Simple and Cheap Multiband Microwave Transverters

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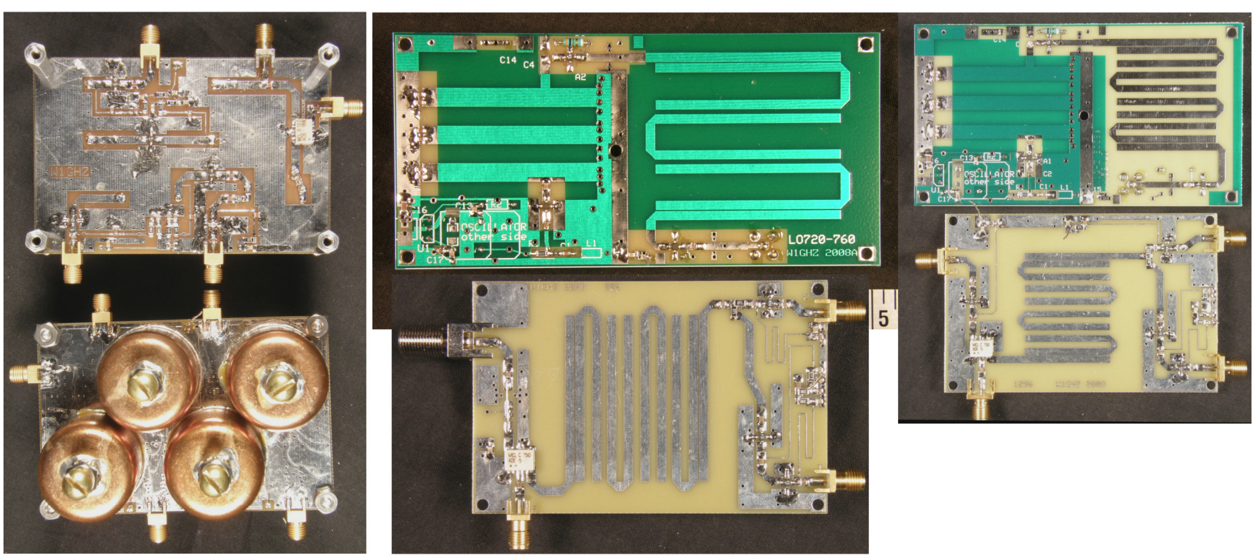
For roughly the past ten years, I have been working on simple reproducible transverters for all microwave bands from 902 MHz up to 10 GHz. It took a while to work up to the higher frequencies, with some painful and expensive lessons along the way. I'll describe some of these learning experiences as well as the final results, with the hope that some readers can learn from them and go on to new mistakes instead of repeating old ones.

Back in the 1960s, Loren Parks, K7AAD, published a small magazine called the VHFER. The motto on every issue was "Learn by Doing." I've found this to be a useful approach in many endeavors.

The original concept was simple transverters to enable rovers to add additional bands without great expense. Operating on multiple microwave bands in VHF contests will greatly enhance a score, as well as lending some excitement to quiet periods. This is particularly true for rover operation. Hilltopping with the microwave gear can also be a lot of fun between contests. However, buying equipment for many bands is not only a considerable expense, but also results in a lot of gear to carry around. These simple transverters could be part of a compact multiband package.

A good number of hams have successfully built some of these transverters, not all of them for rovers. Some saw the opportunity to add a new band, while others built them as a second station to loan out. Others just wanted an opportunity to build something, to try something new or just for fun.



A brief description of each transverter follows, with links to more details. I have PC boards available for all of them, as well as some critical parts like mixers that are difficult to purchase in small quantities. All are described in full detail in papers at **www.w1ghz.org**

Design Philosophy

The basic design philosophy is that today, *gain is cheap*. Traditional microwave engineering worked to minimize losses because gain was hard to come by. We don't need to use exotic parts to keep losses down, because MMICs provide cheap gain – less than 25 cents per dB – so if we give up a dB to use an ordinary, readily available part rather than an expensive microwave part, it is a reasonable tradeoff. We start with the PC boards, using ordinary epoxy-fiberglass board rather than Teflon-based microwave material. The loss is perhaps a dB per inch higher, but fabricated boards are readily available without exorbitant lot charges, and the cost per board is reasonable in modest quantities. For capacitors we use ordinary chip capacitors, at a few cents each, rather than microwave capacitors costing a dollar each. In some applications, two ordinary capacitors in place of one microwave capacitor results in lower loss at lower cost. The final tradeoff is to try and limit the number of different part values, using multiples of each value rather than many different values, since prices are much more reasonable in quantities of 100. Finally, commodity parts that will continue to be readily available are preferred.

The lower frequency PC boards, up to 1296 MHz, use printed hairpin filters (http://www.w1ghz.org/filter/Recipes_for_Printed_Hairpin_Filters.pdf) so tuning is needed – all the magic is in the PC board. Higher frequencies use copper pipe-cap filters (http://www.w1ghz.org/filter/Pipe-cap_Filters_Revisited.pdf) , which are inexpensive but require soldering and tuning.

Most of the MMICs and mixers are readily available from Minicircuits, and the other parts are available from DigiKey or Mouser. Although they are common parts and readily available, the manufacturer and distributor part numbers keep changing so I have given up trying to maintain parts list with distributor part numbers.

When I first built these transverters, a significant part of the cost was SMA connectors – the least expensive ones I could find were about $5 each. I even experimented with F connectors for the LO and IF connections. Today, there are tons of SMA connectors on ebay, for roughly $1 each, much less if you buy 50 at a time. These seem to work fine up to 5760, but for 10 GHz I chose to stick to name brands – Taoglas from Digikey run about $3.50, or you can go for Amphenol at ~$12. W7GLF tried the cheap ones at 10 GHz with poor results, then switched to the Taoglas connectors and saw an improvement of more than 10 dB.

Another improvement at 10 GHz might be to use the more expensive ATC capacitors – W6QIW reports a 2 to 5 dB improvement. At lower frequencies, the difference should be much smaller.

Multi-band Strategy

The original multi-band strategy was s a single oscillator source providing the local oscillator (LO) to transverters for several microwave bands. This not only reduces the power needed for LO, allowing the oscillator to be powered continuously for better stability, but also enables better compensation for frequency errors, since the frequency error on one band each band is a simple integer multiple of the base oscillator frequency. Thus, once a frequency offset is found on one band, it may be quickly predicted and compensated on other bands.

The microwave LO source frequency is at 720 MHz, generated from an inexpensive 80 MHz computer oscillator. The 720 MHz source is multiplied to provide an LO for 1296, 2304, 3456, and 10368 MHz, with normal 2-meter and 432 MHz IF frequencies. Figure 1 shows the overall frequency scheme; each transverter includes the final multiplication needed for a particular band. Harmonics of 720 MHz conveniently occur 144 MHz away from 1296, 2304, and 3456 MHz, and 432 MHz away from 10368 MHz, except that all but 2304 MHz are above the activity frequency. Thus, the calling frequency lands at about 143.9 MHz or 431.9 MHz, with inverted SSB. This is a minor inconvenience, since most of the common IF transceivers can be readily modified to tune slightly out of the amateur band. Many of us have been tuning upside-down on some of the microwave bands anyway, using surplus "brick" oscillators for the LO, and accurate frequency readout is only a coincidence.

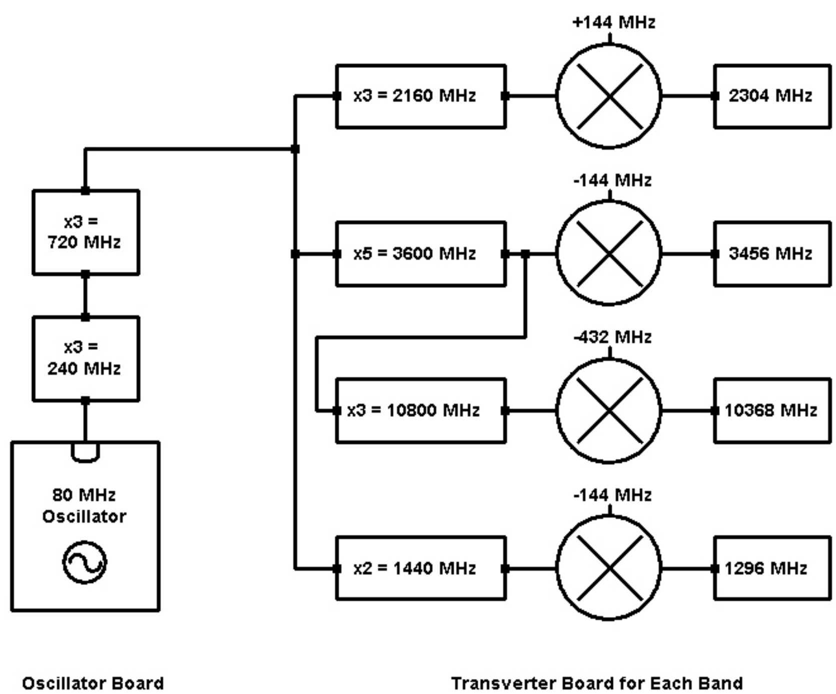
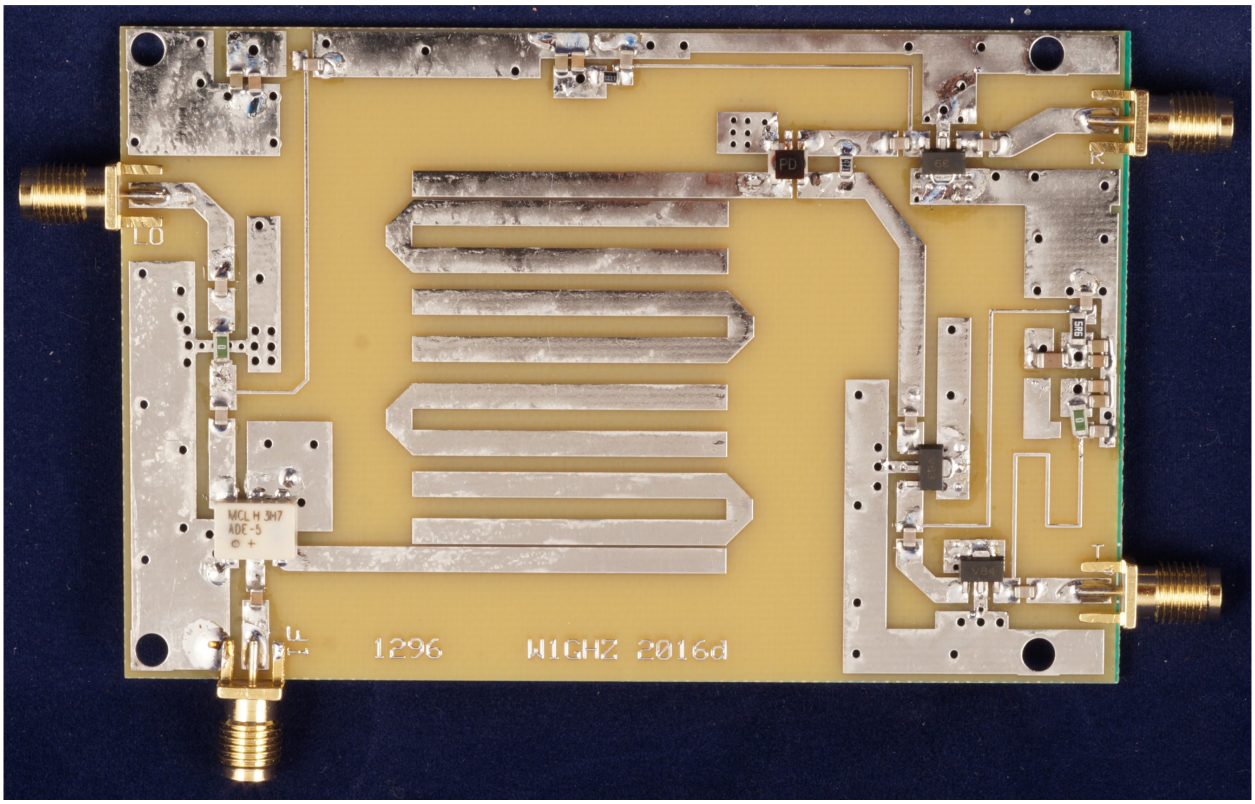


Figure 2. Multi-band Frequency Scheme

1296 MHz

The microwave band with the most activity is 1296 MHz, and this transverter is the most popular. The original multiband strategy with “upside-down” tuning and SSB was not popular at 1296 MHz, and there seemed to be enough demand to make a standalone transverter and LO at 1152 MHz for a normal 144 MHz IF. This transverter is simple to build, and features a printed hairpin filter, so no tuning is necessary.

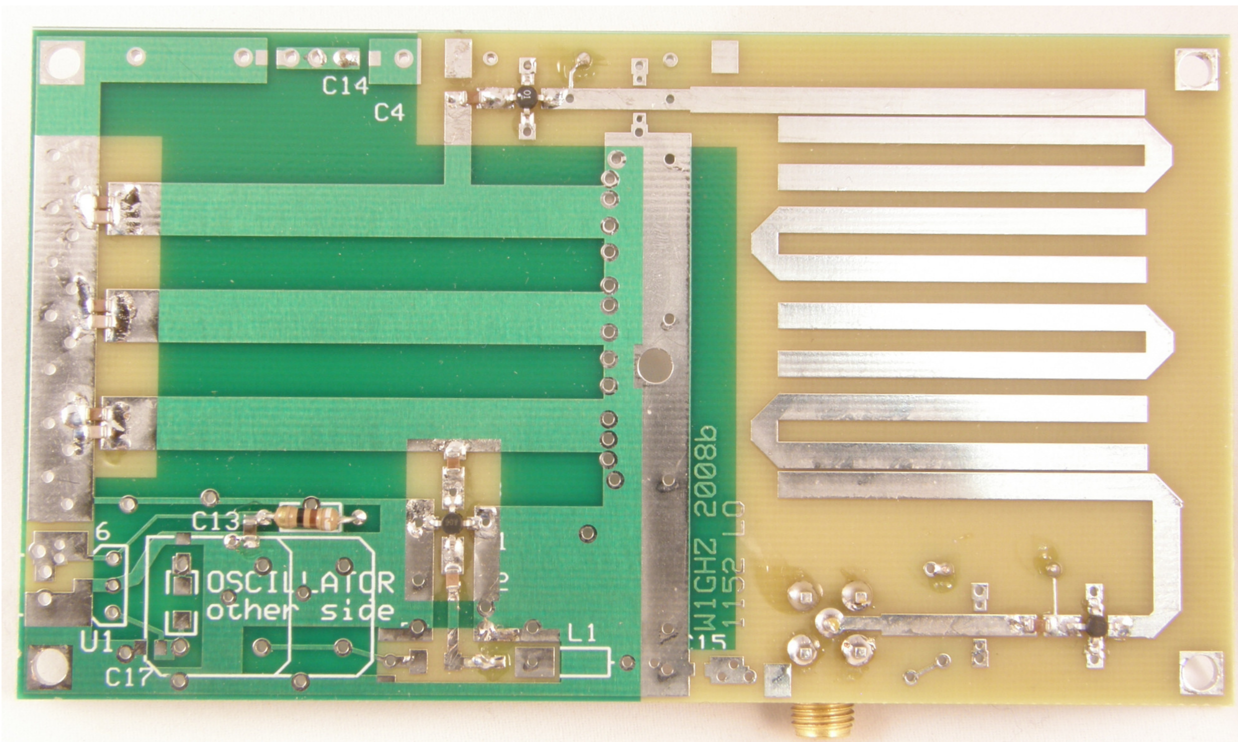
The latest version has provision to use some of the newer MMICs in SOT-89 packages for higher performance, and a Minicircuits power splitter to separate transmit and receive.



1152 MHz Local Oscillator Board

The most common LO frequency for 1296 MHz is 1152 MHz, to provide an IF at 144 MHz. A low-cost frequency source is a 64 MHz computer crystal oscillator, which is then multiplied on the board. There are two printed filters: a hairpin filter at 1152 MHz which needs no tuning, and a combline filter at 192 MHz which is tuned by chip capacitors. The tolerance variation in cheap capacitors sometimes necessitates a bit of fiddling for maximum output.

Alternative LO sources also work. One choice is a 64 MHz VCXO locked to GPS (http://www.w1ghz.org/small_proj/VCXO_for_Microwave_LO_update2.pdf) for frequency accuracy and stability with low phase noise. Another possibility is a frequency synthesizer, like the ApolLO-32 from Down East Microwave, or a cheap Chinese one from ebay.



2304 and 3456 MHz

These two bands use the same PC board – the frequency is determined by pipe-cap filters, which can be tuned to either band, or other calling frequencies in these bands. The board also includes the final LO multiplier and amplifier, with pipe-cap filters for a clean LO signal. The input to the LO multiplier is at 720 MHz, multiplied by three to 2160 MHz for 2304, and by five to 3600 MHz for 3456, providing a 144 MHz IF for both bands. Other input frequencies also work, since the pipe-cap filters have a wide tuning range.

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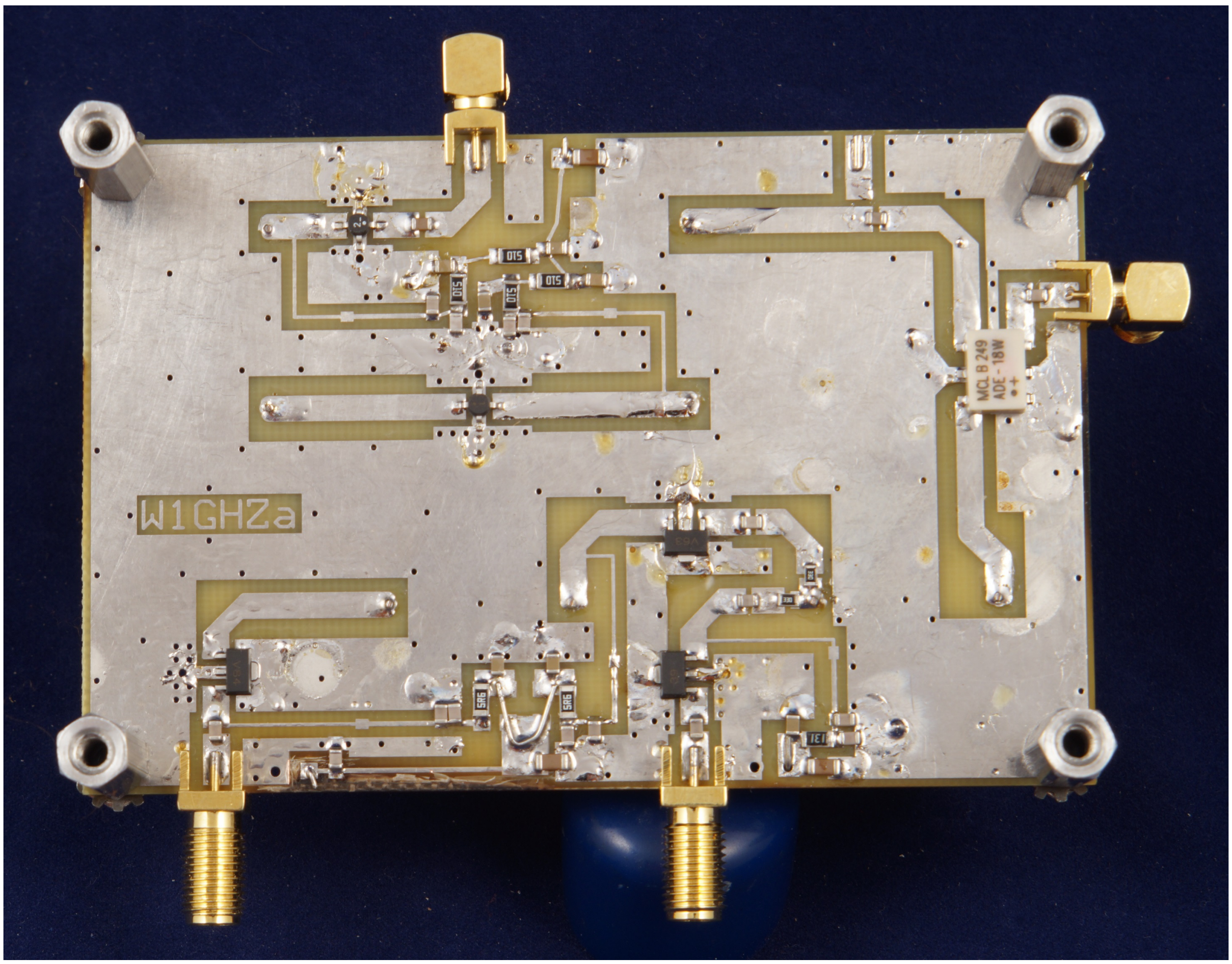
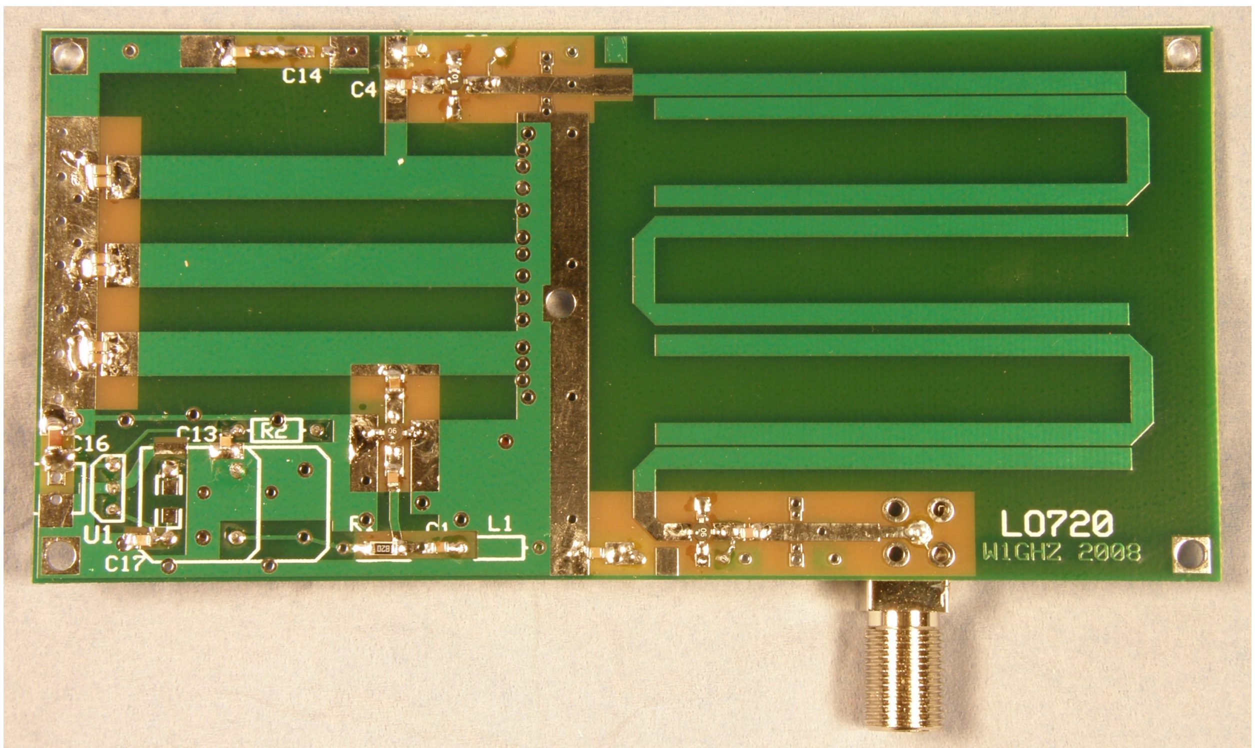


720 MHz Local Oscillator Board

The LO board to generate the 720 MHz signal is similar to the 1152 MHz board, except that the hairpin filter is for 720-760 MHz. The low-cost frequency source is an 80 MHz computer crystal oscillator. The combline filter, tuned to 240 MHz by chip capacitors, seems to be more forgiving than at 192 MHz.

Alternative LO sources also work. One choice is a 80 MHz VCXO locked to GPS for frequency accuracy and stability with low phase noise. Another possibility is a frequency synthesizer, like the ApolLO-32 from Down East Microwave, or a cheap Chinese one from ebay.



902 MHz

The next band was 902 MHz. The transverter board was straightforward, just swapping a different printed hairpin filter into the 1296 MHz artwork. The LO was harder, since an appropriate computer oscillator was not available, but I found that a 36 MHz oscillator could multiply to 756 MHz for a 146 MHz IF for 902 or 147 MHz for 903. Then I tweaked the printed hairpin filter on the original LO board to cover 720 to 760 MHz to pass both 720 and 756 MHz so that the revised PC board could be used for both. Of course, a frequency synthesizer is an alternative to eliminate the odd IF frequency.

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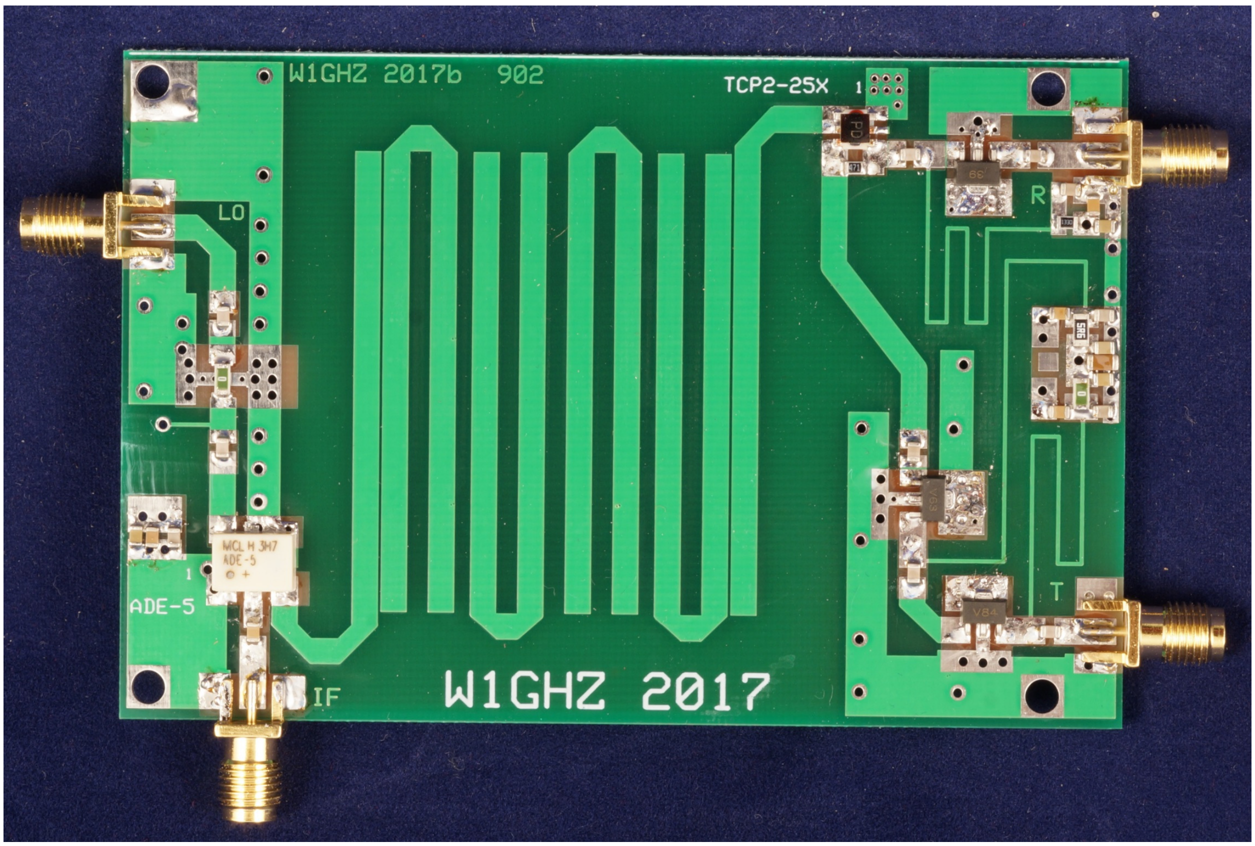
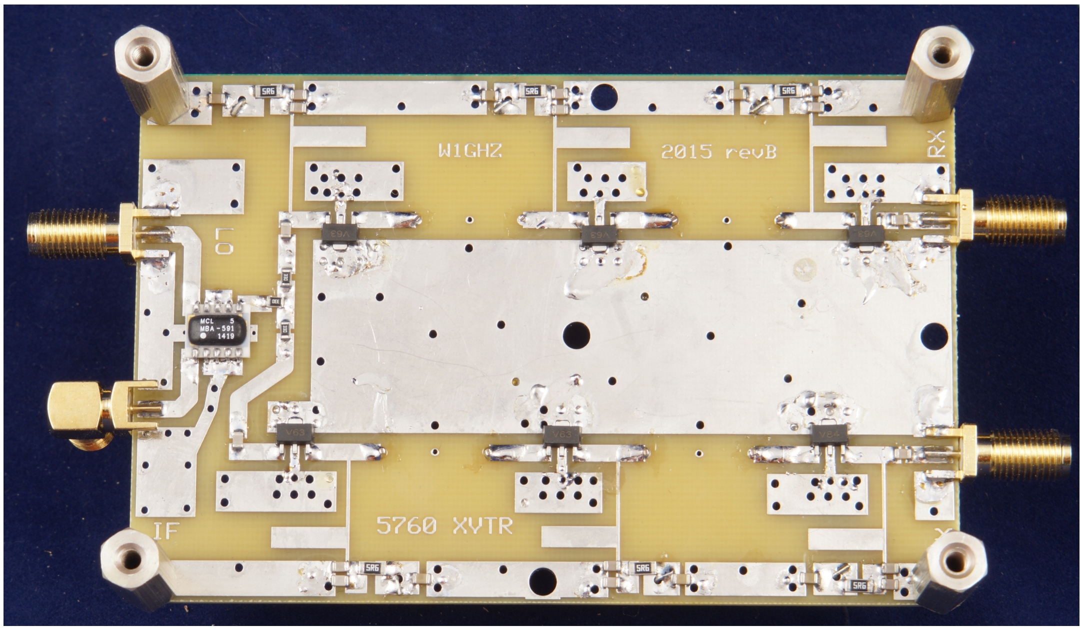


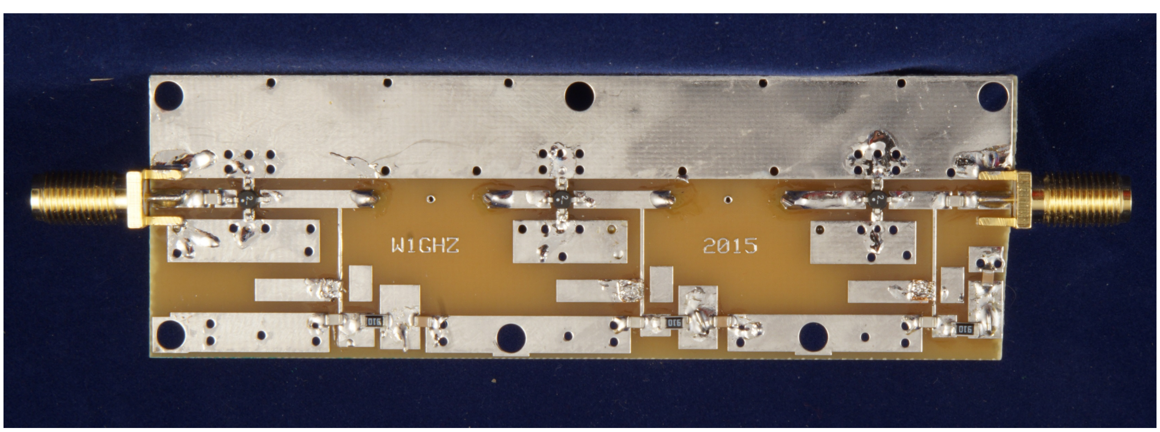
5760 MHz

This band was not included in the original multiband strategy because it didn't fit the LO scheme – 5760 MHz is a multiple of both 720 and 1152 MHz, so a different LO source is required. I never found a suitable computer oscillator, but frequency synthesizers have since become readily available. At this frequency, MMICs have less gain, so I used three stages on both transmit and receive, with a pipe-cap filter between MMIC stages.



3 & 5 GHz LO Multiplier board

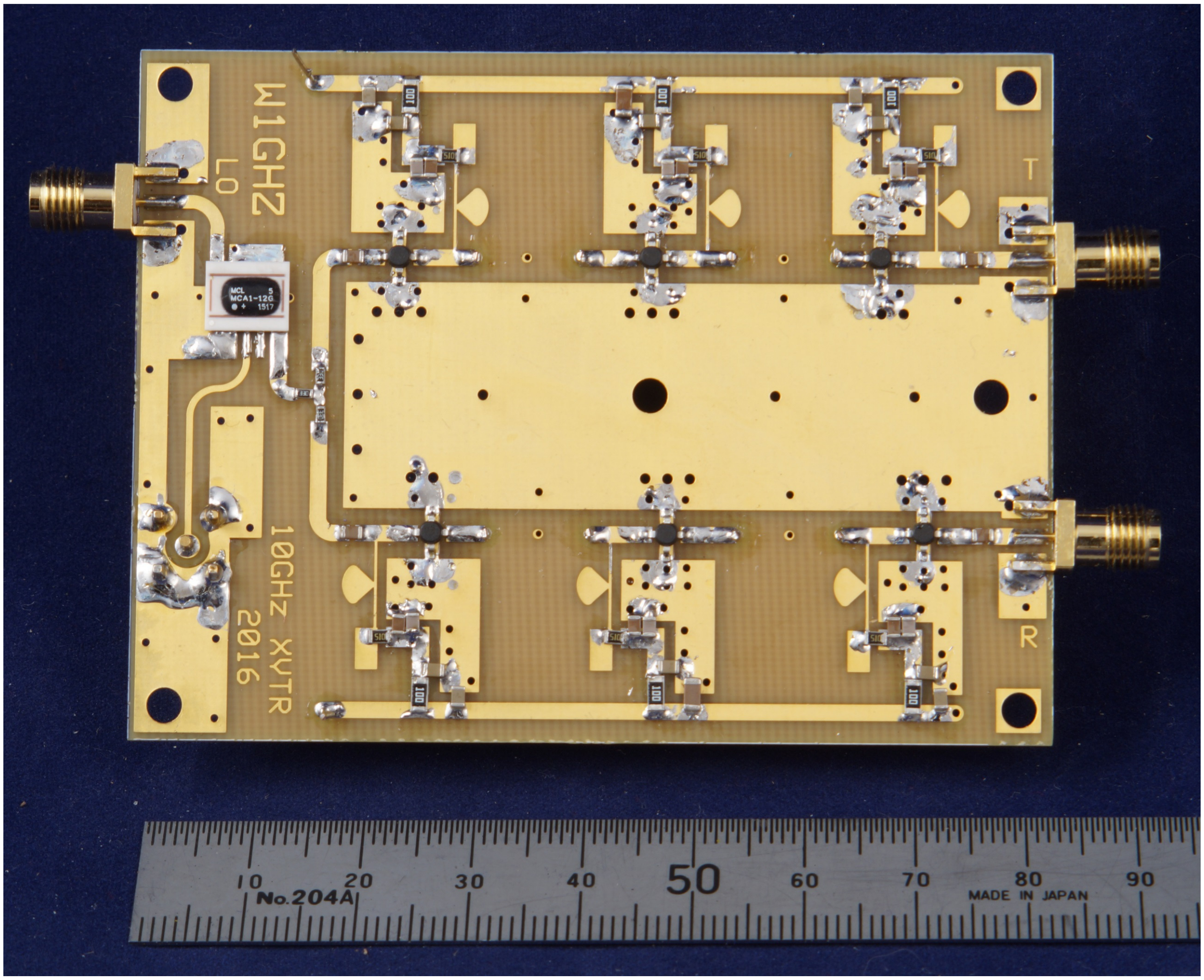
Appropriate frequencies are readily available using frequency synthesizers, but few go high enough in frequency so must be multiplied up to the 5 GHz range. A simple frequency multiplier board using MMICs and pipe-cap filters does the job, with input frequencies between 1 and 3 GHz. The pipe-cap filters can be tuned low enough in frequency for a 3456 MHz LO as well.



10 GHz

A simple transverter for 10 GHz proved much harder – ordinary PC board radiates badly above about 7 GHz, and most MMICs run out of gain. The solution was to use thinner PC board material. Development of this transverter was a somewhat painful learning experience – see the paper for details.

The only MMIC with adequate gain that I have found, the RFMD NLB-310, is discontinued at DigiKey, but can be purchased direct at www.qorvo.com. A possible alternative is the NLB-400, available from Mouser.



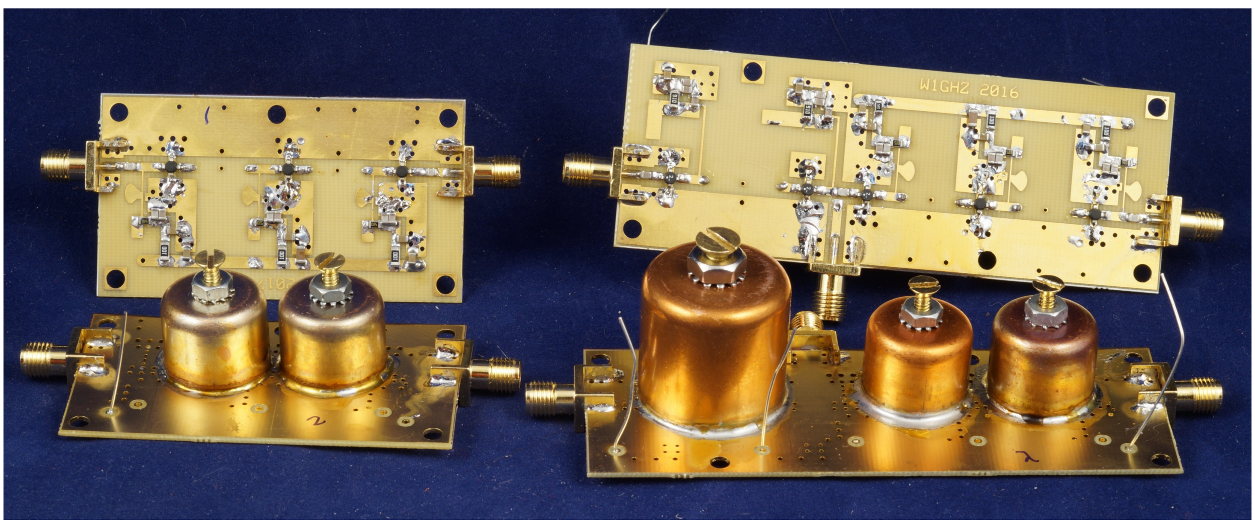
10 GHz LO Multiplier board

Whether we use the original multiband LO strategy or opt for a 2 meter IF, a frequency multiplier is needed. I made a frequency multiplier board using MMICs and pipe-cap filters and called it a "Personal Beacon for 10 GHz." This uses ordinary thick PC board material which has significant radiation, but a beacon is supposed to radiate.

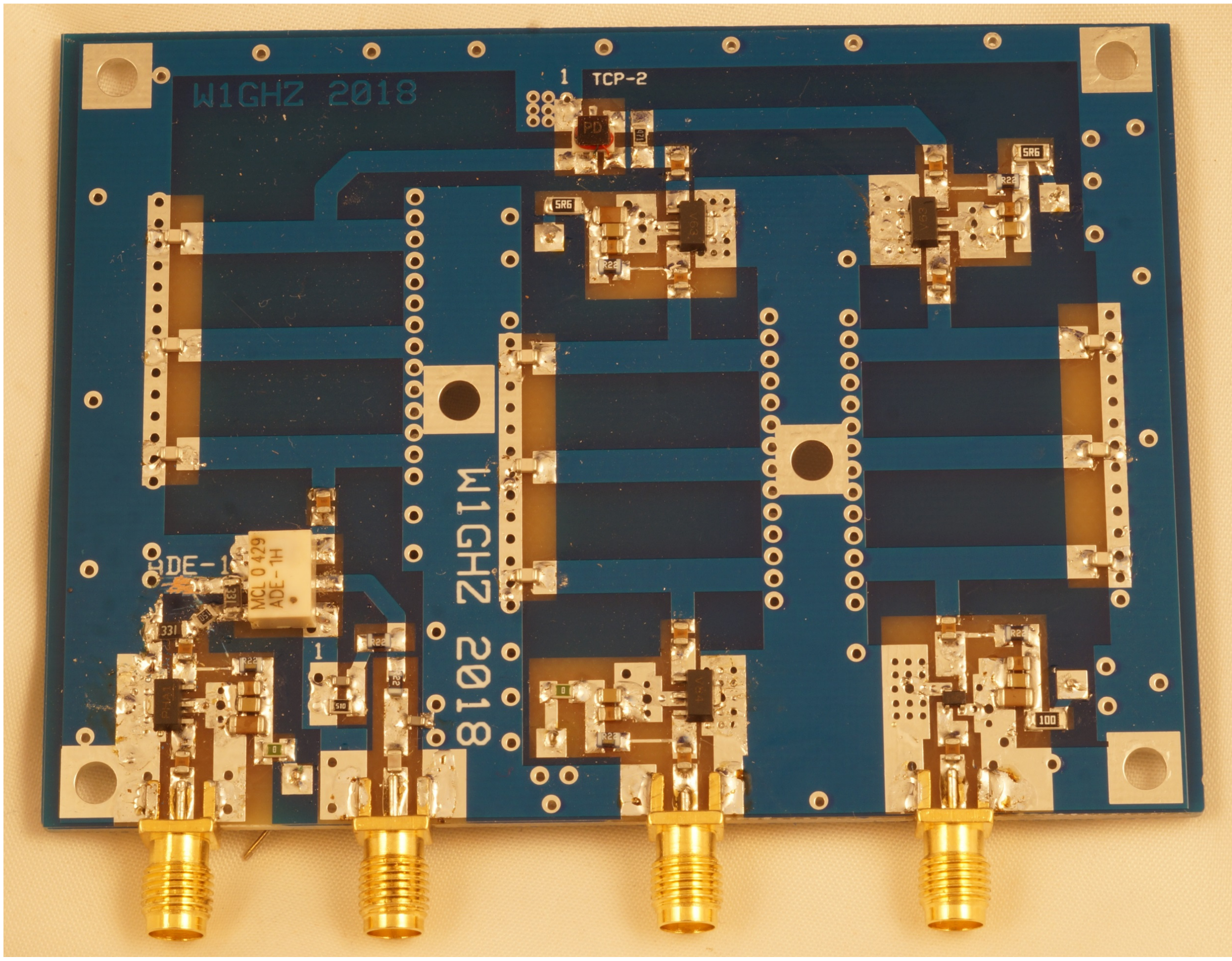
However, for an LO, radiation is undesirable. I modified the board for thinner material, and it works well, multiplying by 9 to provide a 10 GHz LO from a source in the 1 GHz range. This board also works well as a Personal Beacon.

For higher frequency synthesizers, a smaller multiplier board multiplies by 2, 3 or 4 times to provide the 10 GHz LO.

All these multiplier boards use pipe-cap filters with wide tuning range, so they have other potential uses as well.



432 MHz Transverter

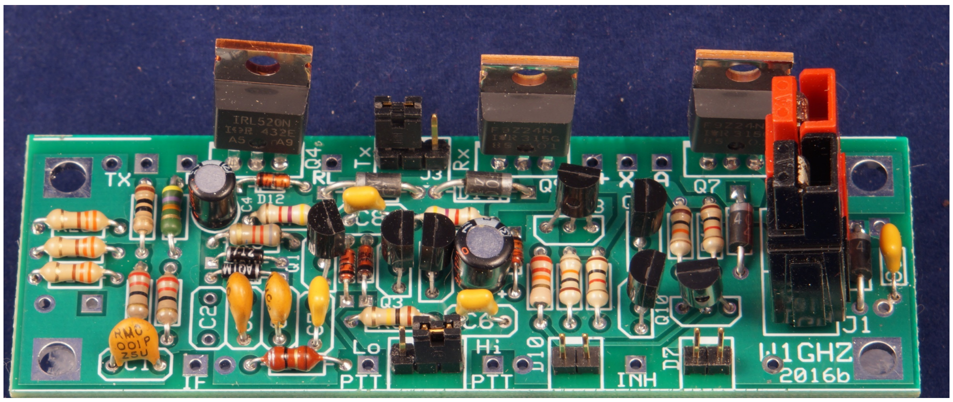


Sequencers

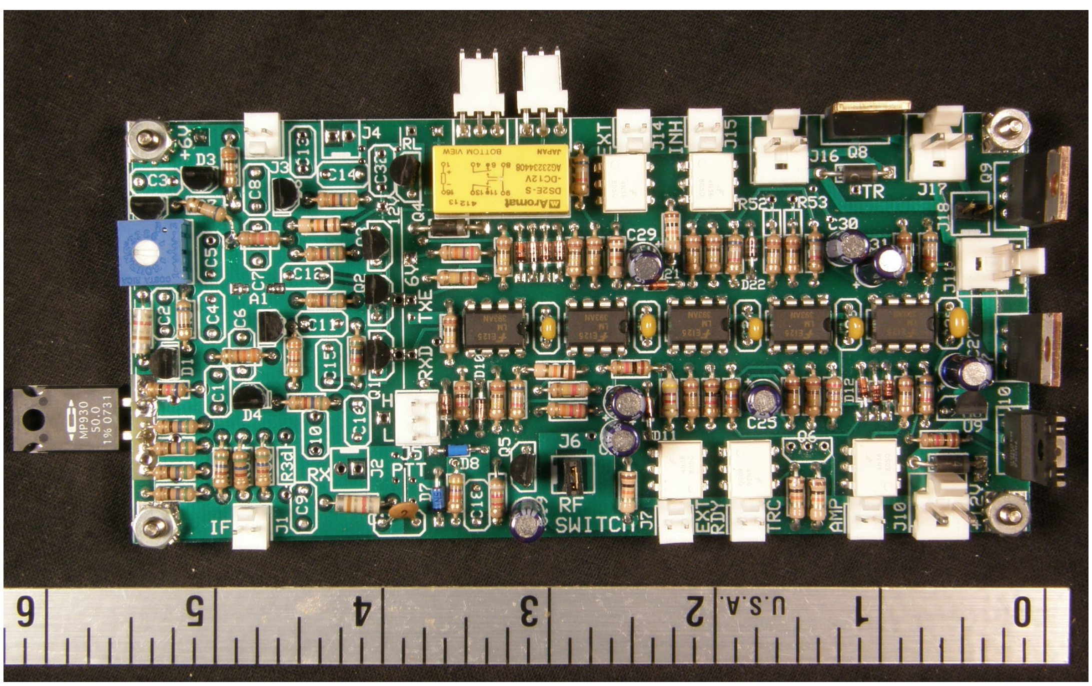
Unless you are only running a basic transverter with a milliwatt IF rig, you need a sequencer. It's cheaper than whatever you will blow up.

I have made four generations of fool-resistant sequencers, and PC boards are available for the last three:

- **Mark2** – a simple sequencer for transverters like those from DB6NT that have the IF interface built in, and only need sequencing of power amplifier and TR relay.



- **Mark3** – is a conditional sequencer with a PIN-diode IF interface that absorbs IF transmit power until switching is complete. A conditional sequencer can wait for external events to complete rather than just operating in a clockwork sequence. This version uses many discrete parts to provide all the needed logic funtions.



- **Mark4** – a smart conditional sequencer with the same PIN-diode interface. The discrete parts are replaced by an Arduino, easily programmable so you can make it as smart as you desire.