A 10 GHz Transverter

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Increasing 10 GHz band activity inspired my assembly of a fixed station system which is minimally EME capable. As is too often the case on the microwave bands, there is a shortage of other stations within easy range to work terrestrially. This creates the desire to maintain a portable station which can rove or be loaned out for grid expeditions and experimentation. This article documents the approach to design and general construction of a such a portable transverter system, assembled from a few reasonably easily obtained surplus components in conjunction with commercial circuit board kits from Downeast Microwave. There is certainly nothing particularly novel about the design or construction. This can be considered a "good thing" from the standpoint of being able to replicate the transverter. Key design criteria are as follows:

- Use of the ubiquitous IC-706 as the intermediate frequency transceiver or other modern HF transceiver.
- Operation from a vehicular 14+ volt power source.
- Minimum of critical microwave circuitry construction by utilizing surplus and commercial assemblies supplemented with Downeast Microwave kits.
- Small size (6X6X6 inches) and simple transceiver integration reminiscent of the "Microwave Modules" transverters.
- Separate transverter and preamp/power amplifier modules for remoting at the antenna (no feedline loss).
- Protection of remote preamp/power amplifier module from transients when not in use.
- One switch in/out selection without recabling.
- No inversion of sidebands and normal direction of tuning through dual conversion.
- First IF in the 432 MHz range and second IF of 10 meters, avoiding active frequencies.
- Provisions for monitoring both LO frequencies to accurately derive operating frequency.

The plan. In addition to the IF transceiver, the portable transverter system consists of two units, a preamp/power amp module and a transverter module. The transverter module contains the local oscillator and associated power supply, mixer, intermediate transverter and transceiver interface. The transverter module will be described in detail first. The preamp/power amp module will be described along with possible alternatives.

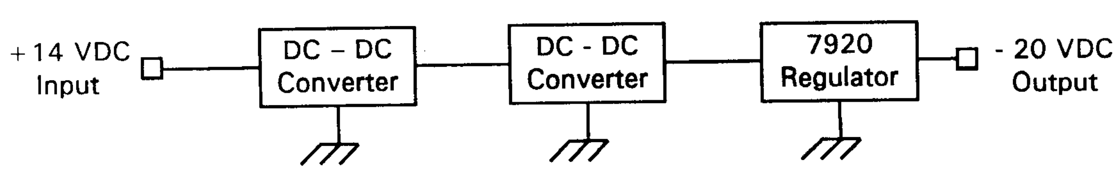
The source. For good frequency stability with minimum complexity, the transverter module employs a Frequency West ovenized microwave source ("brick") operating in the range of 10800 MHz. These devices are commonly available surplus items which have been extensively described elsewhere in the literature. The exact frequency used can vary somewhat depending on the other frequencies you pick for the second conversion stage and the final intermediate frequency. More on that later.

Powering the Source. The desired power source is a vehicular battery/charging system supplying about 14 volts with negative ground. The transverter is designed around a Frequency West ovenized microwave source ("brick"). The ubiquitous brick provides the desired compact, stable first local oscillator, but with the awkward requirement for a source of -20 volts to operate it. This section describes the circuit used to power the brick, which solves both the polarity and magnitude problems. N1BWT and others have published similar designs. The intent here is to show how you might arrive at your own design based on whatever components you have around and what turns up surplus.

Polarity. The significant problem of using the brick is the power requirement for a regulated negative 20 volts, too much voltage and the wrong polarity to run directly from a vehicular electrical system. I started out using a 5 volt to 12 volt DC to DC converter module (because that is what I had accumulated). These are small potted assemblies containing a switching power supply with outputs isolated from the inputs. I have obtained these at flea markets for well under $10. The 5 volt input seems to be most common in surplus. For the ones I have tried, the output voltage is unregulated and is roughly proportional to the input voltage. Although with about 6 volts DC and the output soars to 20 volts, which can be used to directly supply the brick, I fried one unit eventually. So don't exceed the ratings. Next I tried a 5 volt to plus/minus 12 volt converter, which produces 24 volts across both output terminals. Since the outputs are DC isolated from the inputs, the positive output terminal can be grounded and the negative output terminal can be connected to a negative regulator to supply the brick's -20 volt input requirement.

Magnitude. I used a Lambda AS-25-5 DC-DC converter to regulate the vehicular 14 volts down to 5 volts, driving a Computer Products EM-915S DC/DC converter to -24 volts. Steady state current requirement for the brick is about 400 ma, which requires about 2 amperes into the DC to DC converter. These are followed by a 7920 negative regulator IC to supply the LO source. Of course, if you have a 12 to 24 volt converter to start with, the 7920 is all you need (as per N1BWT). Other combinations of pass regulators and converters will no doubt work. Pass regulators will perhaps generate too much heat to mount inside the transverter. The point here is to consider whatever device you might find available and base the overall design on it. In fact, most of the time devoted to building and testing this transverter went into the –20 volt supply.

Other considerations. Since the converter chip is a switching type, and the regulators have



+14 VDC to -20 VDC Power Supply

gain, there is potential for noise generation and oscillation. Commonly applied techniques such as bypass capacitors should be used if found to be needed. N1BWT utilizes toroidal common mode filters both into and out of his DC-DC converter modules (check out his home page for details). In the transverter I built, I elected to use minimal circuitry starting out and to add any filtering when and if any problems are noticed. (Keeping it simple).

Mating the mixer to the source. The mixer used is a small Watkins-Johnson device with SMA connectors. If you are so lucky as to find a brick with SMA output, you can connect between the brick and the mixer local oscillator port through whatever attenuation is necessary. In my case, the brick output level was directly compatible with the mixer, but the brick had a WR-75 waveguide output. I constructed a simple transition from a short section of WR-75. I used a male two-hole flange SMA connector on this transition which allowed the mixer to be directly mounted onto the transition.

Alternative mixer. The Varian orthomode mixer could also be employed. These units are WR-90 double balanced mixers which can be operated at relatively high LO levels. By slotting the holes on the LO brick's WR-75 output flange, the mixer can easily be mated directly. The disadvantage is the higher noise figure (~20 dB), which is compensated somewhat by higher transmit output (>10 mw). Coupled with appropriate low noise front end amplifier stages, this mixer should do fine. I have also constructed an experimental transverter using such a device, and will be comparing the results.

Constructing a transition. I tried something a little different in the construction of the WR-75 waveguide to SMA male transition. Borrowing the dimensions from a commercial transition, I cut and squared the waveguide and prepared a hole for the SMA connector/probe assembly. I applied paste solder flux to all areas to be soldered. First I mated an SMA to N female adapter to the SMA male two-hole flange connector, to help hold it during soldering. Then I clamped the connector/adapter in place with one C-clamp and a thin brass sheet over the cutoff waveguide end, holding the pieces together in a vice. Instead of using a propane torch as usual, I heated the whole assembly with a heat gun (Sears, intended for paint stripping, normally used to shrink heat-shrinkable tubing). This provided plenty of heat and no combustion by-products to foul the work. After soldering (and cooling!) I trimmed the brass sheet flush with the outside of the waveguide. Loss in the homemade transition was much less than a dB.

Getting from the mixer to the first IF. The mixer is a bi-directional device, so received signals and transmit power go in and out of the same port. The first IF board to be described later needs separate connections. A small SMA relay is used to provide these. If a 13 volt capable relay is not available, a 24-30 volt one can be used instead. To use the typical surplus higher coil voltage relay, attach a Downeast Microwave RVD-1 relay driver board to the relay, which tricks the relay into operating reliably from a reduced sustaining voltage.

The first intermediate frequency. Since 432 is used as the first IF, you could go right to a 432 transceiver; however, since high side first local oscillator injection is used, sidebands will be inverted and tuning will be "backwards". To get around this, and allow use of an IF frequency covered by the IC-706, I took advantage of the Downeast Microwave 432-28DCHK. This is a small inexpensive 432 to 28 MHz transverter kit which uses high side injection, intended for use as an intermediate conversion stage in a transverter. The board is easy to build and to align, using a minimum of test equipment.

The transceiver interface. The significant problem in using a 100 watt HF rig as an IF is that you only need a few milliwatts to drive the transverter. There is great potential for inadvertent damage if too much power is applied. Again, Downeast Microwave to the rescue with another inexpensive board kit, the TIBK transceiver interface. This simple kit provided IF transmit/receive RF switching plus active ALC feedback to the IF transceiver to assure that minimal power is applied. The negative ALC voltage is generated by an integrated circuit on the interface board. To assure safety, simply power this board from the same accessory jack that the ALC feedback voltage is applied to. If you forget to plug the control cable into the accessory connector and then transmit at full power, the output passes harmlessly through the interface board to your HF antenna.

Physical construction and layout. Although you may well chose your own favorite packaging, I'll provide the basic details of mine. The layout I used was based on a desire for compactness and an available 6X6X6 aluminum utility box from LMB. This box had a central sleeve box capped with two end pieces. I mounted all input and output connections on one end. A subchassis was constructed from aluminum angle stock and a 1/8 inch thick aluminum plate. The subchassis was secured to the connector end plate with pop rivets. A 5 inch rack handle was mounted horizontally centered on the connector box end to facilitate transport. Above the handle six holes were drilled for one N bulkhead connector (SHF in/out), one cable grommet (remote preamp/amp control cable) and four BNC female panel connectors (28 MHz IF out, HF antenna in, first LO frequency monitor and second LO monitor). Below the handle are three holes (one cable grommet for the IF transceiver accessory connection cable, another for DC supplies and the third for the on/off - in/out switch). The cables for preamp/amp control, DC power and IF rig accessory connections are each one meter long with the appropriate connectors, which remain connected to the transverter during storage so as never to become lost. The two DEM boards are mounted vertically on the subchassis using two aluminum angle brackets such that the IF interface board can be detached for access to the first IF transverter board.

Power distribution. Two fuses are mounted inside the transverter. A two amp fuse protects the power supplied via the IF rig accessory connector to the IF interface board through one pole of the on/off switch. (The IC-706 has an internal 4 amp fuse, but don't depend on it alone.) A three amp fuse protects the separate DC input which supplies the first IF transverter board and brick power supply through the other pole of the on/off switch. Alternately, a second switch could be used to allow keeping the brick hot while using the IF rig for liaison. Another possible configuration could be to add another relay which powers the transverter only when the IF rig is on.

Push-to-talk control. The IF transceiver PTT output is brought into the transceiver through the accessory cable connection and connected directly to the PTT input on the IF interface. The IF accessory interface has a relay output, which I configured to provide a ground output on transmit. This is in turn connected to the appropriate PTT control point on the first IF transverter. The output relay connections on the first IF transverter board are configured to provide a positive supply voltage on transmit. The same output also provides switched voltage for the IF switch relay and the remote preamp/amp transfer relay (more later on that).

Other connections. Two coaxial cables are routed from the first IF RX and TX terminals to the corresponding terminals on the IF interface board. The pigtail cables to the remote preamp/amp module and the DC supply cable terminated in appropriate 4 pin Molex connectors. The IF transceiver interface accessory cable is terminated in the 13 pin DIN connector supplied by ICOM with the IC-706 (or whatever other connector fits your rig, if different).

Remote preamp/amp module. My exact implementation will be difficult to duplicate because it utilizes a surplus Avantek FET amp which is not readily available. This low noise amplifier has a noise figure of about 2 dB and 30 dB of gain. It also produces almost 100 mw of RF if used as a transmit amplifier. It has definite bandpass characteristics so as to suppress the image frequency at 11+ GHz. To create a bi-directional module, I installed the amplifier in a box with an SMA transfer relay. Two N female bulkhead fittings are mounted on one side of the box to connect with the transverter and to the antenna. The transfer relay effectively reverses the direction of amplification between receive and transmit. Since the relay I used desires 26 volts, I included one of the DEM relay boards also. Another feature is a second relay which disconnects and grounds the power connection to the active device when the transverter is off. This hopefully will discourage damage from transients induced on a long control cable (such as when used atop a tower). The pigtail cable DC connections for power and keying are brought into the box through a feedthrough grommet. A 4 pin Molex connector is used on the pigtail cable to mate with the matching cable/connector on the transverter.

Alternative remote module. If you do not have access to a suitable single device as described above, you can do the same using a multiple stage preamp design. Separate gain stages for transmit and receive can also be used by changing the relay to two SPDT relays. This would be the way to go if higher power is desired. Whichever method is used, it may be necessary to filter out the mixer image at 11+ GHz. This should also be done if the transverter is used "barefoot".

Frequency schemes. Before investing in a crystal, I tend to investigate alternatives which make best use of available crystals. Variables include the brick's output frequency, the first IF transverter's LO frequency, and you choice of exact IF frequency. Ideally, my transverter would use a 100 MHz brick crystal to generate a 10800 MHz first LO, which would mix with 10368 MHz to generate a 432 MHz first IF. The first IF transverter uses a 92 MHz crystal to generate a 460 MHz second LO frequency, which mixes with 432 MHz to provide a 28 MHz IF. There is a problem associated with being on the 10 meter band edge. The tranceiver's internal software does not allow transmitting out of band. The solution could be to "mod" the transceiver for out of band coverage. Another approach, which many others and I have adopted is to offset the conversion scheme such that the desired range is well within the band and well away from undesired signals which might feed through. The table line 2 shows the scheme I would use if ordering a crystal. Line 4 shows the scheme I eventually adopted to provide a 29 MHz IF output for a 10368 MHz input, using crystals on hand. A summary of potential schemes are listed below, with the first four involving separate 1st and second LO base frequencies. The other schemes involve extracting out the base 1st LO frequency and using that to inject the 2nd LO multiplier. That would result in maximum frequency stability, since the 1st LO is oven controlled; however, different IF transverter helical filters would have to be selected to pass the resulting 2nd LO and IF frequencies.

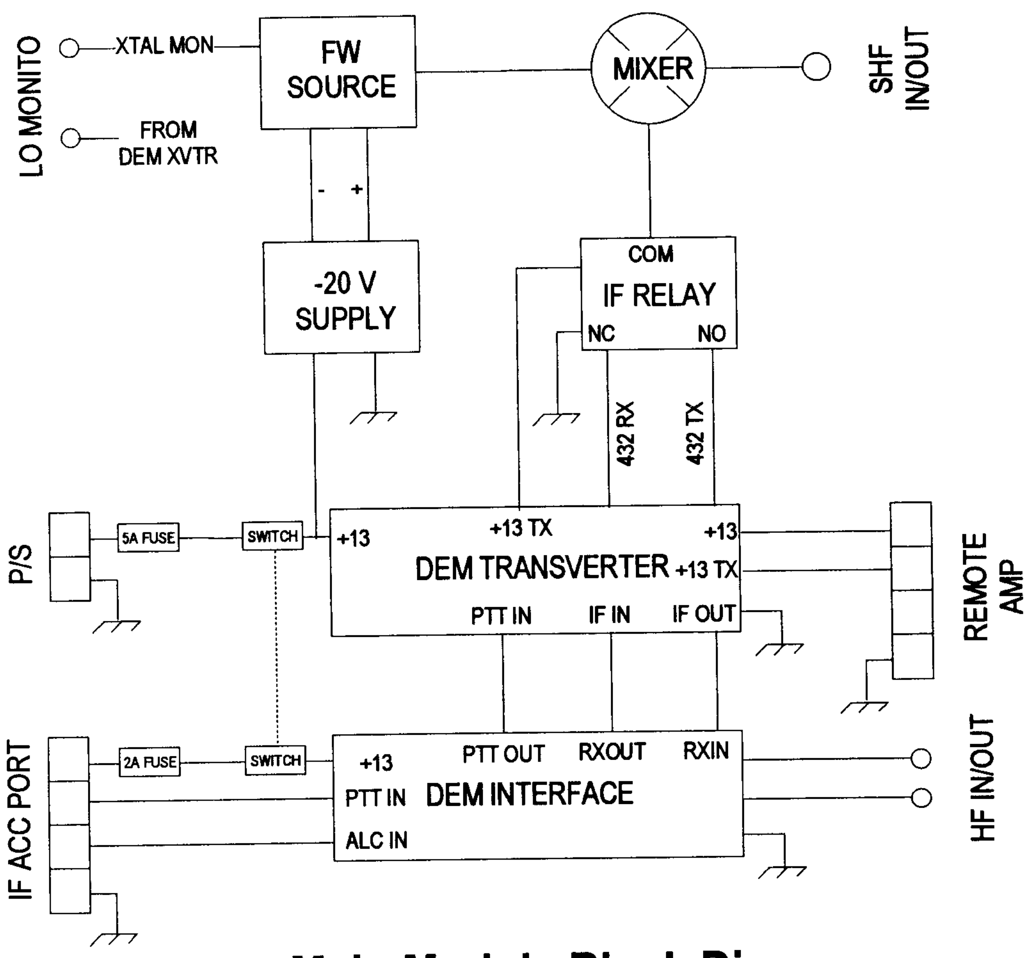
	First conversion				*Second conversion*			
target	xtal	X	LO	IF	xtal	X	LO	IF
10368	100.00000	108	10800	432	92.00000	5	460	28.0
10368	99.99074	108	10799	431	92.00000	5	460	29.0
10368	99.89815	108	10789	421	92.00000	5	460	39.0
10368	99.89815	108	10789	421	90.00000	5	450	29.0
10368	100.38835	108	10841.94175	473.9417476	100.38835	5	501.9417476	28.0
10368	100.37864	108	10840.8932	472.8932039	100.37864	5	501.8932039	29.0
10368	99.21154	108	10714.84615	346.8461538	99.21154	4	396.8461538	50.0
10368	99.18269	108	10711.73077	343.7307692	99.18269	4	396.7307692	53.0
10368	100.17476	108	10818.87379	450.8737864	100.17476	5	500.8737864	50.0
10368	100.14563	108	10815.72816	447.7281553	100.14563	5	500.7281553	53.0

Frequency monitoring. Two BNC connectors are provided to allow monitoring of the first and second LO frequencies using an external counter. To monitor the LO frequencies, I use an Optoelectronics 3000 portable counter with the TCXO timebase (0.2 ppm). The Frequency West first LO source outputs at the 108th crystal harmonic. The DEM transverter board LO is normally 28+432=460 MHz. My actual conversion scheme uses 29+421=450 MHz nominally. To accurately derive the actual conversion frequency, count both LO monitor points, multiply the first LO monitor frequency by 108 and subtract the second LO monitor frequency. Using my conversion scheme, this gives (99.898056 X 108) - 449.990 = 10339.000 MHz. This provides a 29.1 MHz IF for a 10368.1 MHz operating frequency. Having the LO frequencies available for monitoring allows the actual conversion frequency to be determined quickly and accurately whenever desired.

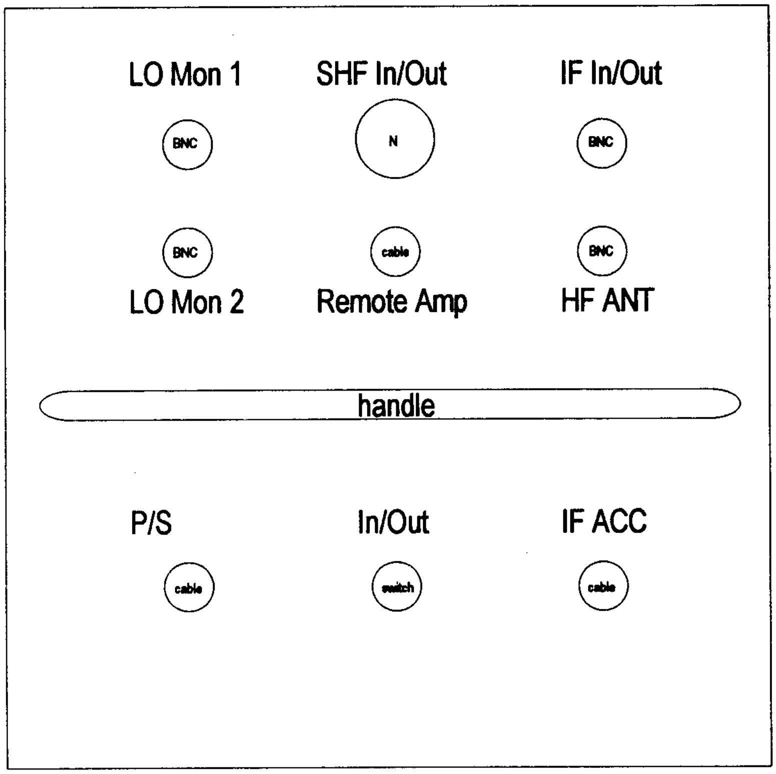
The acid test. I recently assisted WA4PRR in placing a 10368 beacon on the air from FM18qq (Calvert County, MD). We needed a portable station to the receive the beacon for verification of proper operation. The above described transverter was used to determine that the beacon was operating and keying properly. We then proceeded to break in N4ZRW's brand new sport utility vehicle by configuring it as a rolling 10 GHz monitor station. Using a hand held horn antenna inside the moving vehicle, the beacon was heard at distances out to >10 miles. Not bad, considering that the beacon runs 20 mw to a omnidirectional antenna at 50 feet.

Additional intentions. I may yet include some LED status indicators to indicate that power is reaching the circuitry and that the LO brick is frequency locked. I would also like to construct a remote module with higher power output, perhaps using Qualcomm boards. I want to add a 10 GHz filter to the main transverter so it can be used "barefoot" or to drive a wideband amplifier such as a TWT.

Drawings. I have included a block diagram of the basic transverter. Also, mechanical design sketches of the main module and the connector panel layout.



Main Module Block Diagram



Connector Panel Layout

Main Module Physical Layout