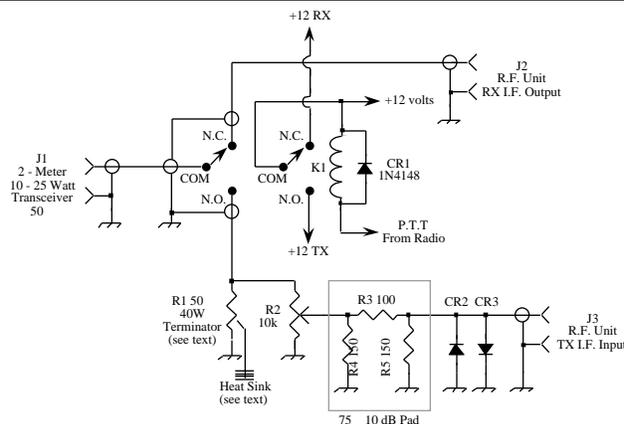


Figure 26.

The large white pointer in this photo shows where to tune the gate of the driver 1 GaAsFET.



Parts List :

- CR1 - 1N4148 or 1N914 diode
- CR2, 3 - 1N4148 or preferably small PIN diodes
- J1, J2, J3 - BNC female connector
- K1 - 12 volt DPDT Relay - 10 amp contacts
- R1 - 50 - 40 watt microstripline terminator mounted to a heat sink KDI model A3RG14 or equivalent (see text)
- R2 - 10 k 1/2 watt cermet potentiometer or other small 10 k pot
- R3 - 100 1/4 watt 5% carbon resistor
- R4, 5 - 150 1/4 watt 5% carbon resistor

Figure 27.

Schematic of the 2 - Meter transceiver interface circuitry. Adjust R2 for -20 dBm output while transmitting on high power.

The circuitry itself is not very critical and can be carved onto the board using an X-acto® knife or whatever method you choose. Always remember to use the shortest lead lengths possible when working at the higher frequencies.

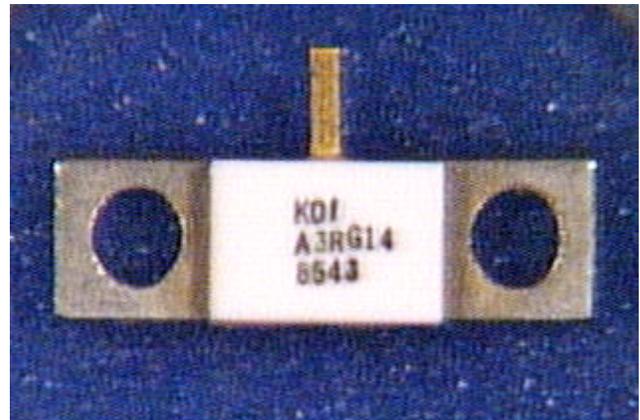


Figure 28.

The 40 watt 50 terminator used in the 2 - Meter interface. Shown at approximately 3-X normal size (see text and figure 27).

Most of the components in the two meter transceiver interface are readily available. Most 12 volt 10 amp relays I have tried are adequate for this purpose as the overall performance of the system is not dependant upon the two meter interface.

What is important, however, is to make sure that the transmit VSWR of the two meter radio be kept to a minimum.

For this reason a good 50 load is necessary. I chose to use a 50 terminator, instead of trying to "create" a dummy load using a bunch of paralleled resistors or some other method, for ease of construction, compact size and performance.

I realize that not every amateur has one of these things in their parts cabinets. Although the terminator can be obtained from a manufacturer's rep. for a retail price of between \$25 - \$40, I have a small quantity of these that I will make available to amateurs for \$10.00 each<sup>5</sup>.

Once you have constructed the circuit, the first thing you need to do is connect it to your radio's antenna connector and the P.T.T. switch.

Make certain that the P.T.T. connection from your radio to the interface is absolutely solid or you could instantly destroy the receive I.F. amplifier in the X-Band R.F. assembly by transmitting into it!

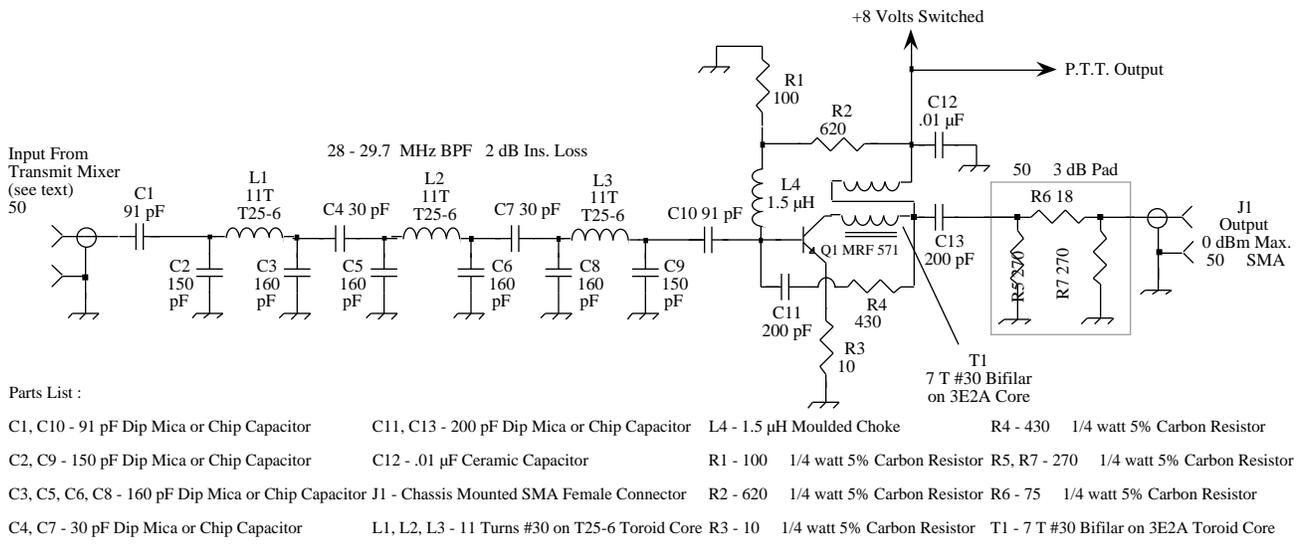


Figure 29.

The 10-Meter filter/amplifier assembly to provide a 0 dBm output signal from the Uniden (President) HR-2600 or the Radio Shack HTX-100.

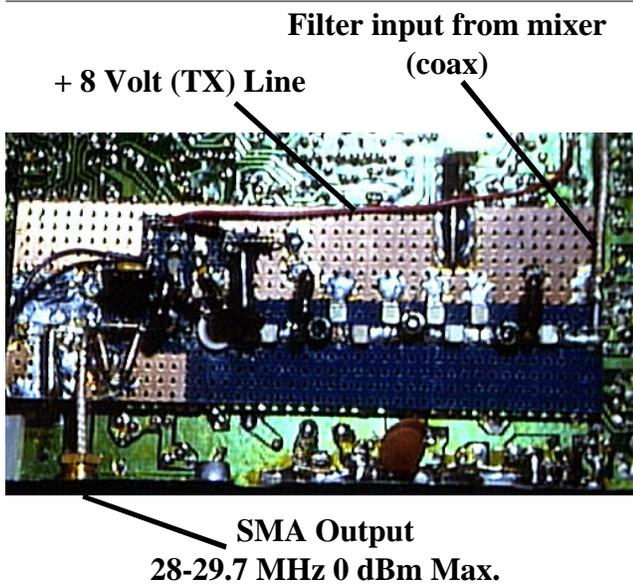


Figure 30.

Inside the Uniden (President) HR-2600 or the Radio Shack HTX-100. The filter/amplifier board is single sided so no insulation was required to mount the board right on the circuitry. Just solder a few ground wires from the radio to the top of the filter/amplifier board. The female SMA connector should be mounted where possible on the back panel (it just fits!).

The next step is to attach an R.F. power meter to J3 and while transmitting at full power, adjust R2 for an output of -20 dBm. You can add additional attenuation as necessary for your particular interface circuit if you find that the one listed is not enough to bring the level down to -20 dBm.

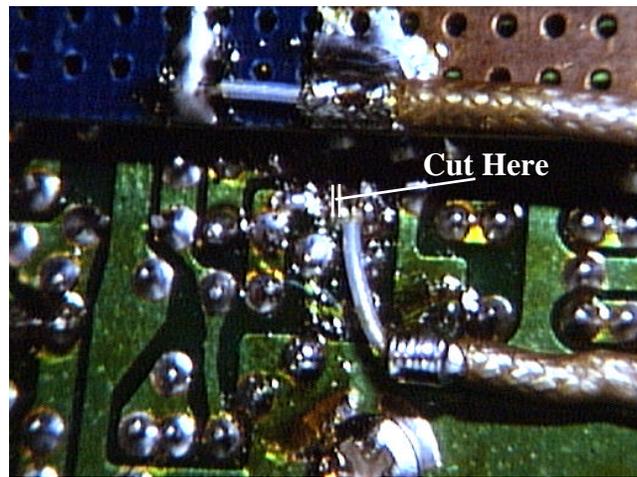


Figure 31.

Close up view of the filter/amplifier connection to the 10-Meter transmit mixer in the HTX-100 and the HR-2600. The foil patterns and physical placement is the same for both radios (also see figure 32).

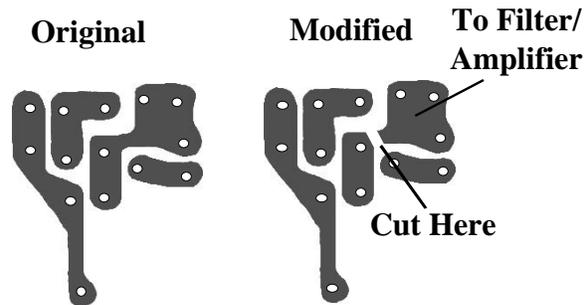


Figure 32.

Close up view of the 10-Meter transmit mixer P.C. Board circuit connections, for both the HTX-100 and the HR-2600, showing where to cut the trace and solder the coax for the filter/amplifier (see figures 33 and 34 for schematic references).

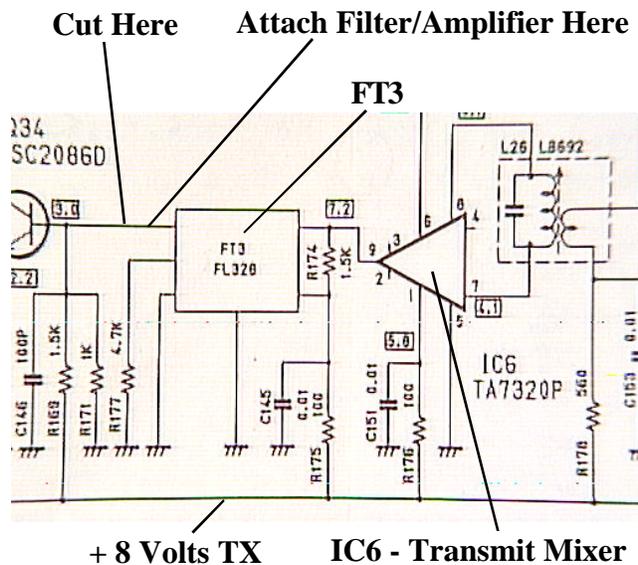


Figure 33.

Close up view of the 10-Meter transmit mixer circuit diagram in the Radio Shack HTX-100, showing where to cut the circuit and connect the coax for the filter/amplifier.

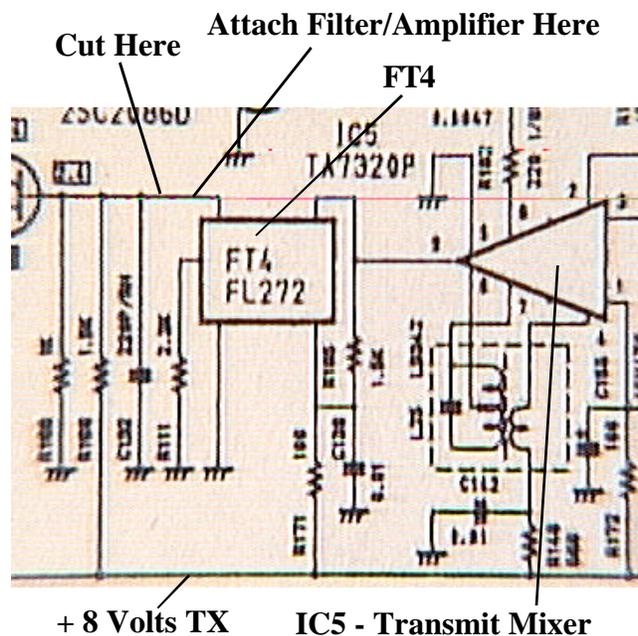


Figure 34.

Close up view of the 10-Meter transmit mixer circuit diagram in the Uniden HR-2600, showing where to cut the circuit and connect the coax for the filter/amplifier.

The reason for using your radio in the high power mode is for your own protection. If you adjusted the system in the low power mode and accidentally pushed the high power button - poof! no more X-Band transmit.

Once you have completed and adjusted the two

meter interface, you are ready to assemble the system into a working unit.

If you plan on using the supplied antenna system, you will need to do two things.

First, you need to re-install the antenna pin on the R.F. unit (that was removed earlier so an SMA connector could be installed). Use the appropriate care when soldering to the R.F. unit's p.c. board.

Finally, you will need to remove the attenuator assembly that is attached to the antenna feed system.

This is accomplished by first removing the gear assembly from the feed system. Then remove the screws that hold the two parts of the antenna feed together and peel off the thin piece of plastic covering the lower half of the antenna feed.

If you have successfully removed all of the gear parts, the attenuator pieces should fall out of the lower half of the feed assembly.

Re-assemble the antenna feed and attach the feed assembly to the R.F. unit. Make sure that the small O-ring around the feed side of the antenna pin is in place and is not being pinched.

Now re-install the R.F. assembly and the L.O. assembly (with the .141" semi-rigid cable) inside the antenna housing. There is plenty of room to install the two-meter interface assembly as well.

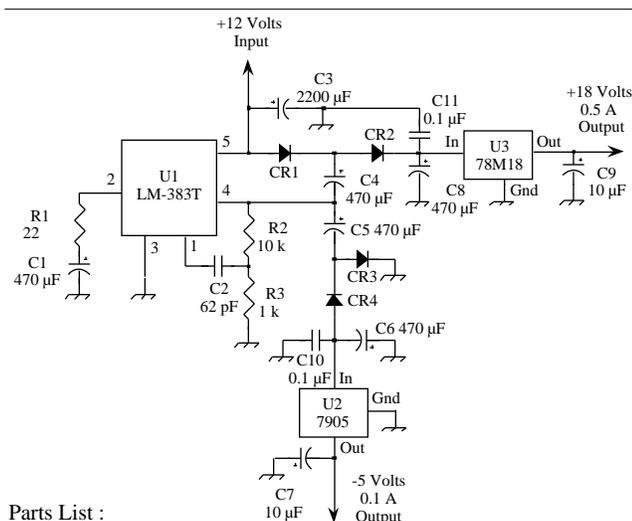
Wire the two-meter interface to the R.F. assembly and run your I.F. and D.C. cables through one of the connector holes in the back of the "tub".

Replace the antenna reflector, the radome, and add the appropriate power supplies (-5, +12, and +18 to +20 volts) and you are operational! But for truly portable operation, you may wish to construct a D.C. to D.C. power converter and regulator to supply the -5 and +18 to +20 Volts from a +12 volt source such as a car battery. This can be accomplished with the following circuit.

The schematic is shown in figure 35 and a suggested layout is shown in figure 36.

The circuit is essentially an oscillating audio amplifier generating a 20 kHz square wave, that is rectified, filtered and regulated. Since the stability of the L.O. is largely dependant upon good power supply regulation, I have chosen to use a + 18 volt regulator in the circuit.

This allows for adequate stability even if the battery voltage should drop to 11.0 volts. The voltage into the three terminal regulator is roughly twice the supply voltage.



Parts List :

- C1, C4, C5, C6, C8 - 470  $\mu$ F 35 v Electrolytic Capacitor
- C2 - 62 pF Ceramic Disc Capacitor
- C3 - 2200  $\mu$ F 35 v Electrolytic Capacitor
- C7, C9 - 10  $\mu$ F 35 v Electrolytic Capacitor
- C10, C11 - 0.1  $\mu$ F 50 v Tantalum or ceramic Disc Capacitor
- CR1, CR2, CR3, CR4 - 1A Hot Carrier (Schottky Barrier) Diode
- R1 - 22 1/4 watt 5% Carbon Resistor
- R2 - 10 k 1/4 watt 5% Carbon Resistor
- R3 - 1 k 1/4 watt 5% Carbon Resistor
- U1 - LM-383T or ECG-1232 8 Watt Audio Amplifier I.C.
- U2 - 7905 -5 Volt Three Terminal Regulator
- U3 - 78M18 +18 Volt Three Terminal Regulator

Figure 35.

Schematic of the D.C. power converter/regulator assembly. Construction can be on standard perf-board and mounted in a metal box.

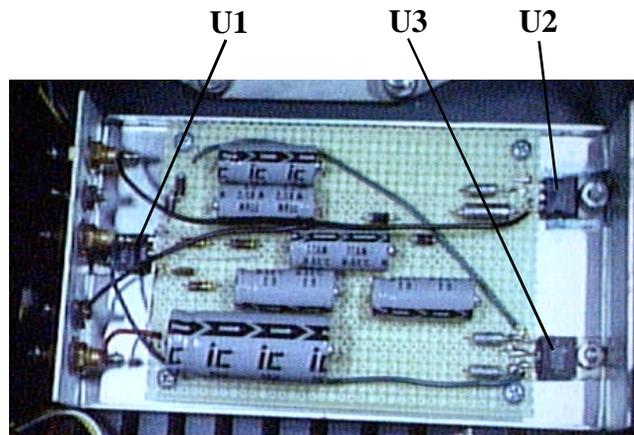
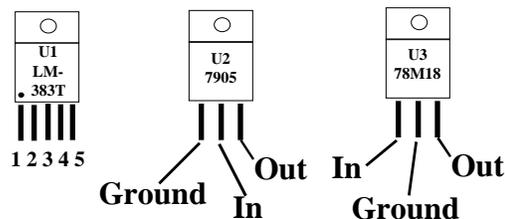


Figure 36.

An inside view of the D.C. power converter/regulator assembly. The unit should be built in a metal box, like the one shown, to shield the radio from possible RFI generated by the supply. Note - the tabs on U1 and U3 should be grounded directly to the chassis, but U2 (-5 V) must be insulated from ground. Note the pin connections as follows :



This circuit was given to me by Chip Angle - N6CA from a design by Ron Brooks - W6QUI.

Mounting this power converter inside the "tub" completes the portable X-Band system using a two-meter radio as an I.F.

## The Complete System.

I will now describe taking the system to completion by providing details of constructing a simple two-meter to 10-meter transverter, and the necessary modifications to either a Radio Shack HTX-100 or a Uniden (President) HR-2600 10-meter mobile transceiver, to make them into general purpose transverter I.F. systems.

The modifications to the 10-meter mobile transceivers are fairly simple.

The modifications for either the Radio Shack HTX-100 or the Uniden (President) HR-2600 are the same (since they are nearly identical).

Start by removing the top cover of the transceiver, and removing the p.c. card used as a power bus jumper for the power amplifier assemblies. Be sure to save this p.c. card as you may want to restore the transceiver to full 10-meter radio operation in the future.

Replace the top cover of the radio, and remove the bottom cover of the radio. This is where the majority of the modifications will take place.

Using any single sided p.c. material (I used perf board), construct the circuit in figure 29. The circuit is not too critical and all I used is an X-Acto® knifeto cut the traces on the board.

The circuit for the filter/amplifier was supplied by Chip Angle - N6CA. The circuit for the filter section is derived from a program designed by Gary Frey - W6XJ, entitled "BLAP"

After building the circuit, physically mount it into the radio by soldering several wires from the ground plane of the filter/amplifier, to several ground connections on the radio's circuit (see figure 30).

Figures 31 and 32 illustrate the circuit board change and figures 33, and 34 are the schematic references for the two types of transceivers.

The only modification to the transceiver's circuit board, is to cut the trace from the output of the filter coming from the transmit mixer.

Solder a peice of small coax (i.e. RG-188, RG-174, etc.) to the output of the transmit filter (FT3 in the HTX-100 or FT4 in the HR-2600) to the input of the filter/amplifier assembly.

Next connect a wire from the switched +8 volt line in your transceiver (see figures 33 and 34) to the + 8 volt input of the filter/amplifier assembly as shown in figure 29.

All that is left is to mount a small 50 ohm connector

on the back of the transceiver such as an SMA chassis mount connector. This connector serves as the transmit I.F. output while the radios' SO-239 connector remains as the receive I.F. input.

Check your wiring and installation. Connect a power meter to the transmit I.F. output SMA. attach a 12 volt supply to the transceiver, and measure the transmit power output.

The power should be approximately 1 mW or 0 dBm. You should increase the attenuation in the output of the filter/amplifier board to acheive this power level if it is too high, or slightly reduce the resistance of R3 (to perhaps 9.1 ohms) to increase the gain of the amplifier and thus increase the output level.

It is always desirable to have at least a 3 dB attenuator at the output of the filter/amplifier to provide a good 50 ohm termination to the transverter.

Replace the bottom cover on the transceiver.

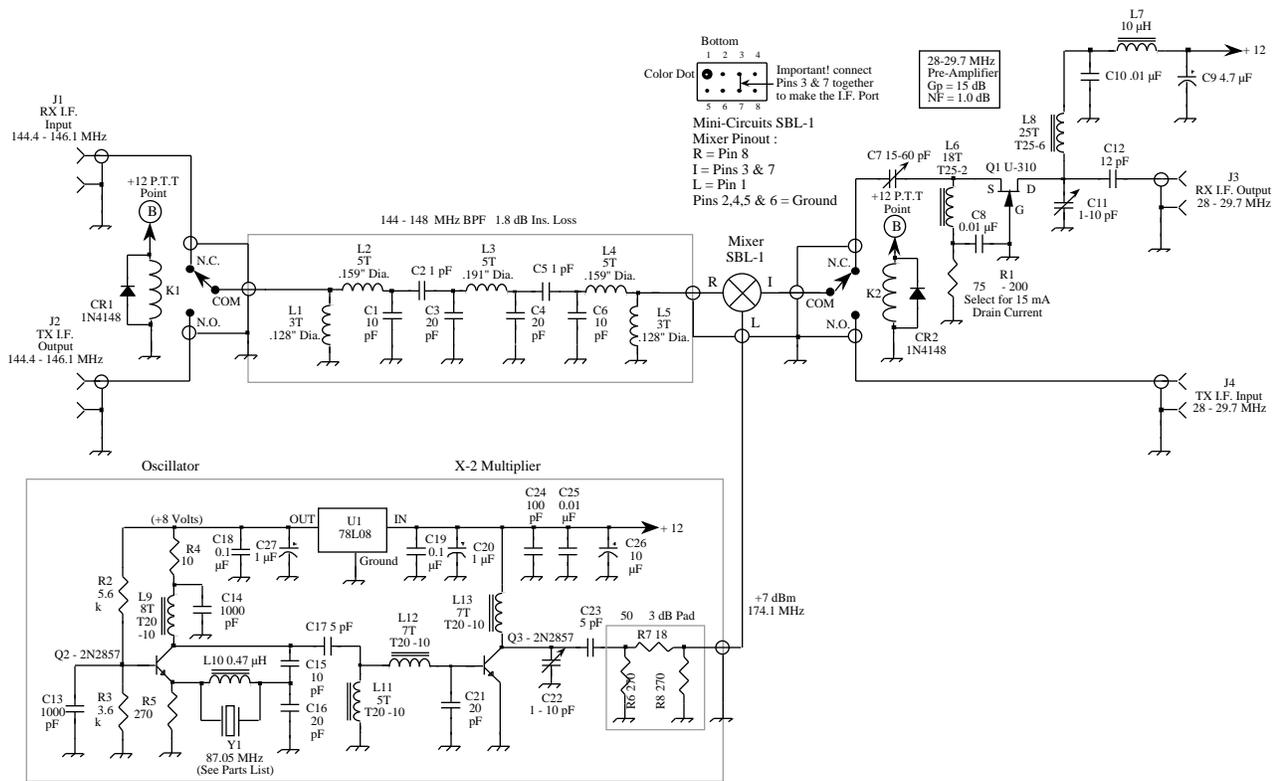
You now have a general purpose I.F. transceiver useful not only for this X-Band project, but with a variety of commercial transverter systems and for future home-brew projects.

The next portion of this project involves constructing a transverter to go between the 10-Meter I.F. system and the R.F. unit.

Figure 37 shows the schematic diagram of the transverter, and figure 39 is a suggested layout of the circuit. Once again, I used single sided perf board as the p.c. material, and an X-Acto® knife to cut the traces.

The components I used were all fairly common, except for the "crystal can" relays, which I found at a swap meet. Most small relays have a reasonable insertion loss at two meters, so I'm sure they won't be too difficult to locate.

The SBL-1 mixer was pulled out of the I.F. processor board from the original M/A-COM assembly



Parts List :

- |  |  |   |   |  |
|--|--|---|---|--|
| C1, C6 - 10 pF Dip Mica or Chip Capacitor      | C16, C21 - 20 pF Dip Mica Capacitor                | L2, L4 - 5 Turns # 24 AWG Air Wound 0.159" ID     | Mixer - Mini-Circuits SBL-1<br>(Removed From MA/COM I.F. Processor Board)         | U1 - 78L08 +8 Volt 3-Terminal Regulator  |
| C2, C5 - 1 pF Dip Mica or Chip Capacitor       | C17, C23 - 5 pF Dip Mica Capacitor                 | L3 - 5 Turns # 24 AWG Air Wound 0.191" ID         | R1 - 75 to 200 1/4 watt 5% Carbon Resistor<br>(Select for 15 mA Q1 Drain Current) | Y1 - Series Resonant 5th Overtone Crystal<br><br>87.05 MHz for 146.1 MHz I.F.<br><br>85.55 MHz for 143.1 MHz I.F.<br><br>Crystals are available from any crystal manufacturer. |
| C3, C4 - 20 pF Dip Mica or Chip Capacitor      | C18, C19 - 0.1 µF Ceramic Capacitor                | L6 - 18 Turns # 30 AWG on T25-2 Toroid Core       | R2 - 5.6k 1/4 watt 5% Carbon Resistor   |  |
| C7 - 15-60 pF Ceramic Trimmer Capacitor        | C20, C27 - 1 µF Tantalum or Electrolytic Capacitor | L8 - 25 Turns # 30 AWG on T25-2 Toroid Core       | R3 - 3.6k 1/4 watt 5% Carbon Resistor   |  |
| C8, C10, C25 - 0.01 µF Ceramic Disc Capacitor  | C24 - 100 pF Dip Mica Capacitor                    | L9 - 8 Turns # 30 AWG on T20-10 Toroid Core       | R4 - 10 1/4 watt 5% Carbon Resistor   |  |
| C9 - 4.7 µF Tantalum or Electrolytic Capacitor | C26 - 10 µF Tantalum or Electrolytic Capacitor     | L10 - 0.47 µH Moulded Choke                       | R5, R6, R8 - 270 1/4 watt 5% Carbon Resistor                                      |  |
| C11, C22 - 1-10 pF Ceramic Trimmer Capacitor   | CR1, CR2 - 1N4148 or 1N914 Diode                   | L11 - 5 Turns # 30 AWG on T20-10 Toroid Core      | R7 - 18 1/4 watt 5% Carbon Resistor   |  |
| C12 - 12 pF Dip Mica Capacitor                 | J1, J2, J3, J4 - Chassis Mounted SMA Female Conn.  | L12, L13 - 7 Turns # 30 AWG on T20-10 Toroid Core | Q1 - Siliconix U-310 J-FET  |  |
| C13, C14 - 1000 pF Dip Mica Capacitor          | K1, K2 - Small 12 Volt Crystal Can Relays          | L12, L13 - 7 Turns # 30 AWG on T20-10 Toroid Core | Q2, Q3 - 2N2857 UHF Transistors   |  |
| C15 - 10 pF Dip Mica Capacitor                 | L1, L5 - 3 Turns # 24 AWG Air Wound 0.128" ID      |   |   |  |

Figure 37.

Schematic of the 2-Meter to 10-Meter Transverter. See figure 38 for system power and relay wiring.

(see figure 1), and the connection diagram is shown in figure 37.

The physical layout in Figure 39 shows where the various sections of the transverter are positioned. I built a shield around the 10-Meter pre-amplifier using double sided p.c. board. There is a 2-Meter pre-amp in the box as well, but it provided too much system gain so I left it disconnected.

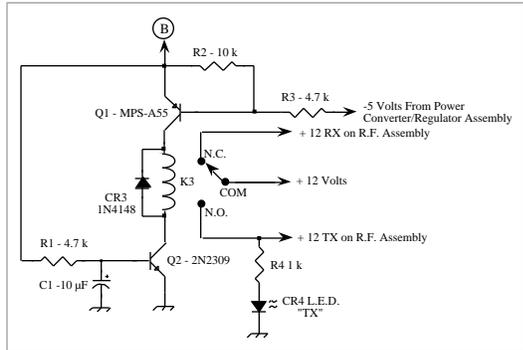
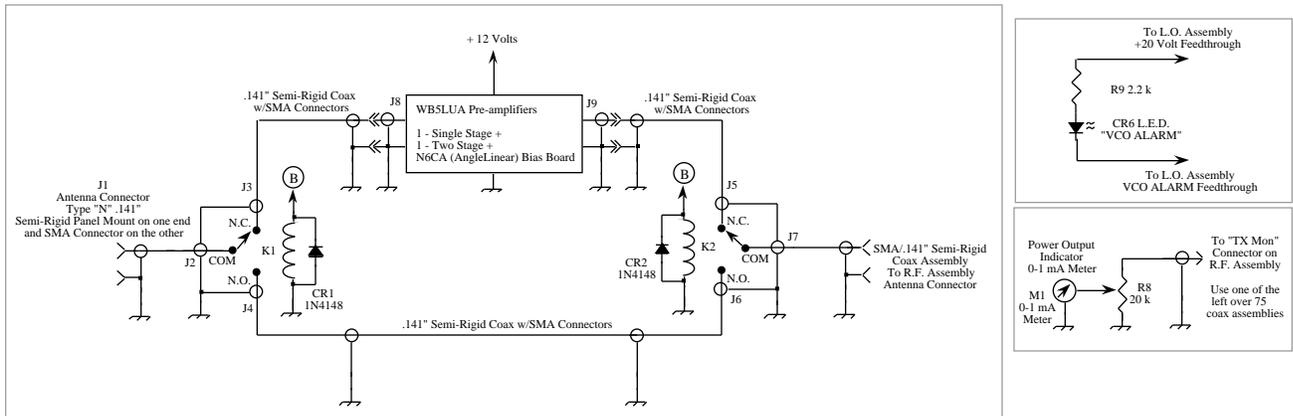
I built the transverter unit in a shielded enclosure with SMA chassis mount connectors for the I.F. input and output connections, and 470 pF feedthrough capacitors for the D.C. and control lines.

The designs for the oscillator/multiplier, 2-Meter filter and 28 MHz pre-amp were supplied by Chip Angle - N6CA.

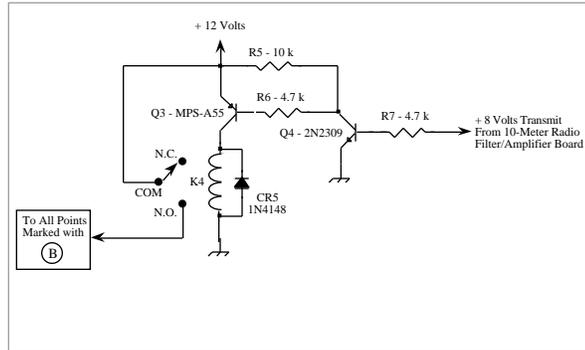
Tune up of the transverter is very simple. Connect an oscilloscope, R.F. probe, or Spectrum Analyzer to the output of the times 2 Multiplier, and tune C22 for maximum output at 2 X the crystal frequency. This output should be between +6 and +10 dBm.

Note that there is no frequency tuning provided for the crystal oscillator. Any final frequency adjustments will be made by tuning the L.O. assembly. Connect a Spectrum Analyzer or a receiver to the RX I.F. output and apply an appropriate 2-Meter signal to the RX I.F. input and adjust C7 and C11

Microwave Coaxial Relay and Preamp Wiring Circuit



R.F. Assembly TX - RX Voltage switching with -5 Volt Interlock and 50 mS Time Delay



+12 Volt P.T.T. and Relay Driver Circuit

Parts List :

- |  |  |   |
|--|--|---|
| C1 - 10 µF 16 Volt Tantalum or Electrolytic Capacitor                      | J8, J9 - SMA Female Connectors on Preamp Assembly  | R2, R5 - 10 k 1/4 Watt Carbon Resistor  |
| CR1, CR2, CR3, CR5 - 1N4148 or 1N914 Diode                                 | K1, K2 - 12 Volt Microwave Coaxial Relays - Dynatech/U-Zinc Model D1-412A20 (D.C.-12 GHz) or equivalent. | R4 - 1 k 1/4 Watt Carbon Resistor       |
| CR4, CR6 - L.E.D.  | K3, K4 - 12 Volt SPDT Relays with 5 Amp Contacts   | R8 - 20 k 1/4 Watt Potentiometer        |
| J1 - Panel Mount .141" Semi-Rigid Type "N" Connector                       | M1 - 0-1 mA Meter (R.F. Output Indicator)  | R9 - 2.2 k 1/4 Watt Carbon Resistor     |
| J2, J3, J4, J5, J6, J7 - SMA Female Connectors on Microwave Coaxial Relays | R1, R3, R6, R7 - 4.7 k 1/4 Watt Carbon Resistor  | Q1, Q3 - MPS-A55 PNP Silicon Transistor |
|  |  | Q2, Q4 - 2N2309 NPN Silicon Transistor  |

Figure 38.

Power, Relay and Misc. Wiring for the Complete X-Band Portable Transceiver Assembly.

Osc. X-2 Mult. 2-Mtr Filter 10-Mtr Preamp L.O. R.F. Assy Preamp Power Supply

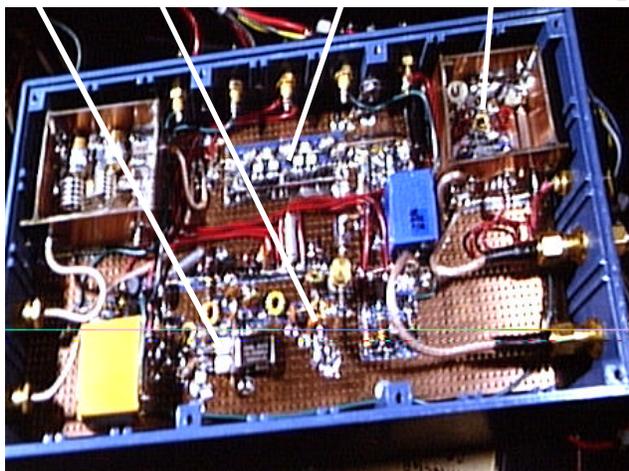


Figure 39.

The author's layout of the 2-Meter to 10-Meter transverter assembly. Single sided perf board was used for construction.

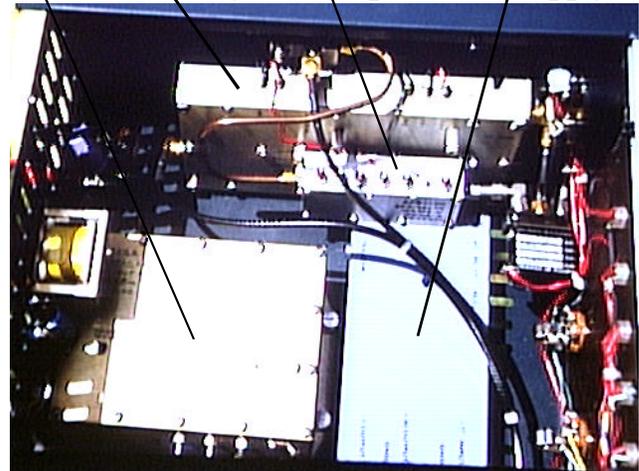


Figure 40.

This is a view of the inside of the completed X-Band Assembly. Not seen is the 2-Meter to 10-Meter transverter located on the opposite side of the R.F. Assembly.

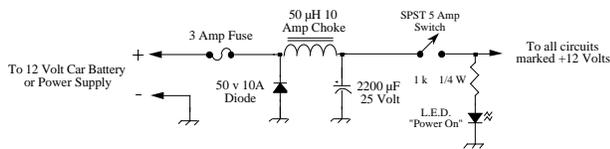


Figure 41.

Added power supply filter, fuse, switch and power indicator assembly to complete the unit.

**Single Stage X-Band Pre-Amp**      **Dual Stage X-Band Pre-Amp**



**N6CA (AngleLinear) Bias Board**

Figure 42.

Inside view of the WB5LUA pre-amplifiers. The chassis and bias board was courtesy of Chip - N6CA.

for maximum output. This completes the alignment of the transverter assembly.

The diagram in figure 38 shows the final system power distribution wiring and relay connections for the completed unit. Relays K1 and K2 are used when an X-Band pre-amplifier is used. K4 provides a +12 volt P.T.T. activated output to the transverter assembly, microwave relays and K3, the R.F. assembly power relay.

The output of K3 provides the +12 volt D.C. switching of the R.F. assembly and has an interlock to prevent +12 volts from getting to the X-Band GaAsFET's in the event of a failure in the -5 volt supply.

Transistor Q2 is used for additional protection of the R.F. assembly by providing a 50 mS time delay before the transmitter is keyed.

Meter M1 is connected through a 20 k potentiom-

eter to the TX MON output of the R.F. assembly using a 75 coax assembly, with one end cut off, left over from the original M/A-COM system.

Adjust R8 for a full scale reading when maximum power is obtained from the R.F. unit.

The entire X-Band Portable System is housed in a 12" x 8" x 14" instrument case obtained from a swap meet. Figure 40 shows how I arranged the individual assemblies into the final unit.

Adding the power circuit shown in figure 41, and completing all chassis wiring, L.E.D. indicators and R.F. connectors finishes the project and the unit is now ready for field operation.

Before going on the air, be sure to adjust the final output frequency by tuning C5 in the L.O. assembly while transmitting into the appropriate attenuators and frequency counter.

A final note on the WB5LUA X-Band pre-amplifiers supplied by Down East Microwave. These come in kit form and require you to provide an appropriate housing and bias circuit.

The housing shown in figure 42 is a luxury, but is not absolutely necessary for satisfactory operation. A box made from brass is adequate for this purpose.

The most critical part of the preamp that you need to provide is the GaAsFET bias circuit.

The suggested circuits in WB5LUA's article are OK but for long term stability and circuit protection, I recommend purchasing a bias board from AngleLinear<sup>6</sup> for \$25.00.

This board provides +5 volt drain voltage as well as negative gate voltage adjustments for up to three amplifiers with it's own -5 volt supply. The circuit runs off of +12 volts and is small enough to fit in almost any pre-amp box.

For those of you wishing to utilize modes other



*Picture of the author with the finished unit ready for the next contest or for a quick hilltop contact! Also shown is the 27" Dish antenna mounted on a tripod.*

than narrow band, here is some additional performance data:

1 dB Bandwidth @ 1 dB compression = 12 MHz,  
 3 dB Bandwidth @ 1 dB compression = 26 MHz,  
 1 dB Bandwidth @ saturation = 15 MHz, and 3 dB  
 Bandwidth @ saturation = 33 MHz.

I would like any comments you may have about this project or about operation on X-Band Single Side Band (or any other microwave bands). You can send them to my P.O. Box listed at the end of the article or catch me on X-Band SSB during the next contest or I can be found on the 224.28 repeater in L.A.

There were a lot of people involved in helping me with this project, especially in being editors, they include: Chris Williams - WB6HGW, Bob Gordon - WA6JGW, Dick Sale - N6QFD, Greg Noneman - WB6ZSU, Bart Rowlett, and my wife Marilyn - WB6OOM.

Photography was provided by Dick Sale - N6QFD and myself.

Special thanks go to Chip Angle - N6CA for his technical advice and assistance.

And to Chuck Swedblom - WA6EXV who first converted the M/A-COM units.

*I produced this article entirely on an 8 MB Apple Macintosh IIfx computer system, with PageMaker 4.01, Truevision's NuVista board with RGB input processor, JVC RGB camera, Truevision Video Capture software, Adobe PhotoShop, Claris' MacDraw II and printed on an Apple Personal LaserWriter NT printer.*



1. "M/A-COM TRANSVERTER MODIFICATIONS" by Chuck Swedblom, WA6EXV, April 17, 1990 - P.O. Box 605, Ridgecrest, CA 93555 (619) 377-4972 13 pp. incl. some diagrams.

2. Crystals are available from Frequency Tronics, Inc. (EG&G) 4914 Gray Rd., Cincinnati, Ohio 45232 (513) 542-5555, Part # 184-07-14 Specify crystal frequency. \$25.00 ea. Ask for Kay.

3. Additional information may be found in the article "SIMPLE LOW NOISE MICROWAVE PREAMPLIFIERS" by Al Ward, WB5LUA in the "Proceedings of Microwave Update '88" p. 65-79 incl. August 25-28, 1988 - Publication No. 89 Published by the ARRL - American radio Relay League Newington, Connecticut 06111. Price - \$12.00. The address for Al Ward, WB5LUA is: 2375 Forest Grove Estates Rd., Allen Texas 75002

4. Down East Microwave - Bill Olson, W3HQT Box 2310, RR1 Troy, Maine 04987 (207) 948-3741. Part # 3-1 LNAK for the single stage X-Band GaAsFET Pre-amplifier kit and part # 3-2 LNAK for the 2 stage X-Band GaAsFET Pre-amplifier kit.

5. The 50 40 Watt terminators are available from the author, Dave Glawson, WA6CGR P.O. Box 4881, Diamond Bar, CA 91765 for \$10.00 each postage included.

6. The GaAsFET preamplifier bias boards are available from Chip Angle, N6CA @ *AngleLinear* P.O. Box 35, Lomita, CA 90717 (213) 539-5395 for \$25.00 each plus postage.