A Portable 10/24 GHz Transverter

Dave Meier N4MW
New Kent, VA
n4mw@amsat.org
http://grumman.net/n26963

Introduction. This paper provides general information for the design and construction of my current project, a combined 10/24 GHz portable transverter. At the time of this writing the transverter is largely assembled but may still undergo some design changes. The project began as a second transverter for 24 GHz and evolved into one covering 10 GHz as well. I tried to incorporate some unique features, building upon previous projects in addition to just assembling the miscellaneous parts I had accumulated into a working system. To establish the variety of designs previously employed, I will briefly describe the transverters, transmitters and receiving converters I have constructed for both 10 and 24 GHz:

- A dual conversion 10 GHz transverter system for portable and fixed station use. This transverter uses double high side injection to achieve an IF of 28 MHz. It is integrated for use with an ICOM 706 IF transceiver. This was documented in the Proceedings of Microwave Update 96.
- A single conversion 10 GHz transverter system for portable use. I used a single high side injection to provide an IF of 431 MHz. The IF transceiver, an FT-490, is built onto the transverter. This one is not documented, but has been nicknamed "The GigaHertz Blaster" by virtue of its death ray style of mechanical construction.
- A single conversion distributed 10 GHz transverter system employing a high side local oscillator for EME. An ICOM 970A IF transceiver is used in reverse satellite tuning mode to provide "right side up" tuning. Pictures and a general description can be found on my web page.
- A hand-held 10 GHz receiver for beacon ranging and OSCAR Phase 3D. This unit also uses high side injection, converting into an ICOM R10 receiver.
- A single conversion 24 GHz transverter for portable use. This transverter is built on the back of a dish antenna. It uses a low side local oscillator and Celeritek up/down converter modules. The IF transceiver is an ICOM 1275A, with an intermediate frequency of 1262 MHz. Pictures and a general description can be found on my web page.
- A 24 GHz beacon transmitter. This consists of a Frequency West 6 GHz brick into a Celeritek module used as a quadrupler.
- A hand-held 24 GHz receiver for beacon ranging and OSCAR Phase 3D. Another Celeritek down converter using low side injection and a 1.2 GHz IF into an ICOM R10 receiver.

Concept. With all that behind me, I contemplated what could be done to make a new 24 GHz system with what was available. I did not have enough of the right parts to duplicate the previous design, nor a particular desire to do so. After inventorying the available parts, a novel scheme occurred to me. The key features of the new portable transverter are as follows:

- Dual band operation, covering both 10 and 24 GHz.
- Dual conversion for image rejection and correctness of tuning sense.
- Common local oscillators for both bands.
- 144 MHz intermediate frequency.
- Dual antennas on 24 GHz (no T/R relay needed).
- Small physical size for easy portability.

What conversion scheme would be best? The two bands to be covered and the 144 MHz intermediate frequency are the known quantities used in deriving the exact conversion scheme. Other factors to be considered are:

- Use of the ubiquitous nominal 11 GHz Frequency West "brick" as the first local oscillator.
- Celeritek up/down converters take care of doubling the 11 GHz for 24 GHz low side injection.
- High side injection on 10 GHz inverts the tuning sense whereas low side injection on 24 GHz does not. The choice of second local oscillator frequency and placement of the resulting first intermediate frequencies should restore the correct tuning sense on 10 GHz and retain it on 24 GHz.

Doing the math. Two conversion equations can be derived based on the knowns and the other factors listed above:

For 10 GHz: $F_{if2} = F_I - F_{lo1} + F_{lo2}$
For 24 GHz: $F_{if2} = F_J - 2F_{lo1} - F_{lo2}$

Where F_{if2} is the second intermediate frequency (144 MHz)
And F_I is the "band I" operating frequency (10368 MHz)
And F_J is the "band J" operating frequency (24192 MHz)
And F_{lo2} is the second local oscillator frequency (unknown)
And F_{lo1} is the first local oscillator frequency (unknown)

Solving this system of simultaneous equations in two unknowns yields:

$F_{lo1} = 11424$ MHz
$F_{lo2} = 1200$ MHz

The resulting first intermediate frequencies are calculated as follows:

For 10 GHz: $= F_{lo2} - F_{if2} = 1200 - 144 = 1056$ MHz
For 24 GHz: $= F_{lo2} + F_{if2} = 1200 + 144 = 1344$ MHz

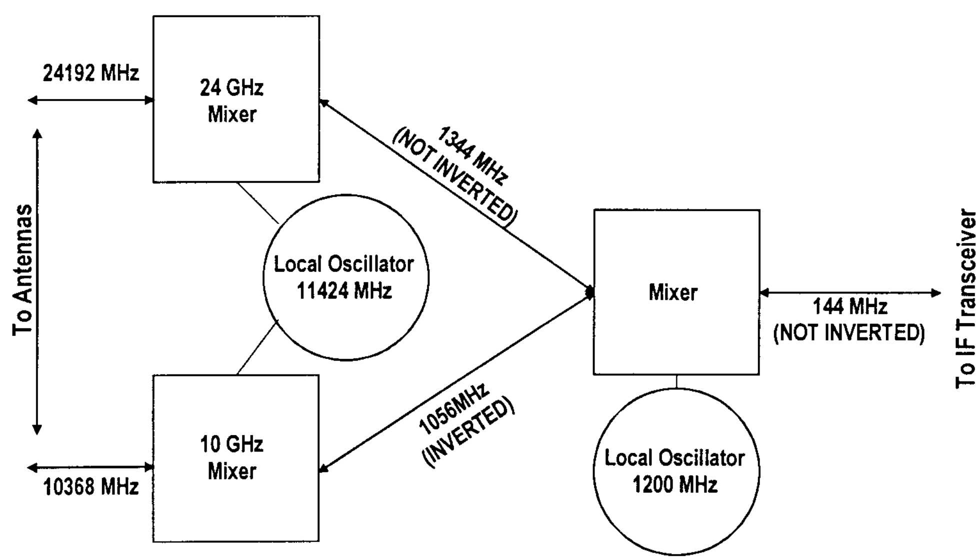
Keeping the same conversion scheme, other frequencies can be calculated for other second intermediate frequencies. The formulae to calculate these are:

$$F_{lo1} = (F_I + F_J - 2\ F_{if2})/3$$
$$F_{lo2} = F_{lo1} - F_J + F_{if2}$$

The table provides the results of calculations for second intermediate frequencies in several VHF/UHF bands, along with the resulting local oscillator and first intermediate frequencies. Use if a 144 MHz second intermediate frequency results in first IF frequencies for which filters may be readily constructed (read on).

IF2	LO1	LO2	IFL	IFH
50	11486.667	1168.667	1118.667	1218.667
144	11424.000	1200.000	1056.000	1344.000
222	11372.000	1226.000	1004.000	1448.000
432	11232.000	1296.000	864.000	1728.000
903	10918.000	1453.000	550.000	2356.000
1296	10656.000	1584.000	288.000	2880.000

Conversion scheme. Based on the concept and the math work above, the following diagram depicts the conversion scheme chosen for the transverters:



10/24 GHz Transverter Conversion Scheme
N4MW Summer 2000

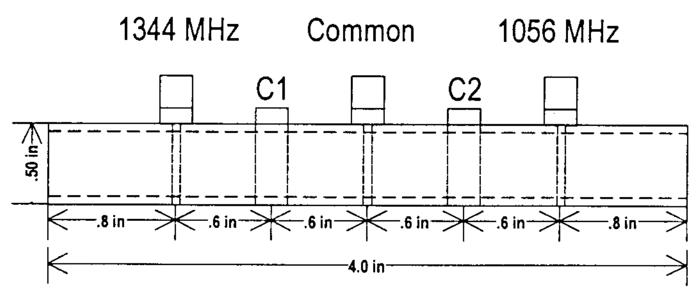
First LO. I used a Frequency West source rated to provide the 11424 MHz frequency. The crystal required is 11424/108 = 105.77778 MHz. Any error at the first local oscillator frequency affects 24 GHz twice as much than 10 GHz due to the internal doubling within the up/down converters. On both bands, errors in the first LO frequency shift the resulting second intermediate frequency in the same direction.

Second LO. A 100 MHz TCXO driving a Downeast Microwave no-tune signal source board provides the 1200 MHz second local oscillator frequency. The board is populated with the optional extra MAR-3 stage for an output of about –6 dBm. One additional packaged MMIC amplifier stage brings the level up to +12 dBm to drive a high dynamic range mixer. Errors in the second local oscillator frequency affect both bands to the same degree but in opposite directions.

Mixers. Four are used, two integrated into the Celeritek up/down converters, one for the 10 GHz band and another for the second IF conversion. Both of the latter are packaged types with SMA connectors. The first mixer is an unspecified model military surplus unit which seems to perform well at 10 GHz. The second mixer is a high dynamic range device (Minicircuits FLM-1H).

Image filtering. On 24 GHz, waveguide filters on the input of the Celeritek modules provide first mixer image rejection. On 10 GHz, the bandpass characteristics of the amp/preamp used provide image suppression. Second mixer Image rejection on both bands is provided at the respective first intermediate frequencies (1056/1344 MHz) using filters (see Diplexer section).

Diplexer. Both high and low second mixer products are used, for each band respectively. A simple diplexer was constructed to provide filtering and to separate the mixer frequencies, which also eliminates the need for a band switch relay in the first IF. This diplexer is based on the evanescent mode filter article by W4CQH in the 1996 Microwave Update Proceedings. Two filters back-to-back with a common input connector form the diplexer. It is built in a 4 inch length of WR-90 waveguide. One side is tuned to 1056 MHz and the other to 1344 MHz. The filter insertion loss is about 1.5 dB and the image rejection is almost 30 dB. Capacitors C1 and C2 are 1-16 picofarad ceramic piston types. The three connectors are SMA two-hole flange style. The center connector of each connector is carried through across the waveguide to the opposite wall to form coupling loops. I constructed the device with 4-40 tapped holes opposite the connector centers. 4-40 X ½ screws in these holes are used to complete the coupling loop circuits.



Evanescent mode diplexer

Signal switching. No RF switching is needed at 24 GHz due to the use of two separate horn antennas. On 10 GHz, a common amplifier/preamplifier is alternated for transmit/receive using a transfer relay. First IF transmit/receive switching between the Celeritek up/down converters employs a DPDT SMA relay. The evanescent mode diplexer described above automatically routes the IF frequencies for each band, eliminating the need for another relay. Except for the transfer relay, power dividers could eliminate all the relays, with the ensuing higher signal path losses. I opted for relays in order to reduce the need for IF gain stages.

First LO distribution. The first local oscillator power must be provided to the two Celeritek modules and the 10 GHz mixer. I originally intended to route all the power using a three-pole single throw SMA relay. The particular LO I used provides a whopping +18 dBm, so I decided to use power dividers instead of relays to simplify the switching as well as to provide the appropriate mixer injection levels. One two port power divider provides about +12 dBm to the 10 GHz mixer after a 3 dB fixed attenuator. The remaining port drives a second power divider which provides about + 11 dBm to each Celeritek module.

Power supplies. The primary power is supplied from an external +12 volt source, such as a vehicle battery. The negative voltage for the Frequency West first LO is generated from the +12 volt input using a DC-DC converter module, which produces –24 volts. A 7920 regulator reduces that to the required –20 volts. Everything else runs from the +12 volt nominal input, either directly or through integrated voltage regulators. Another regulator and DC to DC converter are used for the transmit/receive relays (see below)

Transverter Control. T/R, band and bypass control circuitry is built into the bottom side of the RF deck along with the various power supplies. The following table describes the voltage states required for devices in all conditions.

Transverter State Table

Device	Band and T/R State				Transverter power/bypass state		
	10 GHz		24 GHz				
	TX	RX	TX	RX	On	Standby	Off
10 GHz amp/preamp	+12	+12	0	0	TX/RX	0	0
24 GHz upconverter	0	0	+12	0	TX/RX	0	0
24 GHz downconverter	0	0	0	+12	TX/RX	0	0
10 GHz transfer relay	+24	0	0	0	TX/RX	0	0
High IF relay	0	0	+24	0	TX/RX	0	0
Transverter bypass relay	+12	+12	+12	+12	+12	0	0
1200 MHz LO/amp	+12	+12	+12	+12	+12	+12	0
11424 MHz LO	-20	-20	-20	-20	-20	-20	0

T/R switching. The only devices requiring switching of supplied voltage are the relays and the Celeritek modules. Both RF relays used are 24-volt types, activated during transmit. A 5 to 12-volt DC to DC converter is connected to provide a 24 volt source. 12 volts switched on transmit is available from the interface (see below). This voltage drives a 7805 regulator, which in turn drives the DC to DC converter to supply the relays. This method keeps the relays isolated from the active RF devices to prevent spikes from causing damage. (An alternative is two Downeast RVD relay driver boards)

Band switching. A small toggle switch is used to alternately route power to the active modules for each band. If appropriately wired, It is also possible for both bands can be activated simultaneously, perhaps desirable for use as a beacon. Receiving on two bands at once is also possible, albeit potentially confusing.

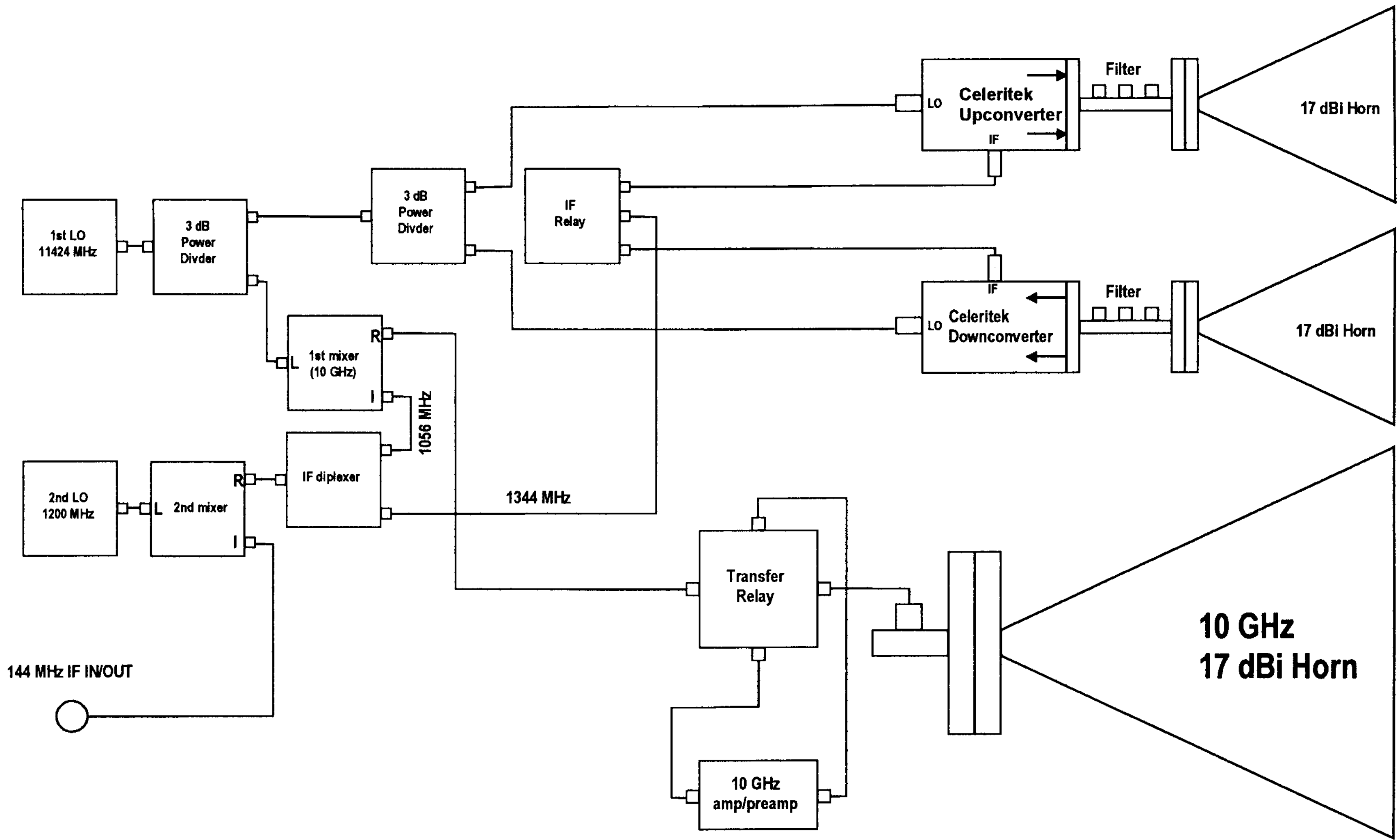
IF interface. A Downeast transverter interface board (TIB) is built into the transverter package. This board produces an ALC voltage which sets the transmit drive level. The auxiliary relay is wired to provide a switched +12 volts for application to the appropriate points in the transverter. A four conductor cable connects between the IF transceiver (ICOM 706) accessory jack and the transverter. A small toggle switch enables/disables the transverter, although power remains applied to the oscillators. BNC jacks are provided for connection to the IF transceiver antenna jack and for passthrough to an antenna when the transverter is disabled.

Packaging. The transverter is constructed on a thin aluminum subchassis. RF components are located on top of the sheet and supporting circuitry is below. This subchassis fits inside a cover made from aluminum plate. A thicker plate inside the bottom of the box is tapped ¼-20 to provide a tripod socket. Plastic feet and a side handle make it portable. The flat top provides a place for the IF transceiver. Overall, the transverter resembles an oversize Heathkit lunch box transceiver.

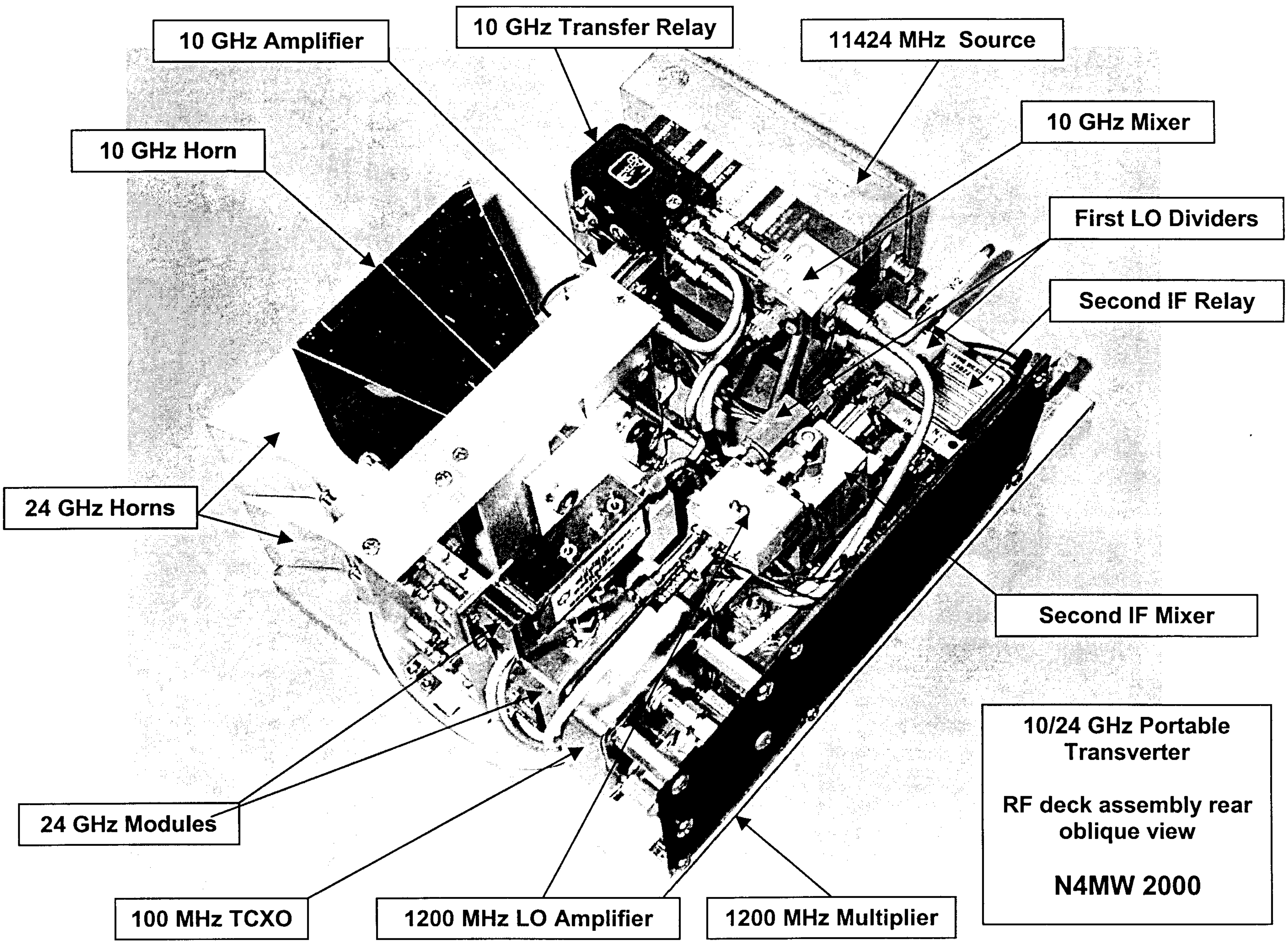
Conclusion: The information above is not intended to be detailed enough to exactly duplicate my project. I hope that enough information is provided to give some ideas on ways to configure and package transverters for more than one band.

Attachments:

1. Block Diagram
2. RF deck assembly rear oblique view photo (annotated)
3. RF deck assembly front oblique view photo



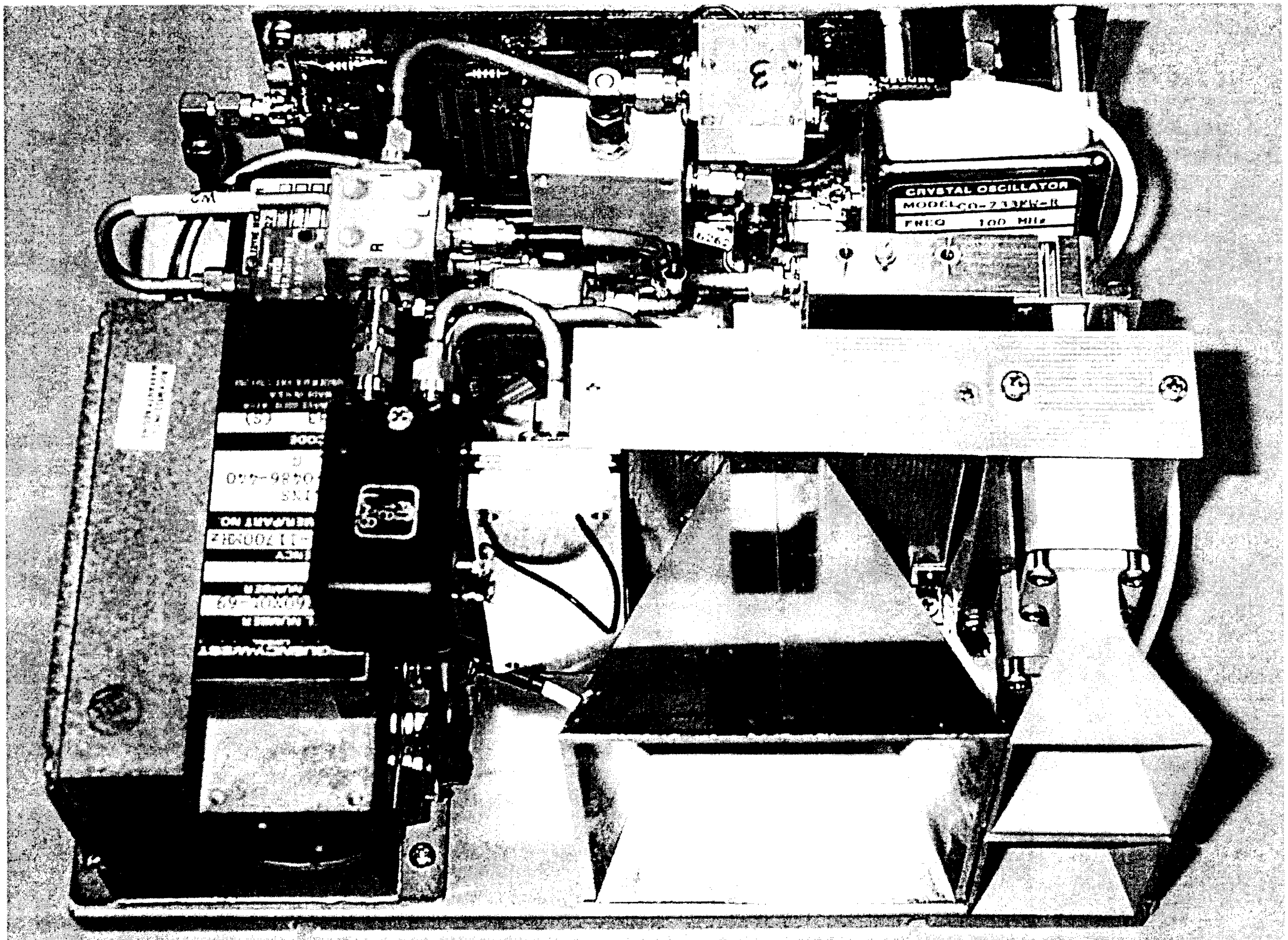
10/24 GHz Transverter Block Diagram
N4MW Summer 2000



10/24 GHz Portable Transverter

RF deck assembly rear oblique view

N4MW 2000



10/24 GHz Portable Transverter - RF deck assembly front oblique view – N4MW 2000