

OH2GAQ 5760 MHz Transverter

This article describes the design criteria and construction details of the 5760 MHz transverter used at OH2GAQ for portable and fixed-station usage, including potential EME communication in the future. The overall system has been planned so that it should not be necessary to “re-do” parts when additional functions are added, and to this end the transverter has been divided into 2 parts initially. The main transverter functions, shown in Figure 1, are contained in a unit which can be placed indoors or outdoors. Figure 2 shows the functions contained in a small ODU, which can be placed easily directly at the antenna feedpoint.

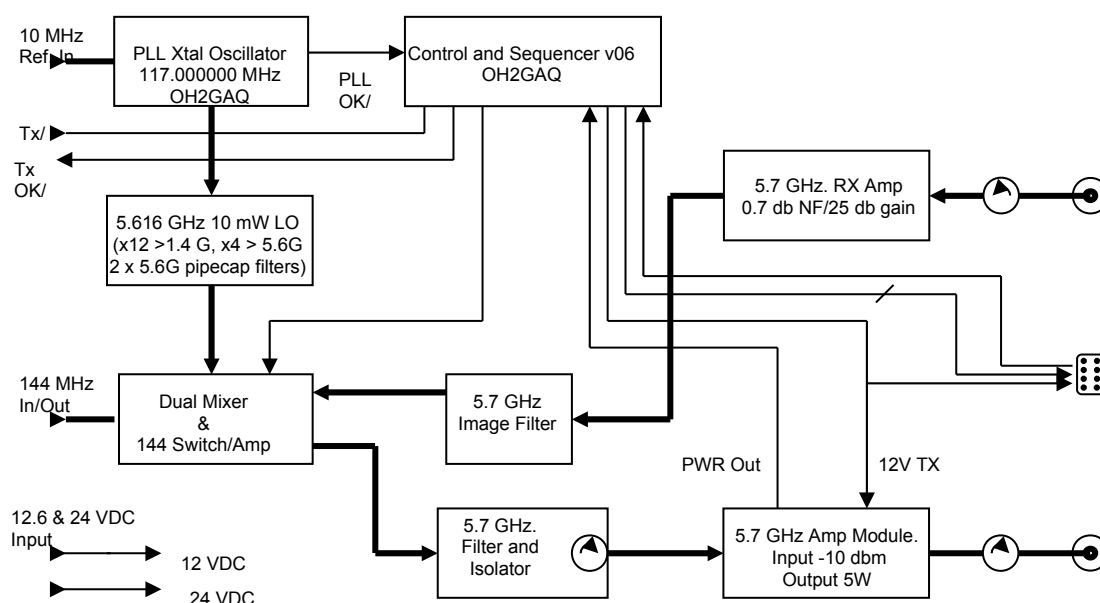


Figure 1. Main transverter functionality, providing basic RX and TX functions and which can be used with an antenna by just adding an RX/TX relay.

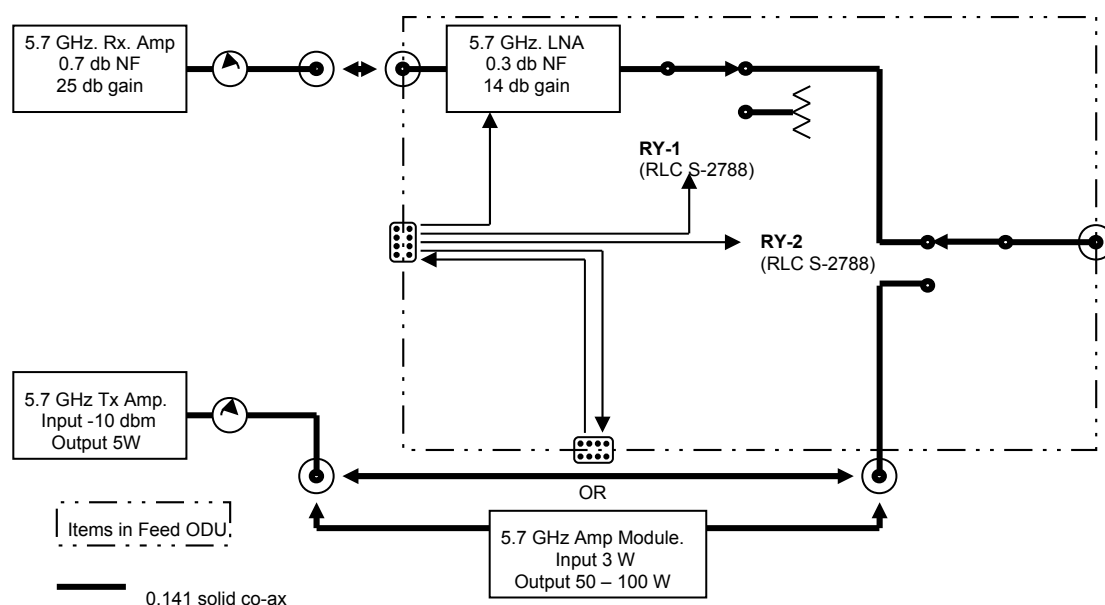


Figure 2. Feed-point mounted ODU, containing RX pre-amp, and switching/protection functions for the LNA and external HPA (if used).

Overall design Strategy.

It has been envisaged that at least three different types of operation will eventually be required for the 5760 GHz equipment:

1. Portable or Home station use with a small dish (80 cm) and linear polarization antenna.
2. Home station use with a larger dish (1.4 M) and higher power, using linear polarization or possibly circular polarization.
3. Home station use with a larger dish (1.4 + M) and higher power, using circular polarization with a dual-feed (polarization direction isolated) for EME communications.

The basic transverter functionality in Figure 1 plus an antenna change-over relay (with or without additional LNA functionality) can be used to satisfy requirement 1. If only a change-over relay is added, no additional ODU is required.

By adding the antenna feed ODU in Figure 2, lower noise performance can be obtained, and if the HPA amp. module is also employed, then requirement 2 is satisfied. The control logic must switch RY-1, before switching RY-2 and powering the TX chain. This is the normal functionality provided by the Control and Sequencer function. It can be used with a linear polarization antenna or a single/dual feed circular polarized antenna.

Similarly for EME work the same feed ODU can be used, but in this case RY2 is only used as an additional protection switching function to isolate the RX LNA during transmit as the dual mode antenna feed provides basic isolation. RY1 provides protection for the LNA.

In the implementation of the various microwave related functions, several isolators have been employed in order to either protect key devices (for example the 5 W PA transistor if cables are missing or not properly connected) or enhance the functionality (terminate the TX filter over a broader band, reduce potential reflection/stability issues between the RX LNA sections)

Local Oscillator Chain.

As shown in the block diagram, the LO starts off at 117 MHz, with the "standard" OH2GAQ crystal oscillator phase locked to an Rb. reference (1). This is followed by a series of multipliers to 1.4 GHz, with dual resonator helical filters to keep the unwanted harmonic content reasonably low, and a final x4 multiplier to 5.6 GHz. A "pipe-cap" filter separates out the 5616 MHz wanted harmonic, which is then amplified and again filtered with a "pipe-cap" filter. A spectrum analyzer was used to go through all the potential unwanted frequencies from 702 MHz to 12636 MHz. The only spur found above -70 db from the wanted +9 dbm 5616 LO output was the 11232 second harmonic, which was 40 db below the wanted 5616 MHz signal.

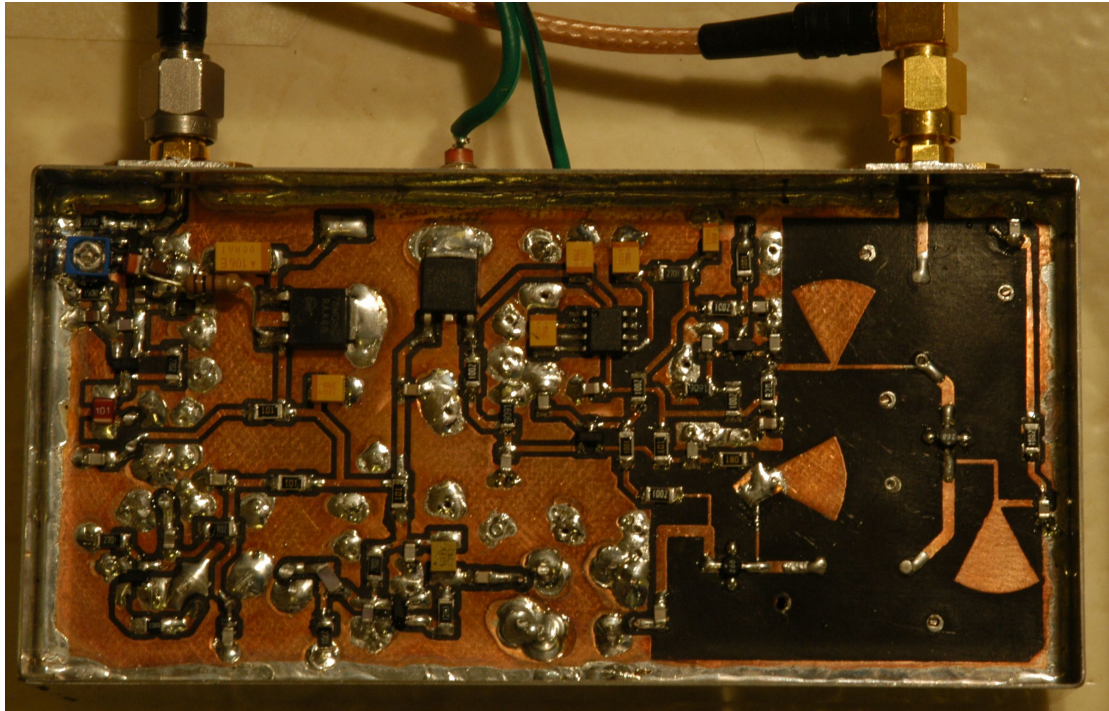


Figure 3. The 117 MHz to 5616 MHz multiplier module. The input is on the upper left, the signal proceeds down the left side of the unit, across the bottom and then to the upper right- There was only need to add 1 "snowflake" to the drain supply of the multiplier FET in order to obtain +9 dbm output, which was adequate to drive the Dual 5.76 GHz mixer.

Dual 5.76 GHz Mixer

In designing the transverter the first approach was to use a surplus commercial mixer that was on hand. The performance had been previously checked when used as a down-conversion (Rx.) mixer and was adequate. However when used as an up-converter (Tx.) it was highly lossy and the LO was not well nulled. Eventually some data was found concerning the mixer and it became clear that it probably used a 90 degree hybrid design, which is OK as a down converter but does not work as an up-converter.

A new approach was required. A commercial Double Balanced Mixer could have been purchased, but another approach was to try and build a dual mixer similar to the design by Paul Wade from the mid-1990's (2). A further advantage of this approach was that it would prove the design of the 3 db hybrids which may also be used later in a high-power transmit amplifier.

In designing the mixer, three basic components are needed:

1. A 3 db hybrid coupler operating at 5616 MHz to split the LO signal into two equal parts. 90 degree, 180 degree or a Wilkinson divider would be suitable for this function.
2. A 90 degree 3db hybrid operating at both 5760 MHz and 5616 MHz to provide the Rx. mixing function.
3. A 180 degree 3db hybrid operating at both 5760 MHz and 5616 MHz to provide the Tx. mixing function (a $3\lambda/2$ design).

To implement the design, a spreadsheet was made to calculate the key dimensions (trace width, radius of the arcs, etc). The parameters of the PCB material at each of the frequencies and for each of the track impedances was taken from the Rogers simulation/synthesis program (3), as the author normally uses Rogers 7880 .015 inch material. For the hybrids operating at 2 frequencies the mean values were used.

The author uses Eagle (Version 5.11) for designing PCB's and has made a library of microwave "components" to use in the design of PCB's. The spreadsheet was arranged to make the needed commands for the Eagle Component Editor, so the correct arcs could be generated without having to always remember or check the command syntax in the component editor.

As a check on the design process, the components used in Pauls' design were designed first. He used a different PCB thickness, and material. The generated components were compared to printed layouts of his dual mixer, and seemed to be compatible, at least to the accuracy of comparing magazine artwork with a transparency of the locally designed artwork. So it seemed a possible way to proceed.

Next the design was completed for the material available to the author. The material is .015 inches thick, compared to the .031 inch material used by Paul, so the width of the tracks was about half that in the original implementation. Accuracy of etching was a concern. A PCB was etched based on the design and mounted in a suitable box with connectors (the second half of the box has the 144 MHz diplexer and RX. filter, made on normal fiberglass PCB material), as shown in Figure 4. The Rx. and Tx. Parts of the mixer were quickly measured, initially without any "snowflaking". Both had acceptable loss (less than 10 db), and the Tx mixer had in excess of 16 db LO rejection at an input level of 0 dbm at the 144 MHz IF input. Also a brief check was made by varying the LO frequency over a few hundred MHz, to see if the overall dual mixer assembly had been implemented at about the correct frequency.

A small optimization was made on the transmit mixer, by adding one small snowflake to the transmit mixer. This optimized the balance so the the LO was rejected by at least 25 db. Also the upper and lower fundamental mixing products (5616 +/- 144 MHz) were seen to be well balanced. The snowflake can be seen near the output line on the TX mixer in the lower right corner of Figure 4.

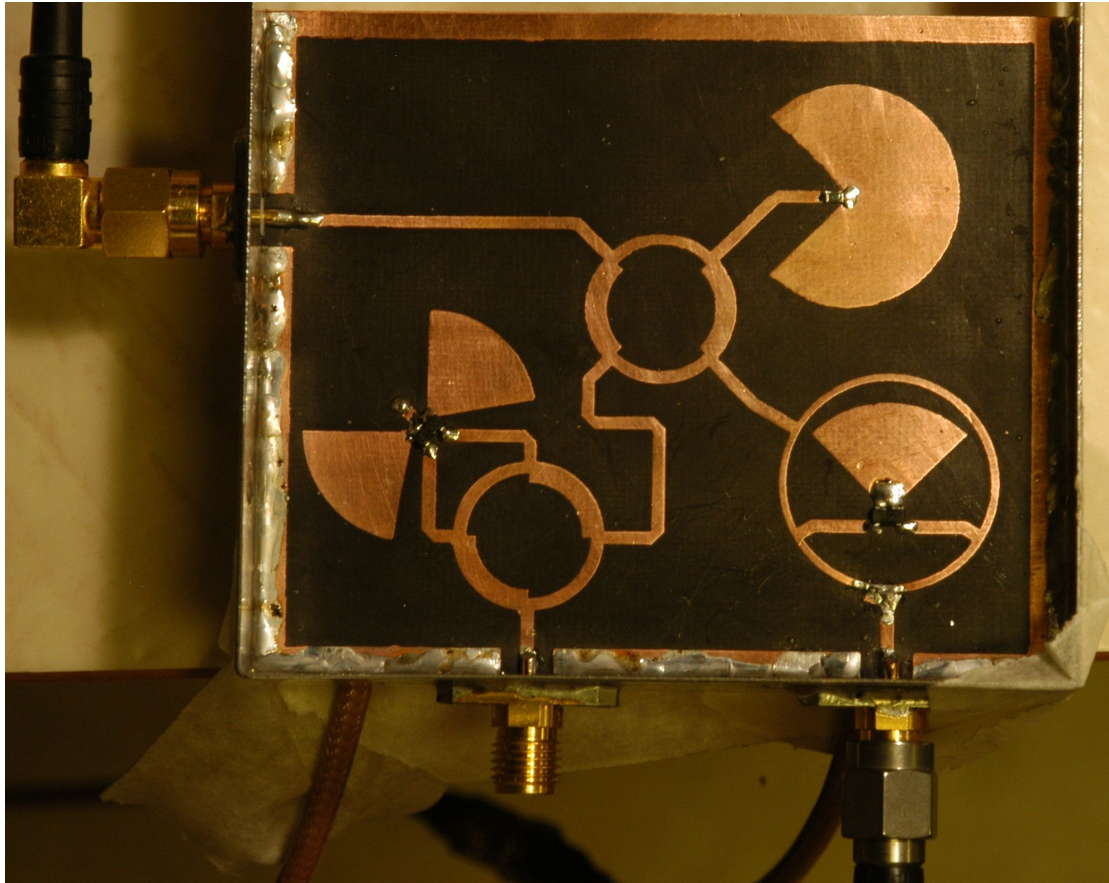


Figure 4 The dual mixer implemented on Rogers 5880 material, the LO connector at the top left. The Rx mixer, using a BAT15-099 double diode is on the lower left. The Tx. Mixer, using the same diode type, is on the lower right. There are no connections to ground with this design, so no need for through holes (except for the 144 MHz IF input and output)

The final measured performance values for the Rx and Tx mixers are shown below:

Rx. Mixer loss		Tx. Mixer loss	
Input Level (dbm)	Loss (db)	Input Level (dbm)	Loss (db)
0.0	9.7	5.8	10.7
-10	7.7	-0.1	8.0
-20	7.7	-10.0	7.3
-30	7.7		
-40	7.7		
-50	7.7		

It can be seen that the Rx. Mixer has about 7.7 db loss, and starts to saturate somewhere between -10 dbm and 0 dbm input at 5760 MHz. It is quite linear from -3 dbm input and down.

The Tx. Mixer shows about 1 db compression at 0 dbm input at 144 MHz. It is linear below -3 dbm. The mixer loss is about 7.3 db.

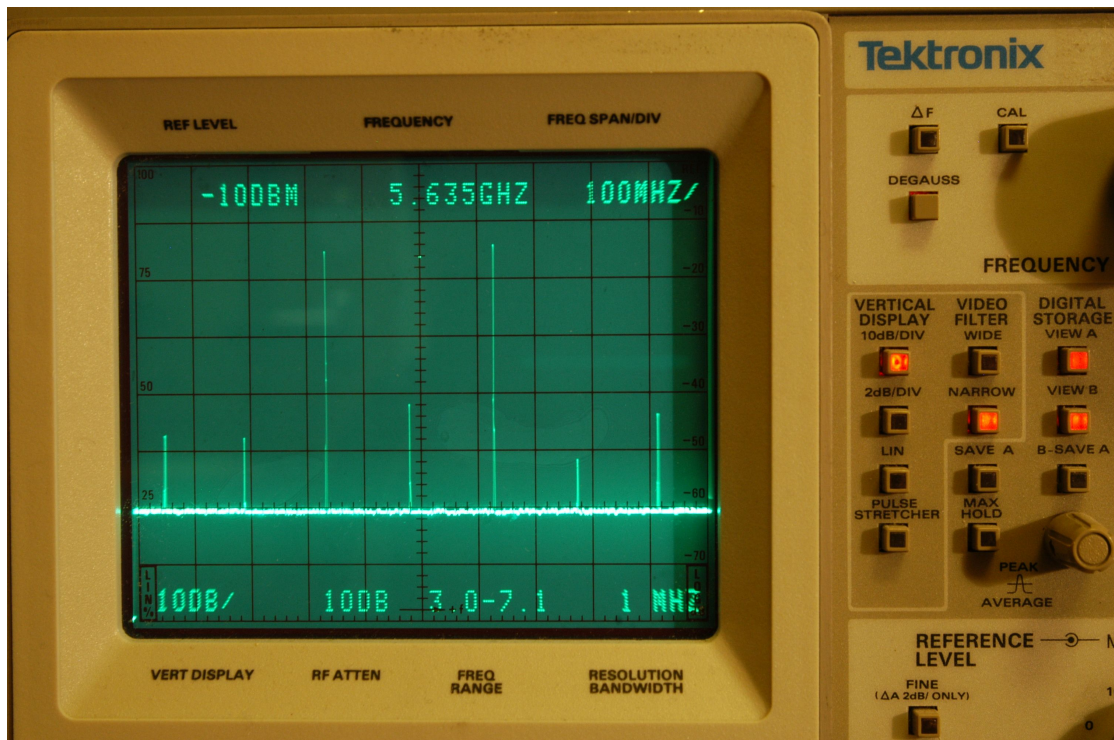


Figure 5. Wideband output spectrum of the Transmit mixer.

Figure 5 shows the wideband spectrum from the mixer, covering from the LO to ± 500 MHz. The trace has been offset slightly from the screen center so the LO leakthrough can be seen. The “pip” near the center is the LO at 5616 MHz, the adjacent “pips” are the wanted upper product and the unwanted lower product. They are within about 1 db of equal amplitude. The following products are at $F_{LO} \pm 2 \times 144$ and $\pm 3 \times 144$. There are no other products seen within -60 db of the wanted product at 5760 MHz.

When the signal is passed through the transmit filter, which is a multi-resonator filter with integrated isolator centered at 5760 MHz, the only output product seen is the wanted 5760 MHz signal. All other products are more than 70 db lower. This filter has a mid-band insertion loss of 1 db. The transmit filter was found at a surplus sale, but could be replaced by a multi-post home made waveguide filter.

Mixer 144 MHz Tx/Rx section.

The completed mixer assembly, including the IF portion, which has been implemented on standard 1.6 mm. glassfibre PCB can be seen in Figure 9. The circuit details are the same as has been used in the authors 10 GHz transverter. A schematic is available for anyone interested.

Transmitter Amplifier Chain and PA.

It was decided to build a 3 stage amplifier with a nominal gain of 45 db, the first two stages being MMIC's (RFMD NLB400 followed by a Transcom TC3531) and the final amplifier being a MGFC36V7177 (with tuning stubs) to provide a nominal power output of approximately 36 dbm (4 watts). The amplifier incorporates a -30 db coupler and monitor diode, and is described in detail in a separate article (4).

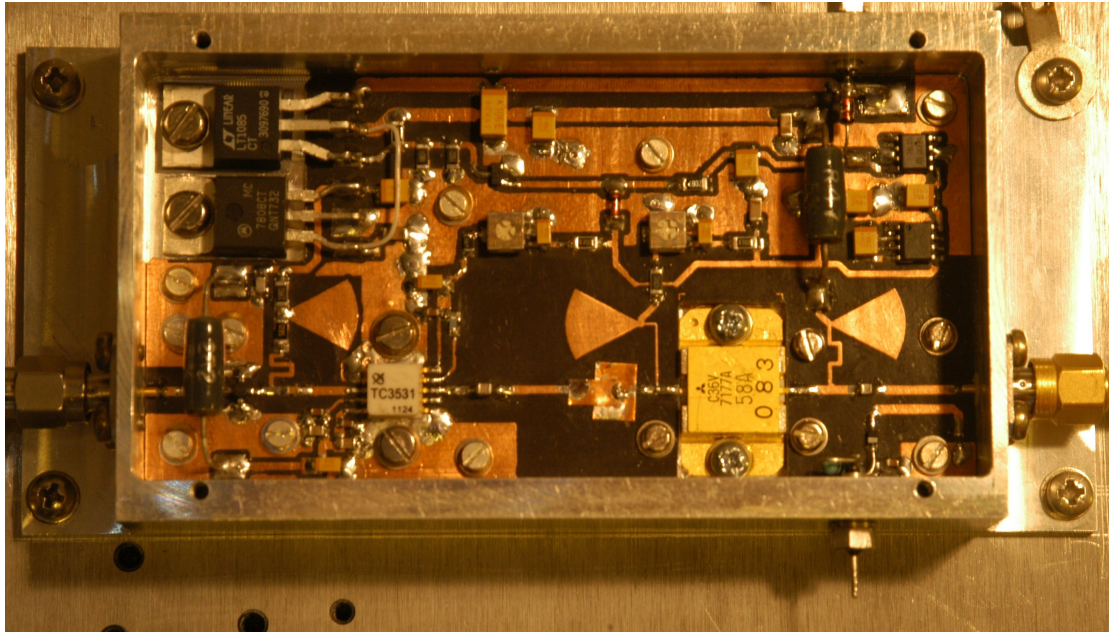


Figure 7. The transverter power amplifier. Input is to the left, and output is to the right. The final alignment added a couple of small snowflakes to the drain of the MGFC36C7177 chip, not shown in this photo.

A major challenge in the design and construction was implementing the grounding and heatsinking of the TC3531 MMIC amplifier, which dissipates about 3.5 W and has a gain of about 24 db. The final result was that the amplifier is stable with no lid attached (as photographed), and with the lid attached and lined with microwave absorbing foam.

The final performance measurements were:

Gain: 44 db small signal at up to 4W output.
Power: 37 dbm (5.2W), 1 db compression.
DC Current: 1.7A at 12.6 V

The Rx. amplifier was first implemented by using a modified 7 GHz commercial Rx. pre-amp, but the performance was not optimum. There were significant losses where the input isolator was removed, which impacted on the gain and NF. It finally seemed simpler to just implement a two-stage amp. for the frequency of interest. A design was made using the NEC NE32584A as the first stage with a following HP ATF26884. This gives 27,5 db gain from device data, and the measured gain was 25.25 db. The noise figure was measured as 0.99 db. Figure 8 shows the layout of the Rx. amp.

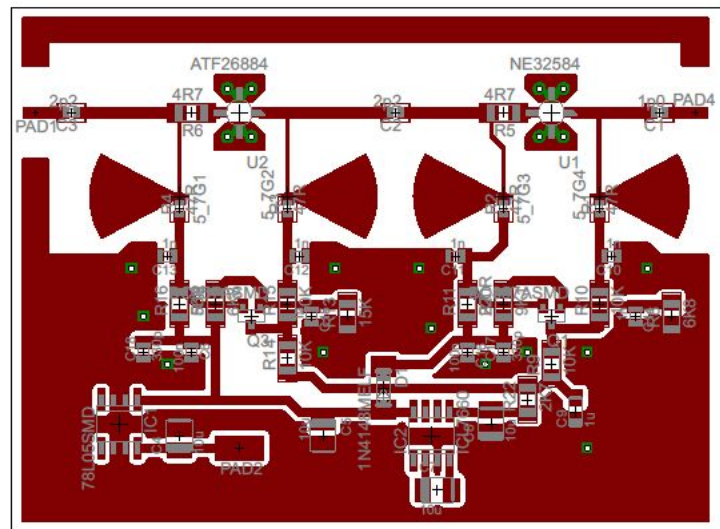


Figure 8. Rx. Amplifier PCB layout. The completed unit fits into a 55 by 74 by 30 (mm) tinplate box. Tuning snowflakes have to be added to the transmission lines.

Overall mechanical implementation of the main unit.

Figures 9 and 10 show the overall mechanical layout of the main unit, which has been made out of a disused aluminium casting from a satellite microwave link. A small milling machine has been used to modify the shape where needed.

This implementation of the transverter has all the items in the two case sections, there are no external switches and LNA's etc., so it is suitable for portable use. By simple change of two co-axial cables, it can be re-configured to have separate Rx. and Tx. connections and an external LNA and/or HPA can be added.

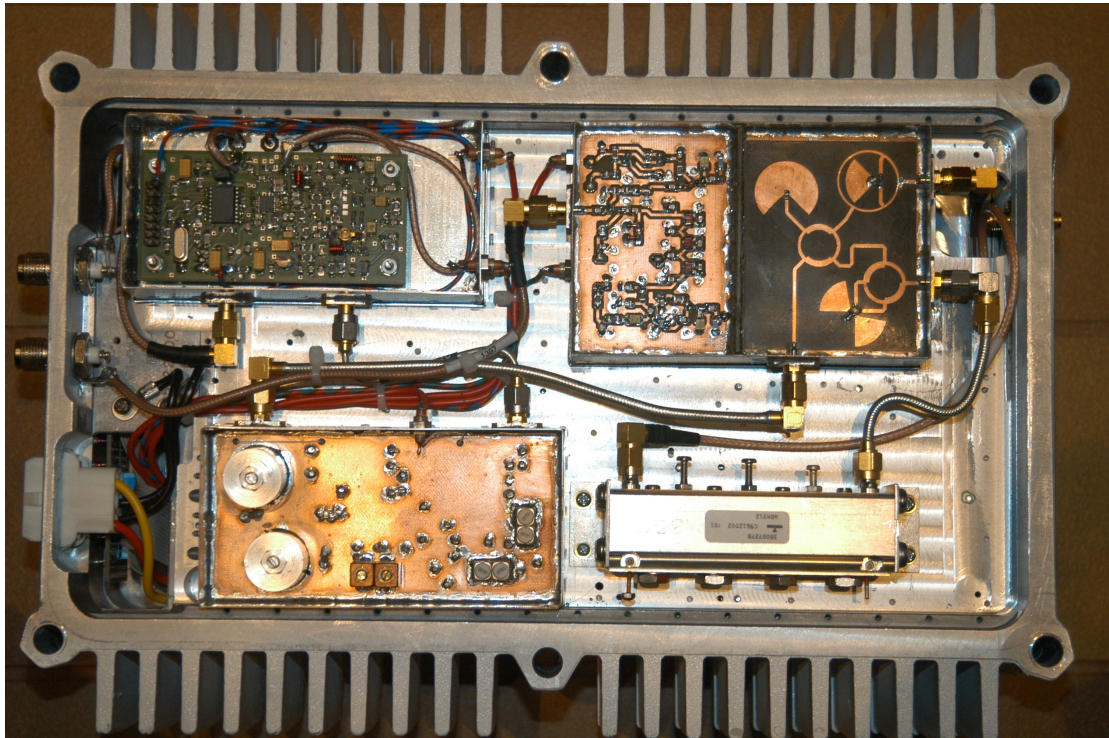


Figure 9. View of the transverter unit showing, clockwise from top left, the PLL oscillator, the Tx./Rx. mixer unit, the Rx. image filter and the LO multiplier unit. Covers are removed to show the internal unit construction.

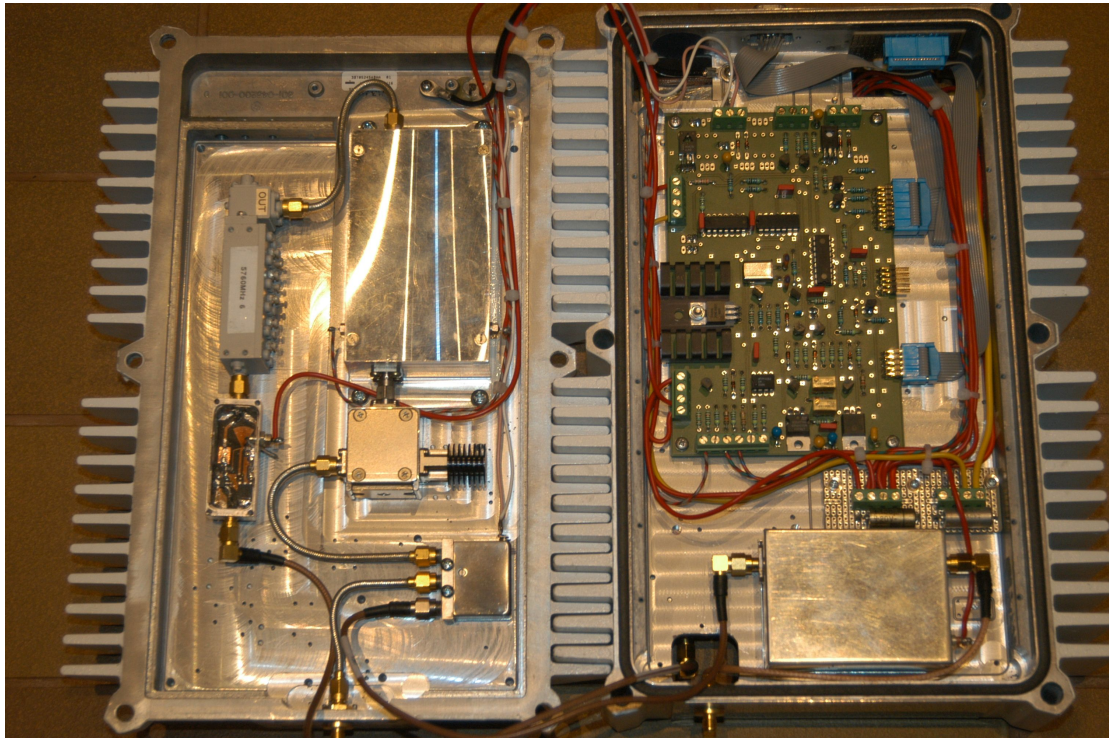


Figure 10. Opened-out case showing (on the right) the controller and Rx. amp, and (on the left, starting from top left) the Tx. Filter and isolator, the Tx. PA module with isolator on the output, the Rx./Tx. relay, and a 10 db amp. between the mixer and Tx. filter.

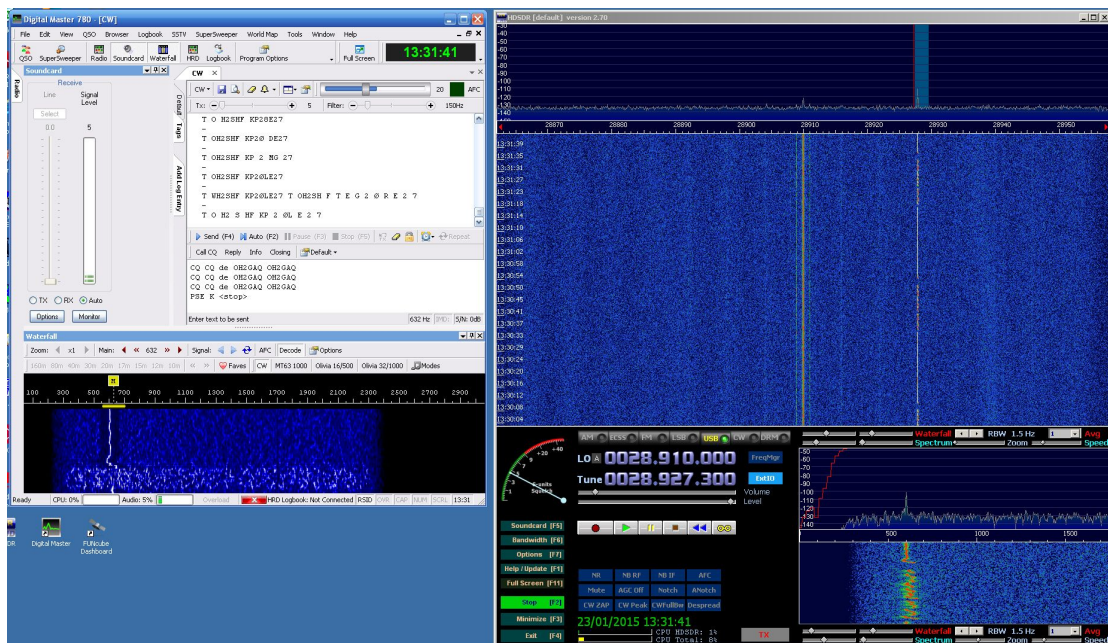


Figure 11. Screen capture of the Pasila 5.76 GHz beacon, received at OH2GAQ QTH by scatter from the Espoo TV tower. There is no line-of-sight path. The beacon has frequency shift when it is modulated, which can be seen in the high resolution lower display window. 28 MHz on HSDR corresponds exactly to 5.760 GHz.

The author thanks the many amateurs and others who have published material covering the design of similar transverters and/or parts of them. There are many articles with key information available on the web. Michael Fletcher, OH2AUE, was a key source for the aluminium castings and the GaAs power device.

References

For those interested in more details of the transverter parts, I can be contacted and will post the material requested on my website under the "Projects" section.

(In this reference list I have not used links as they often change over time, but rather leave it to interested people to use a search engine to find the relevant material, all of which is available on the web).

- 1) "Yet another PLL Xtal Oscillator" by Hamish Kellock OH2GAQ, OH2GAQ website Projects section.
- 2) "A Dual Mixer for 5760 MHz with Filter and Amplifier" by Paul Wade, N1BWT, QEX for August, 1995, pages 9-13.
- 3) "MWI-2010 Design Software" Manual and Program, available for free download from Rogers Corporation.
- 4) "5.7 GHz Power Amplifier" by Hamish Kellock, OH2GAQ, Radioamatööri for April, 2014 and OH2GAQ website, Projects section.