Cheap and Simple Transverter for 2304 or 3456 MHz, Mark 2

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The Multiband Transverters for the Rover[1] include a transverter which could be tuned for 2304 or 3456 MHz, and an update[2] to use newer MMICs improved performance. The accompanying LO board has a 720 MHz output, so the transverter has an LO multiplier and amplifier to produce either 2160 MHz for 2304 or 3600 MHz, for 3456. One downside is that 3456 MHz is upside-down, so tuning is backward.

While this arrangement is simple and cheap, it lacks flexibility. In different areas, frequency allocations and activity are on different frequencies: 2320 MHz, 2400+ MHz, and around 3400 MHz. Inexpensive computer oscillators are not available for these other frequencies, and inexpensive frequency synthesizers operating up to 4 GHz with reasonable performance have become available. Using a synthesizer offers frequency flexibility and makes the multiplier stages unnecessary.

There also seems a possibility that the amateur frequency allocation may be moved from 3.3 to 3.5 GHz. This transverter can easily be adapted to other frequencies between 2.5 and 4 GHz, if we do end up with some allocation.

Mark 2 Transverter

Inexpensive PC boards seem to have a 4-inch size limit. Only four large (nominal 1-inch) pipe caps fit in the available area. In the earlier version, one pipe cap was needed to filter the multiplier, so I used two between transmit stages and one with a single receive amplifier.

The Mark2 transverter retains the four pipe caps, using the 4th for better receive filtering, and adds a second receive amplifier stage for better noise figure. The four pipe caps were originally staggered, but this made the layout of the new board cramped. I chose to make the board slightly larger so that the layout is symmetrical – it looks like a larger version of my 5760 transverter, as seen in Figure 1.

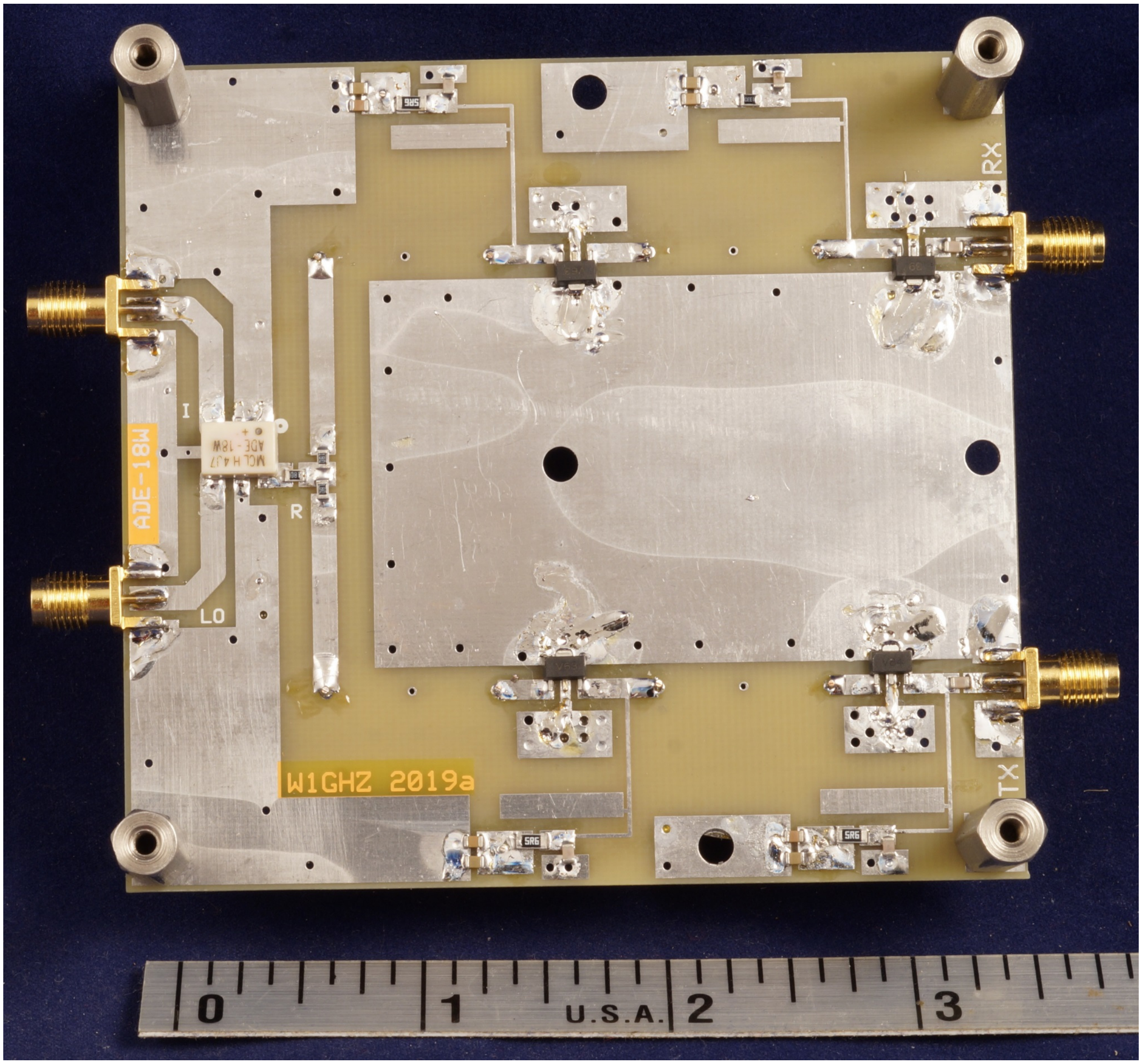

Figure 1 – Transverter for 2304 or 3456 MHz – only difference is pipe-cap tuning

The MMICs have more gain at S-band (2 to 4 GHz) than at higher frequencies, so only two amplifier stages are used in each direction, rather than the three stages used for the higher bands. The schematic diagram is shown in Figure 2. The PCB layout of all amplifier stages is identical; DC is supplied through a quarter-wave choke for 3456, with a quarter-wave stub for decoupling. For 2304, there is a decoupling capacitor a quarter wavelength from the MMIC. The combination seems to be adequately broadband – I had intended to cut the stub when building for 2304, but it proved unnecessary. Thus, the only difference between the two bands, or any frequency from 2.3 up to about 4 GHz is the tuning of the pipe caps.

The receive front end MMIC is a GALI-39, which provides good gain and noise figure at these frequencies, but needs a higher voltage and a bias resistor for operation.

The transmit final stage is a VGA-84, which provides good power and high gain.

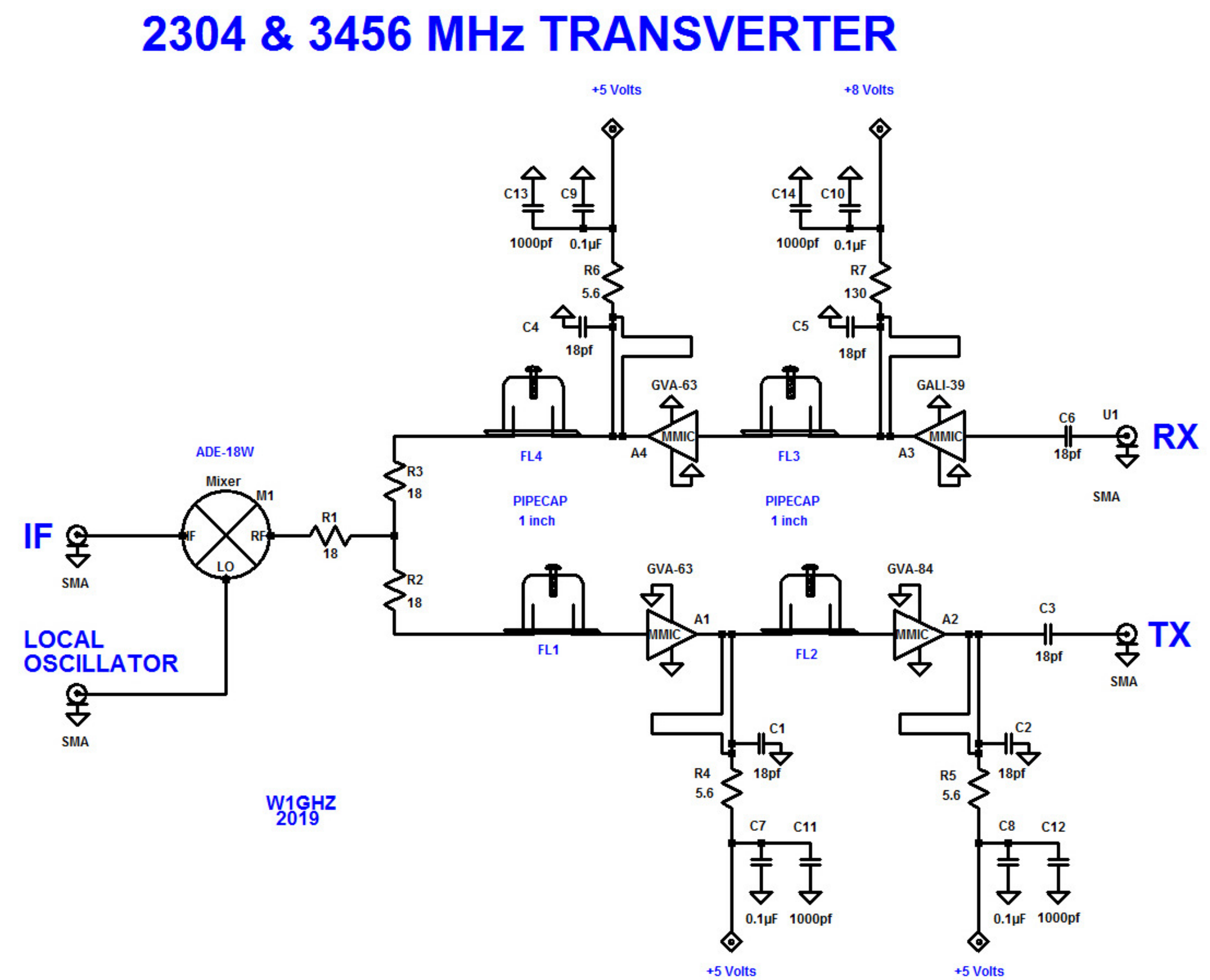

Figure 2 – Schematic diagram of Transverter for 2304 or 3456 MHz

The pipe caps, shown in Figure 3, are tuned by 10-32 brass screws or a similar metric screws. Steel screws probably work with slightly more loss. Screw length of one inch is adequate for 3456, but the screws must reach nearly to the bottom of the pipe cap to tune down to 2304 MHz, so a longer length is needed.

Performance

The transverter performance is pretty good. With LO of around +7 dBm at 2160 or 3312 MHz, transmit power was about +17 dBm at one-dB compression, and noise figure around 3.5 dB, on units tuned for 2304 and for 3456 MHz. At 3456, LO rejection was >50 dB and image rejection about 45 dB. The 2nd harmonic was about 30 dB down, 3rd about 40 dB down, and 4th nearly 50 dB down. At 2304, harmonic levels were similar and LO rejection about 60 dB. I apparently didn't note the image rejection.

Performance was tested with LO levels down to +2 dBm, resulting in a dB or two less output power, so the transverter will still work well if you a little short on LO power. But *gain is cheap* – a simple MMIC amplifier can easily fix LO problems.

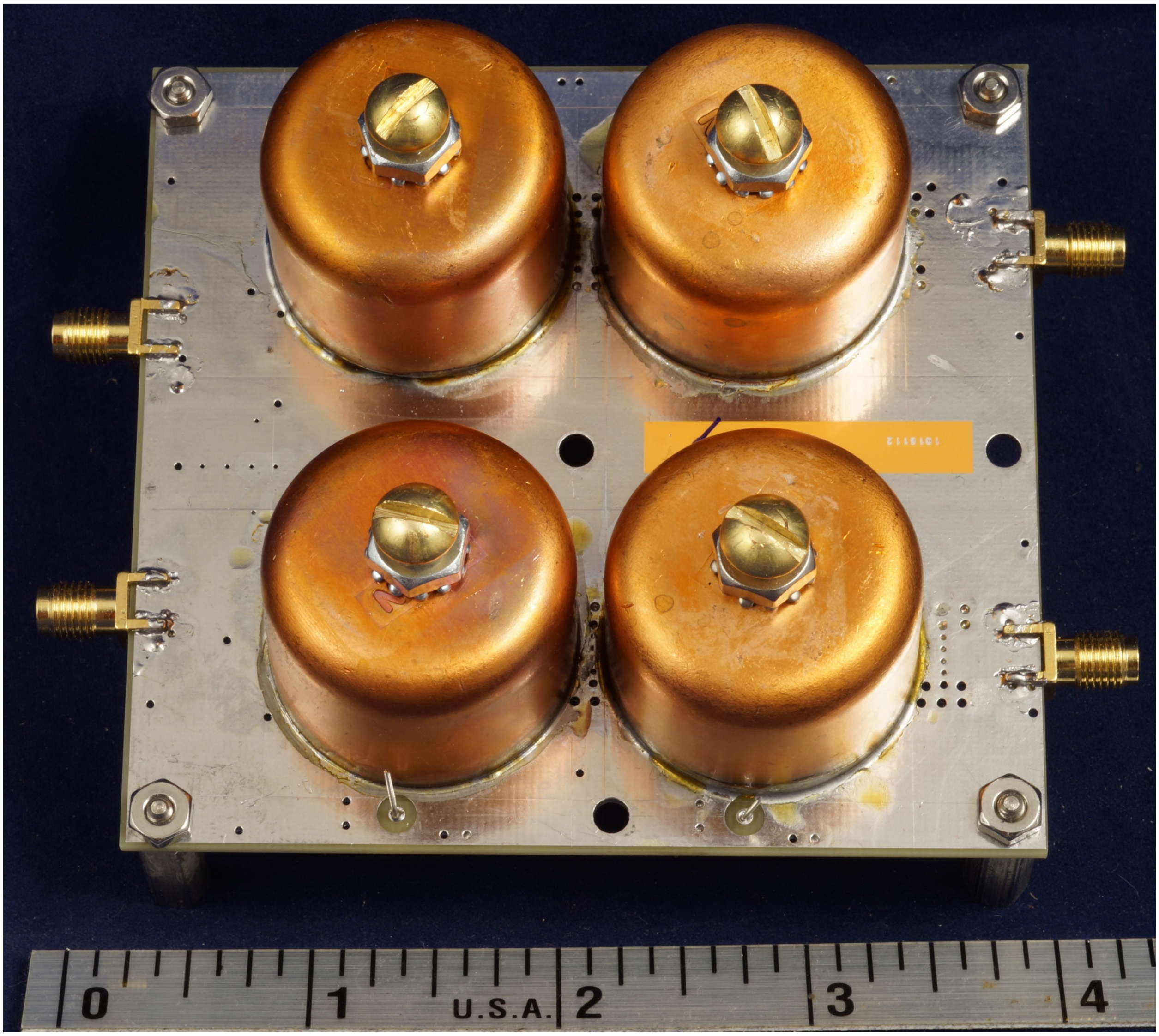

Figure 3 – Pipe cap side of Transverter for 2304 or 3456 MHz

Construction

The first step in assembly is to solder the pipe caps to the board, after drilling and tapping the 10-32 screw holes in the top of the caps. Each pipe-cap location on the PC board has a hole at the center, halfway between the probe locations. I scribe lines on the bare board half the pipe cap diameter away from the center hole, making a square to line up each pipe cap. Then I put a bit of paste flux on the rim of each cap, place the caps in position, and put a ring of wire solder around the base of each cap. I solder the caps one at a time, holding the one being soldered in position with a screwdriver while heating the top of the cap with a hot air gun. The copper conducts the heat down to the board; when the joint reaches temperature, the ring of solder melts and flows around the base of the cap, without overheating the board. As soon as the solder flows, remove the heat, let it cool until the solder solidifies, then move on to the next cap. A torch could also be used, but tends to oxidize the copper.

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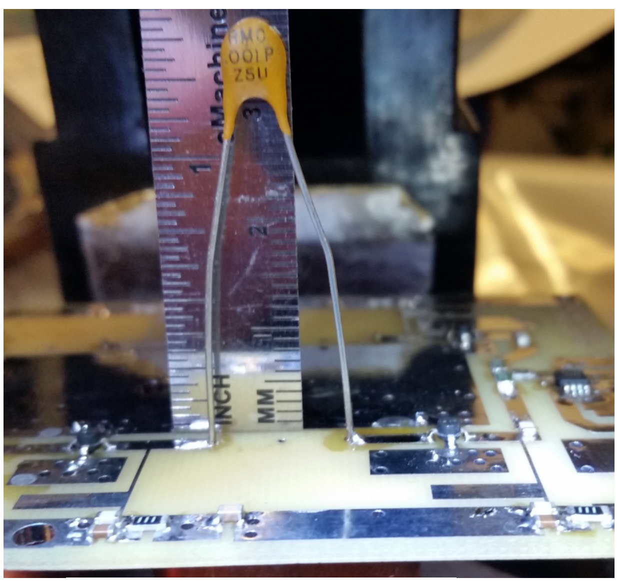

Figure 4 – Setting Probe Length

Brass screws are preferred for pipe-cap tuning, and I like to use a KEP nut, with attached lockwasher, as the locknut. The probes are just bits of wire – I keep them straight and the desired length by using leads from an ordinary disc capacitor, as shown in Figure 4. Measure the full lead length, then insert it until the desired length is inside, and allow another 1.5 mm for the board thickness. The best probe length inside the pipe cap is about 11 mm for 3456MHz, and about 12.5 mm probe length for 2304 MHz. (Hint: when trimming the probes, leave enough sticking up to grab onto in case they need removal. Trim flush after final tuneup.)

Construction is straightforward, except that the large pipe caps are excellent heat sinks. Some of the MMICs have the wall of a pipe cap directly under them, so more heat is needed to melt solder under the ground tabs of the SOT-89 package. The MMICs need a good ground connection for RF and for heat sinking to the PC board. To ensure this, I flow solder onto the ground areas of the board under the tab and center lead, enough to fill the holes, flowing it sufficiently to leave it flat. Then I add a puddle of solder on the output lead and attach the output lead, making sure the ground tab sits flat. Next I use a soldering iron with a larger tip, heat the board next to the tab, and add more solder so it flows under the part. When the solder under the center lead melts onto the lead, remove the heat. Since the device temperature has barely reached the melting point of solder, no damage can occur. Finally, solder the input lead and touch up the output lead if necessary.

For SMA connectors, I have been using connectors from China found on **ebay**, which cost about a dollar. The edge mount PCB versions shown fit snugly on the board and provide adequate mechanical strength. Right-angle connectors are convenient, but I only use them at lower frequencies. And I only use female connectors from China – too many snap rings fail on the male types.

Tuneup

The only thing needing adjustment is the tuning screws in the pipe caps. Start by setting the depth of the screws inside the pipe-caps: ~16 mm for 3456 or ~23 mm for 2304. Other frequencies can be estimated from my paper[3] on pipe-cap filters. The depth can be estimated by allowing about 1.5 mm for the pipe cap wall thickness and measuring the remaining screw length outside the cap. Screw adjustment is done with small wrench and screwdriver – loosen the nut just enough to be able to turn the screw, then hold the nut with the wrench while turning the screw. When the screw is tuned, hold it with the screwdriver while tightening the nut.

There are at least three techniques for tuning:

- Spectrum analyzer – apply LO power and TX voltage and about -10 dBm at IF, tune transmit filters for maximum output at operating frequency. Then move spectrum analyzer to IF port, apply RX voltage only and a weak signal at receive port, and tune receiver.
- Network analyzer – with TX voltage applied but no LO power, sweep gain between LO port and TX port. Tune transmit filter to operating frequency. Then apply RX voltage only and sweep gain between RX port and LO port. Tune receive filters to operating frequency. (The mixer has high loss without LO but the amplifiers compensate enough to enable tuning.) Final tuning with LO and signals.
- Power detector only – apply LO power and TX voltage, detecting output from TX. Tune TX screws inward for maximum at LO frequency. Then apply power to LO port, roughly -5 dBm, and tune TX screws out simultaneously (one, then the other, in increments) until the output drops off and then peaks again further out. Measure screw length above caps and set RX screws to same setting. Final tuning with LO and signals.
- No test equipment – needs another station, close enough for strong signals. Tune for best signals.
- If you can measure noise figure, give the receive filters a final tweak. It shouldn't be sharp.

If the tuning is really sharp and touchy, the probes may be too short. Grab the end, melt the solder, and pull it out. Clean up the hole and install probes perhaps a millimeter longer.

Summary

This transverter provides good performance and is simple and easy to build. It could easily be the heart of a serious microwave system for either band, and can be tuned to various regional operating frequencies. And it is flexible enough to accommodate any change in amateur frequency allocations.

Notes

1. Paul Wade, W1GHZ, "Multiband Microwave Transverters for the Rover," *Proceedings of 34th Eastern VHF-UHF Conference,* 2008. http://www.w1ghz.org/MBT/Multiband_Four_Microwave_Transverters.pdf
1. Paul Wade, W1GHZ, "Updating the Simple Low-cost 2304 MHz Transverter," *Proceedings of the 2016 VHF Super Conference*, ARRL, 2016. http://www.w1ghz.org/MBT/Updating_the_Simple_Low-cost_2304_MHz_Transverter.pdf
2. Paul Wade, W1GHZ, "Pipe-Cap Filters Revisited," *Proceedings of 34th Eastern VHF-UHF Conference,* 2008. ," www.w1ghz.org/new/Pipe-cap_Filters_Revisited.pdf