Dualband Feed for EsHail-2 / Qatar-OSCAR 100

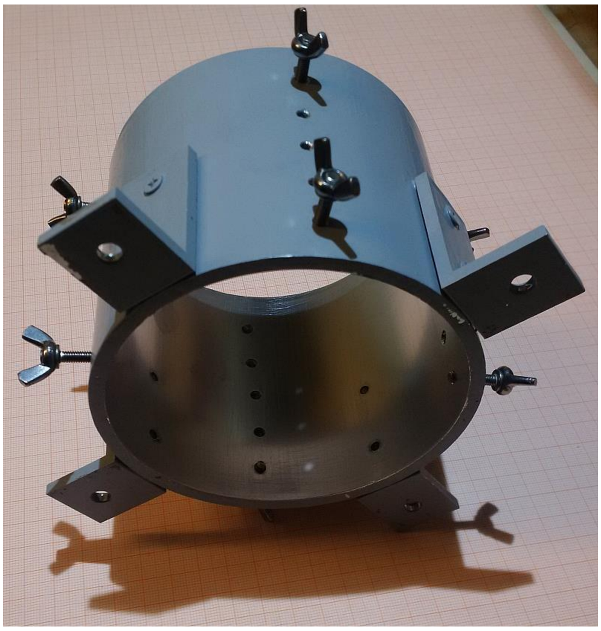
Matthias, DD1US, 03.06.2021, Rev 1.0

Hello,

Now that EsHail-2 has been successfully launched and has started its regular operation including the amateur radio payload Qatar-OSCAR 100, it was time to build a suitable feed.

I've built a universal quick release mount for all my parabolic dishes, so I can quickly change the feeds for different frequency ranges. A detailed description can be found on my homepage www.dd1us.de.

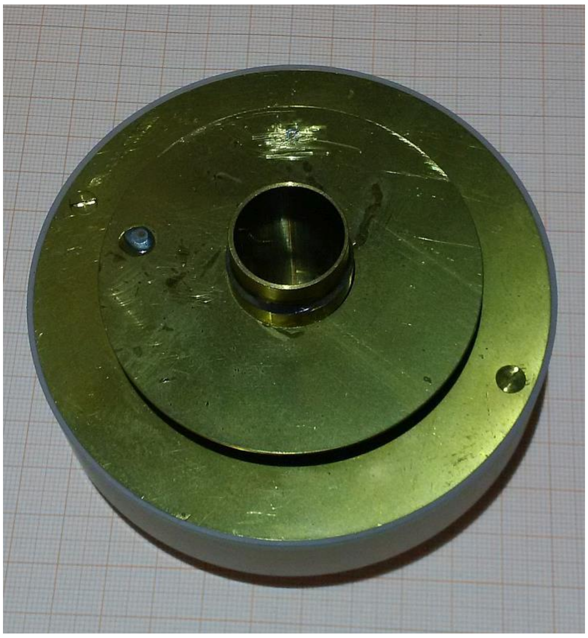
Enclosed pictures of the quick release mount:

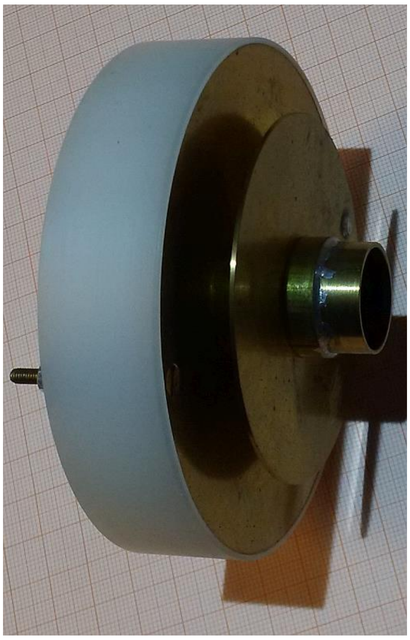
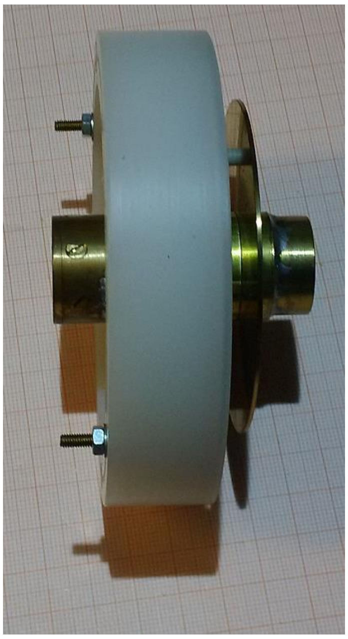


The feeds, which are to be fixed in the holder, can be held by means of a cylindrical housing with a maximum diameter of 109mm. If it is a thinner feed then I use additional spacers made of PVC-U.

For EsHail-2 I have built a dual-band feed according to DJ7GP. Here my radio friend Heinz (DJ5JN) helped me with his excellent mechanical processing capabilities.

First, we have built a version with 2 probes/exciters (H and V) for 3cm, as I want to receive the WB (wideband) and NB (narrowband) transponders simultaneously.

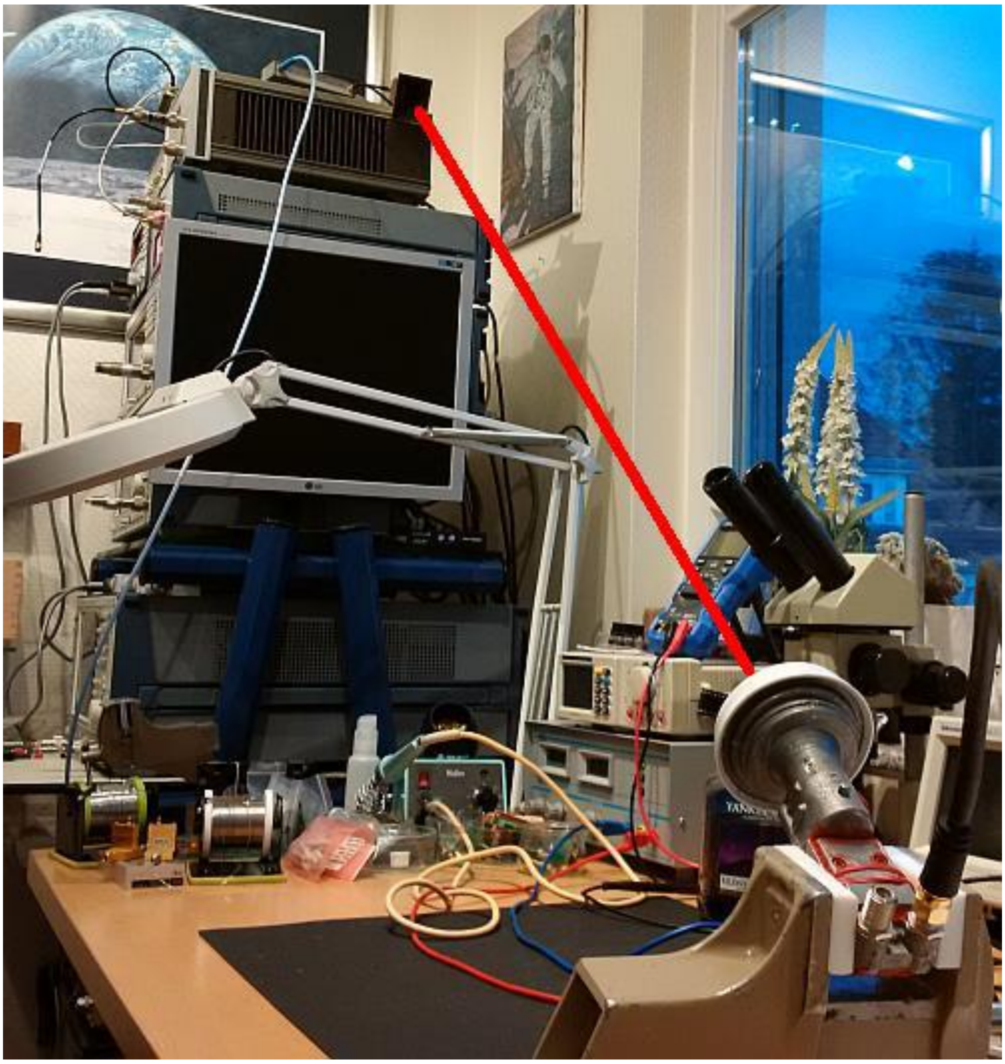


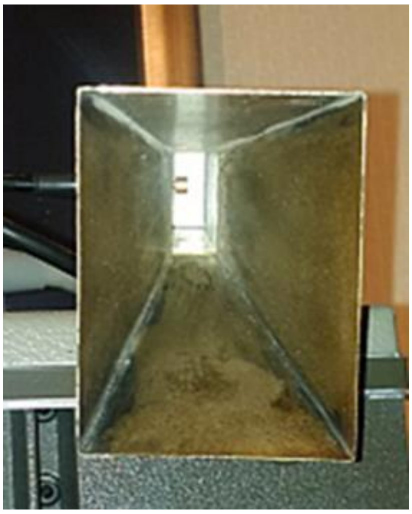

Unfortunately, the decoupling of the two orthogonal exciters is not high enough. I should have mounted them with an axial offset but then I would also need an additional reflector for the exciter further away from the backplane. In addition, the conversion of an LNB to coaxial feed of the H and V signals is not trivial and usually degrades the sensitivity of the LNB due to imperfect impedance matching and the additional losses of adapters and cables to the LNA.

That's why I decided to use an Octagon Twin PLL LNB. In order to push up the IF frequency and to improve the frequency accuracy and stability of the local oscillator (LO), I have replaced the internal 27 MHz crystal oscillator with a 26 MHz temperature compensated crystal oscillator (TCXO). In addition, the flange of the LNB was removed and the LNB was adapted directly to the circular waveguide of the dual-band feed.

First, I measured several Octagon LNBs without modification of the electronics by means of a test setup. Here is a picture of the "test track" inside my shack.



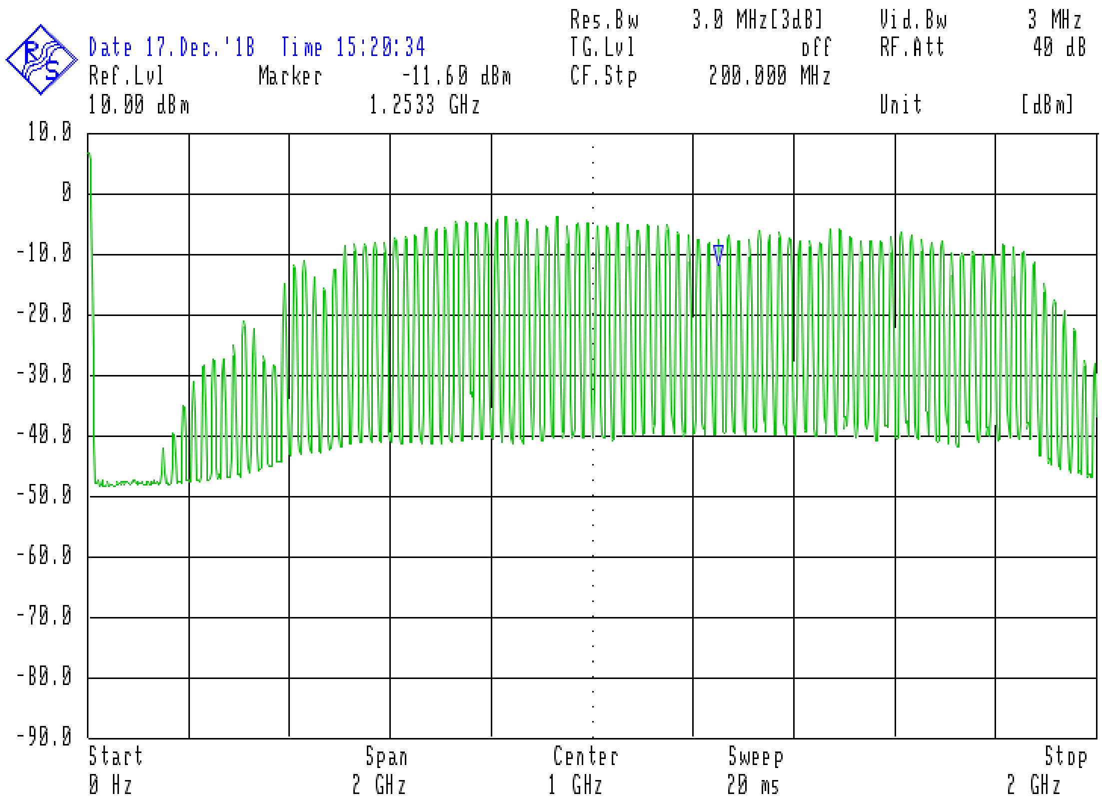
I was using a 6 GHz signal generator SMIQ06 with an additional frequency doubler and a small horn antenna. By means of a switchable attenuator after the frequency doubler, I was able to adjust the transmit power in 1 dB steps. Below you can see the Octagon PLL LNB. On the picture below, you can see the transmitter horn.



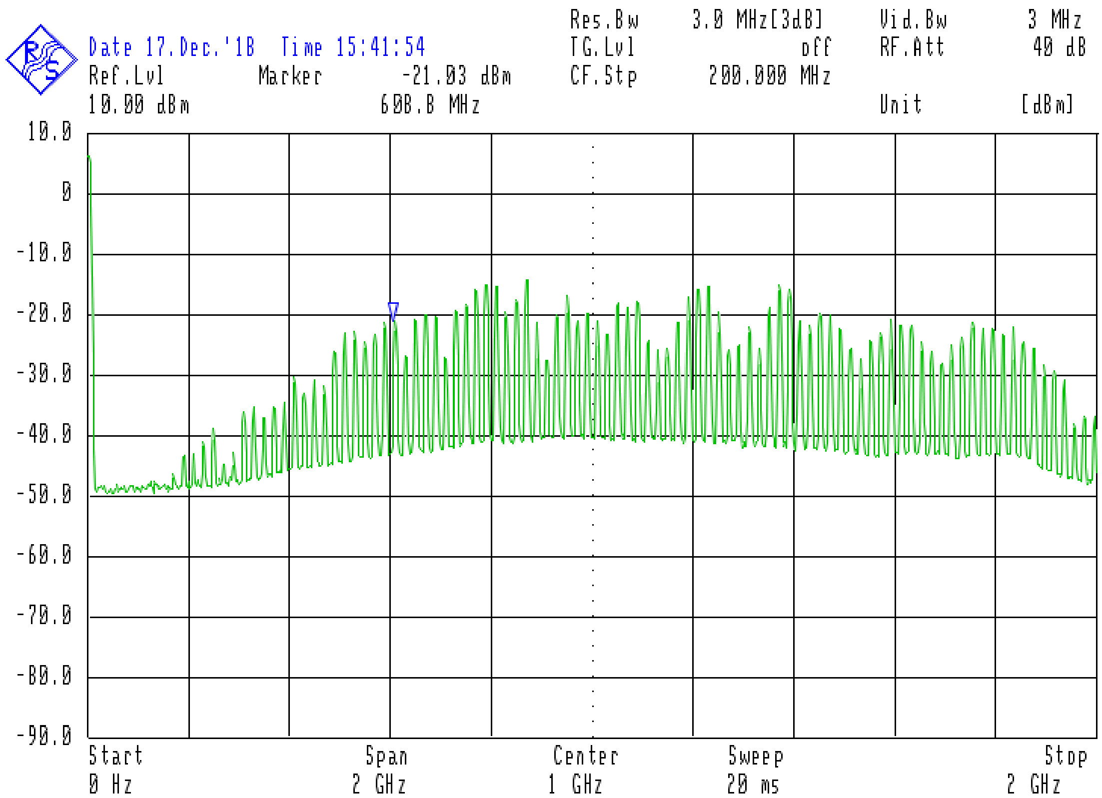
First, I measured the frequency response of the unmodified LNB. The transmitted signal was varied by means of the transmitter between 10 GHz to 12 GHz and the received IF signal (LO = 9750 MHz) measured with a spectrum analyzer in max-hold mode. I measured a total of 3 Octagon LNBs (same model) and found that the results were very similar and that the frequency response of the LNBs was very similar.

The power consumption of the Octagon LNB is approximately 140mA (when using one output).

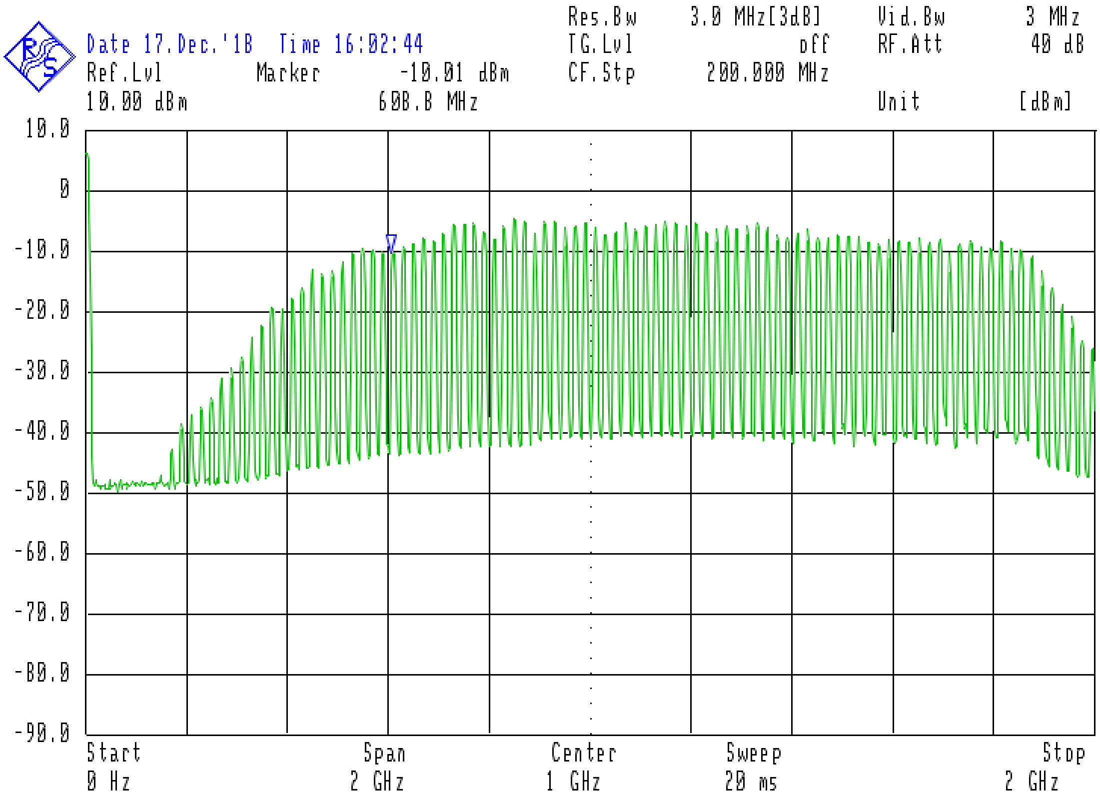
Here are the measurement results:
LNB#1, Vs=18V, Port A



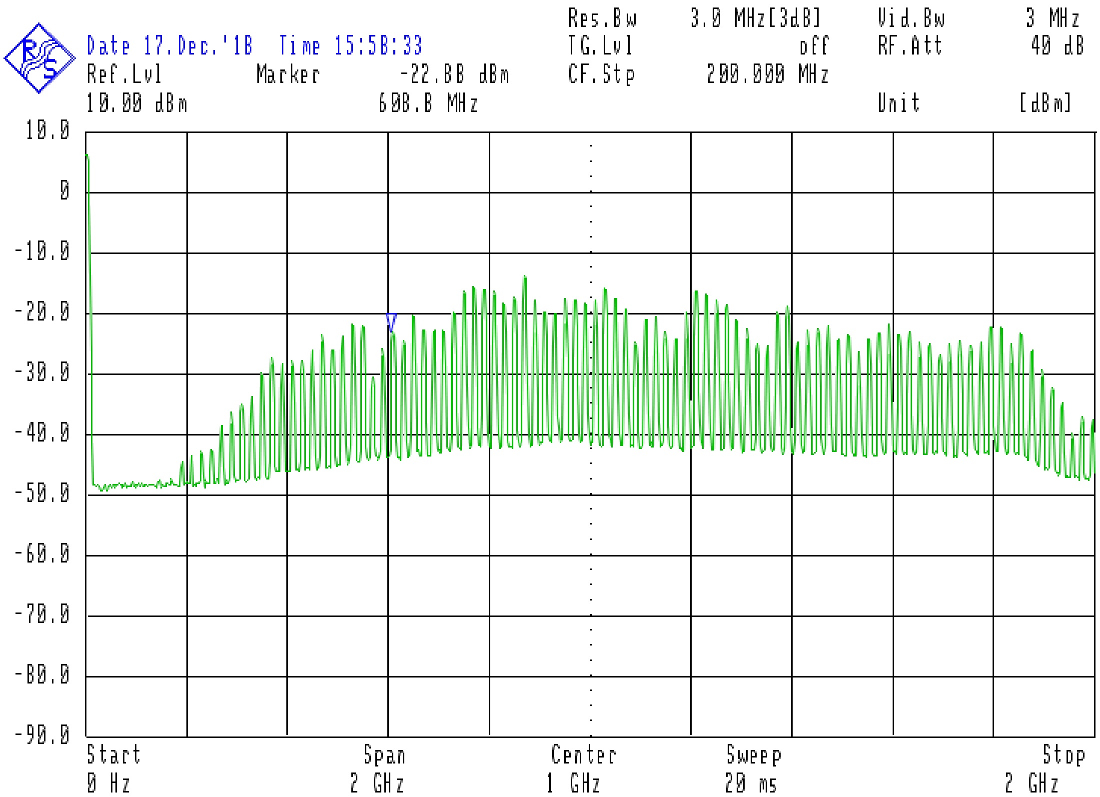
LNB#1, Vs=12V, Port A 6



LNB#1, Vs=18V, Port B



LNB#1, Vs=12V, Port B 7



As you can see, both ports A & B behave very similar. Since the transmit horn is linearly polarized, one of the two planes (here the plane selected by the supply voltage of 18V) has been chosen to match the polarization of the transmit antenna. The second output, which is rotated by 90 degrees, receives a signal that is about 15 dB weaker. At a transmission frequency of 10500 MHz this results in an IF frequency of 750 MHz. As can be seen, the output level at 750 MHz does not drop too much.

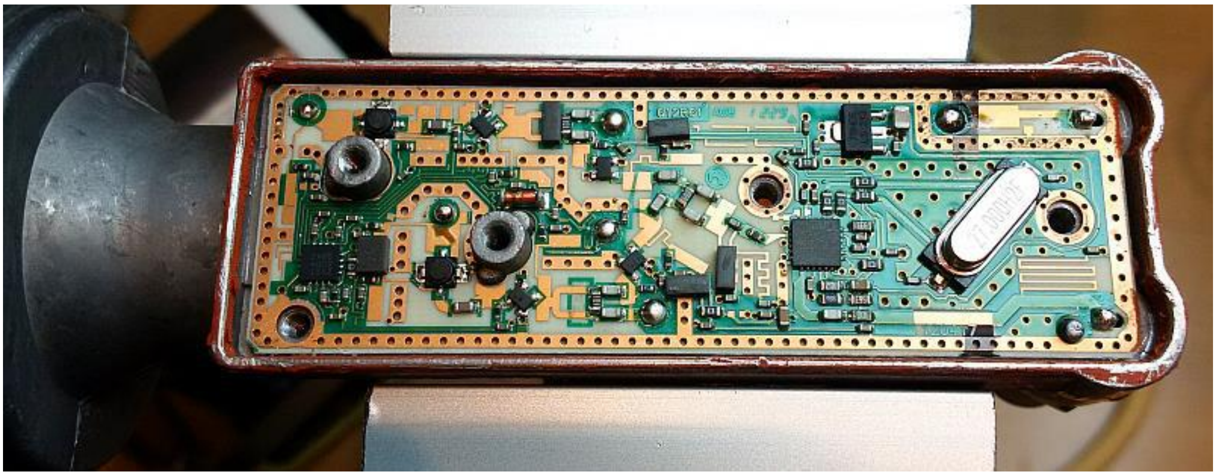
Next, I modified the LNB. The two 27 MHz quartz crystals were removed and replaced by 26 MHz TCXOs. This significantly improves the accuracy and stability of the LO. With the change of the reference frequency from 27 to 26 MHz the local oscillator was shifted from 9750 MHz to 9388.88888 MHz. When receiving a signal at 10500 MHz the IF frequency is shifted up to 1111.11111 MHz which is in the optimal range of the IF amplifier of the LNB. Therefore, DATV can be received with standard DVB-S2 satellite receivers (as long as they support low symbol rates as they are used on QO-100). Below is the calculation.

Mode	Low Edge	High Edge	Bandwidth
Wideband RF Downlink /MHz	10491	10499	8
Narrowband RF Downlink /MHz	10489,55	10489,8	0,25
LO low /MHz	9388,888889	9388,888889	
LO high /MHz	10207,40741	10207,40741	
Wideband IF low /MHz	1102,111111	1110,111111	8
Wideband IF high /MHz	283,5925926	291,5925926	8
Narrowband IF low /MHz	1100,661111	1100,911111	0,25
Narrowband IF high /MHz	282,1425926	282,3925926	0,25

Multiplier Low	361,1111111
Multiplier High	392,5925926
TCXO /MHz	26
LO low/MHz	9388,888889
LO high /MHz	10207,40741

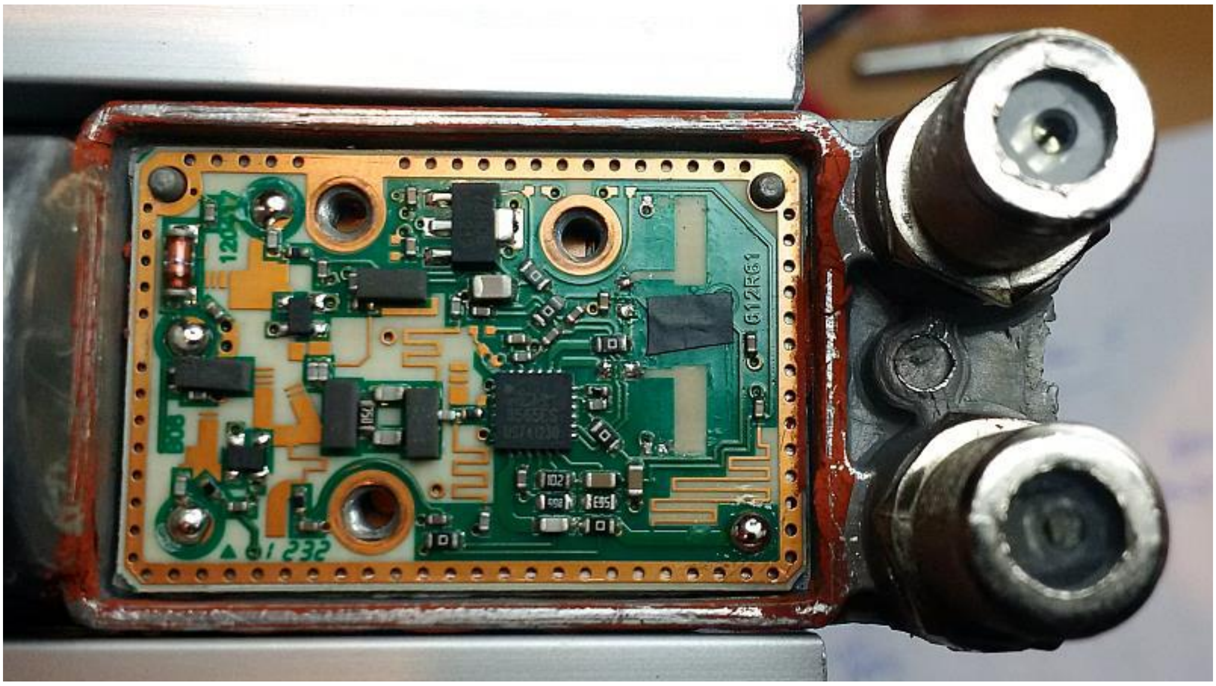
I intend to use only the LO frequency of 9388.8888 MHz, i.e. no 22 kHz signal is needed to switch to the higher LO frequency.

Here are pictures of the two boards of the unmodified LNB:

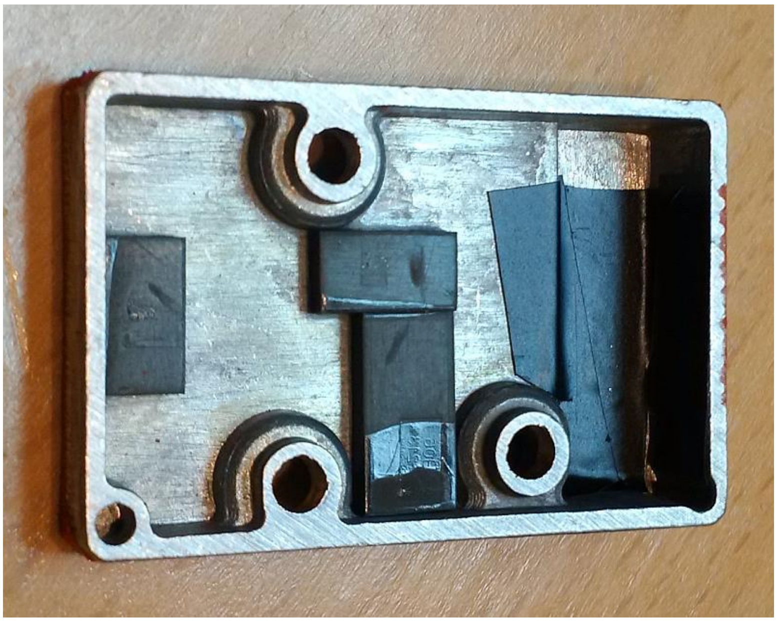


The LNB is fed with a DC voltage via the coaxial cable (phantom feed), which supplies the IF to the receiver. Each of the two outputs supplies the vertically polarized receive signal when a supply voltage of 8-13V is applied, and the horizontally polarized receive signal at a voltage in the range of 15-19V. The term horizontal and vertical is to be considered relative and depends on the later orientation of the feed in the parabolic mirror.

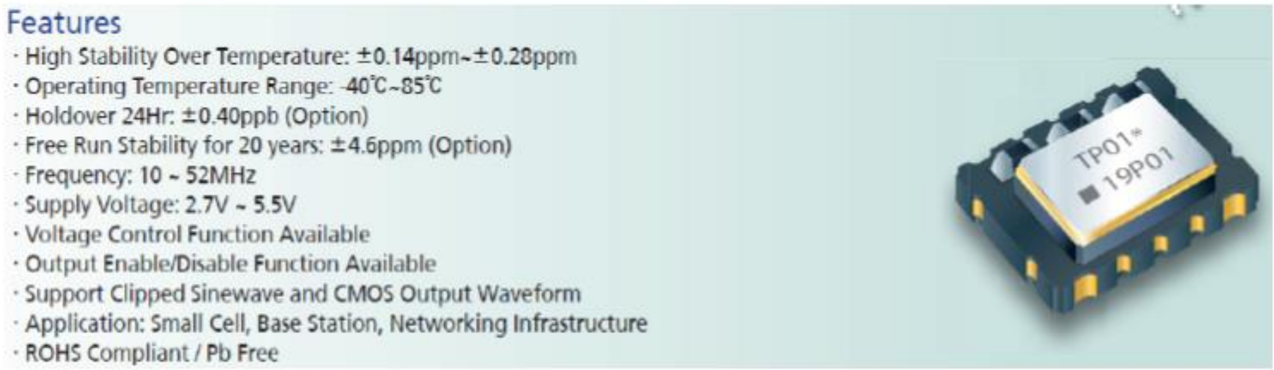
As part of the modification, the quartz was first de-soldered and the non-required traces removed to prevent later possible short circuits or unwanted inter-couplings. In the picture below you can see the smaller board. A trace on the PCB, which will be below the TCXO was isolated by means of a small piece of isolating tape.



In addition, the lid must be partially covered with isolating tape to avoid any shorts, as space is quite tight.



I used TCXOs from a company called TXC. The exact model is 717-7N-26,000MBP-T. The SMD package used is small enough that it can be installed instead of the quartz in the LNB encasing.

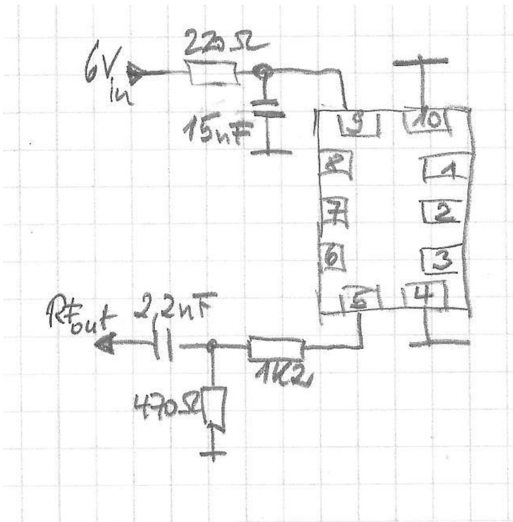


This TCXO has a voltage range of 2.7-5.5V and a current consumption of max. 10mA. Thus, it can be easily powered by a 220 ohm resistor from the existing 6V voltage regulator and therefore no additional voltage regulator is needed. The output signal is attenuated by a voltage divider and fed by means of a coupling capacitor for decoupling of the DC voltage to the reference frequency input of the PLL-ICs RDA3565ES.

The TCXO has a specified frequency tolerance of ± 2.0ppm and a temperature stability of ± 0.28ppm.

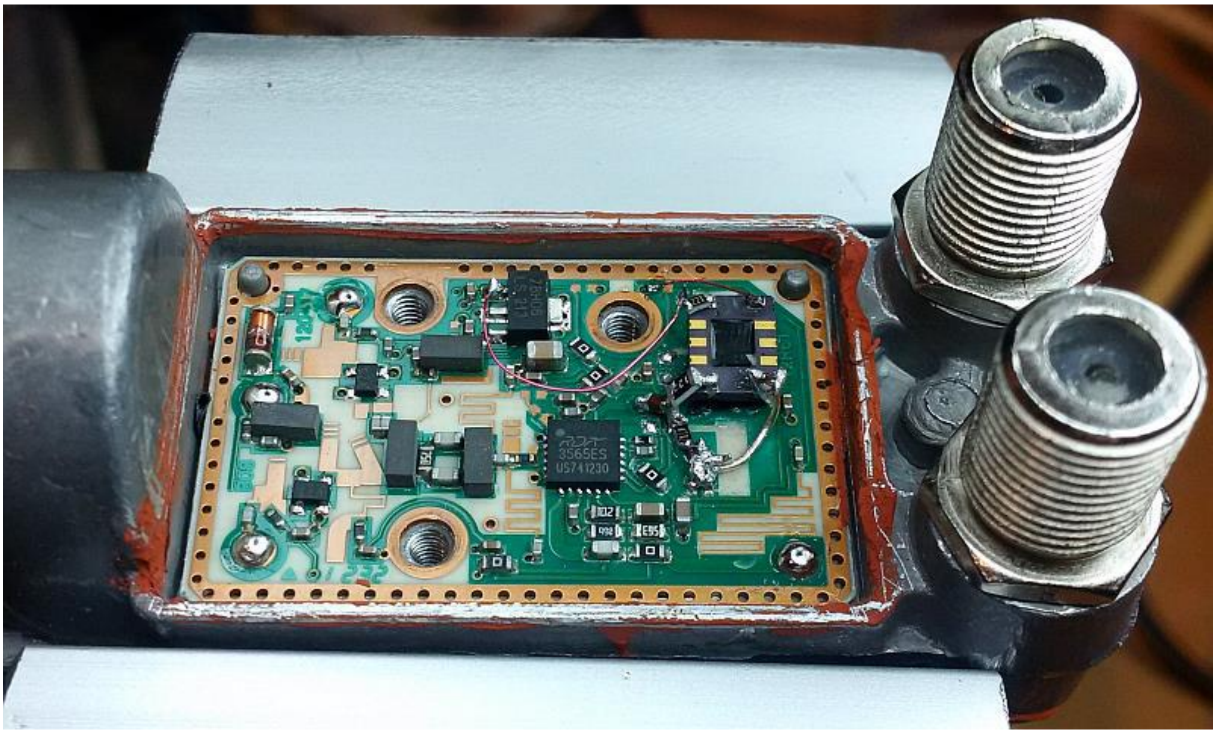
The TCXOs are mounted upside down and glued to the PCB. Thus, the connection pads are directed upwards and easily accessible.

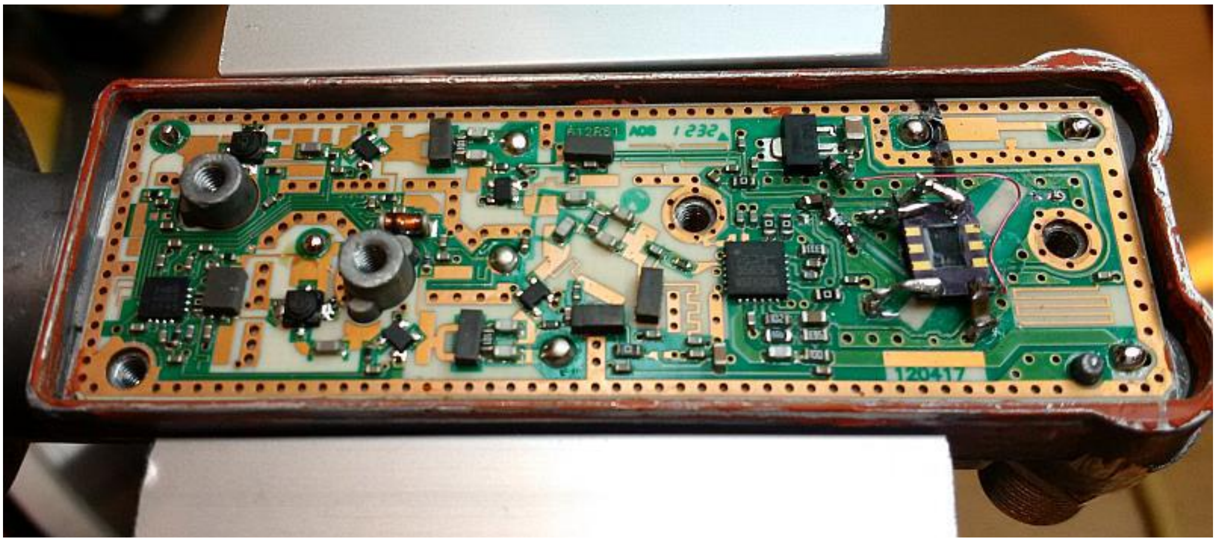
The circuit is very simple and is constructed by means of SMD components and thread wire "free-floating":



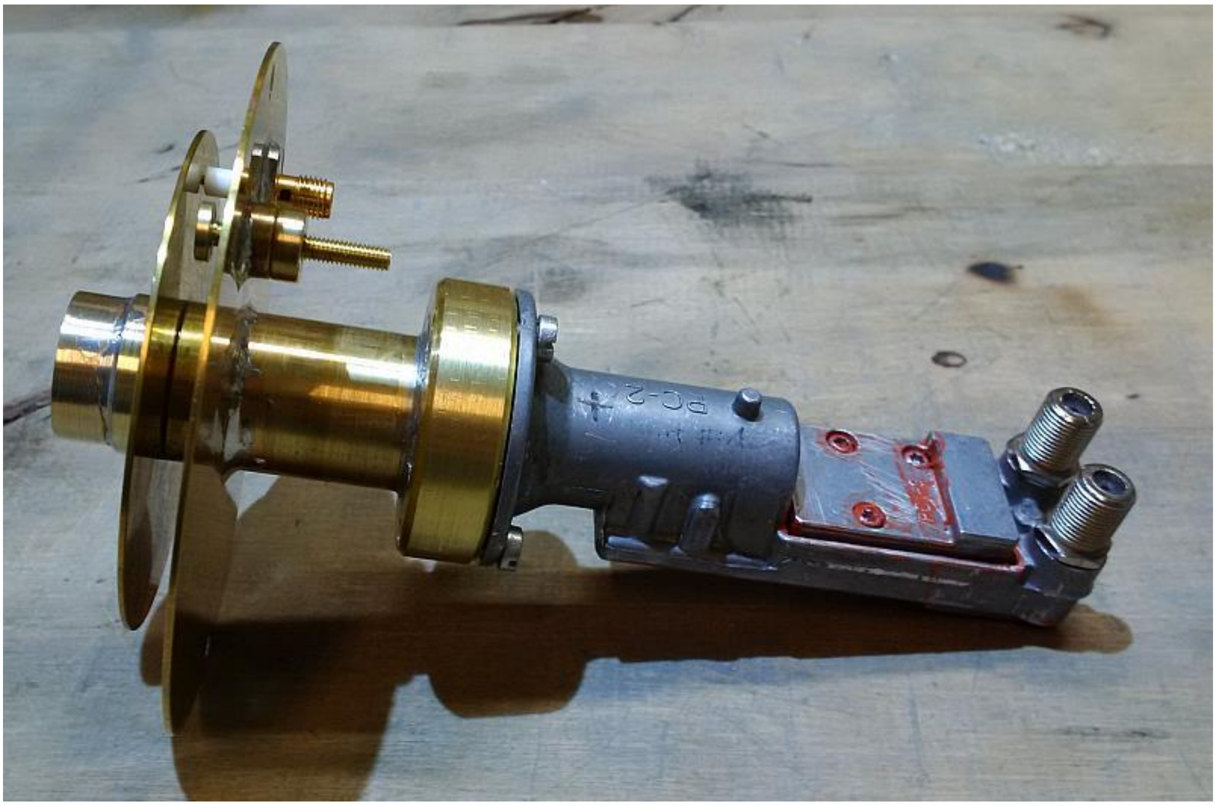
Most component values are not likely to be overly critical and so similar values, which you have on hand, can be used.

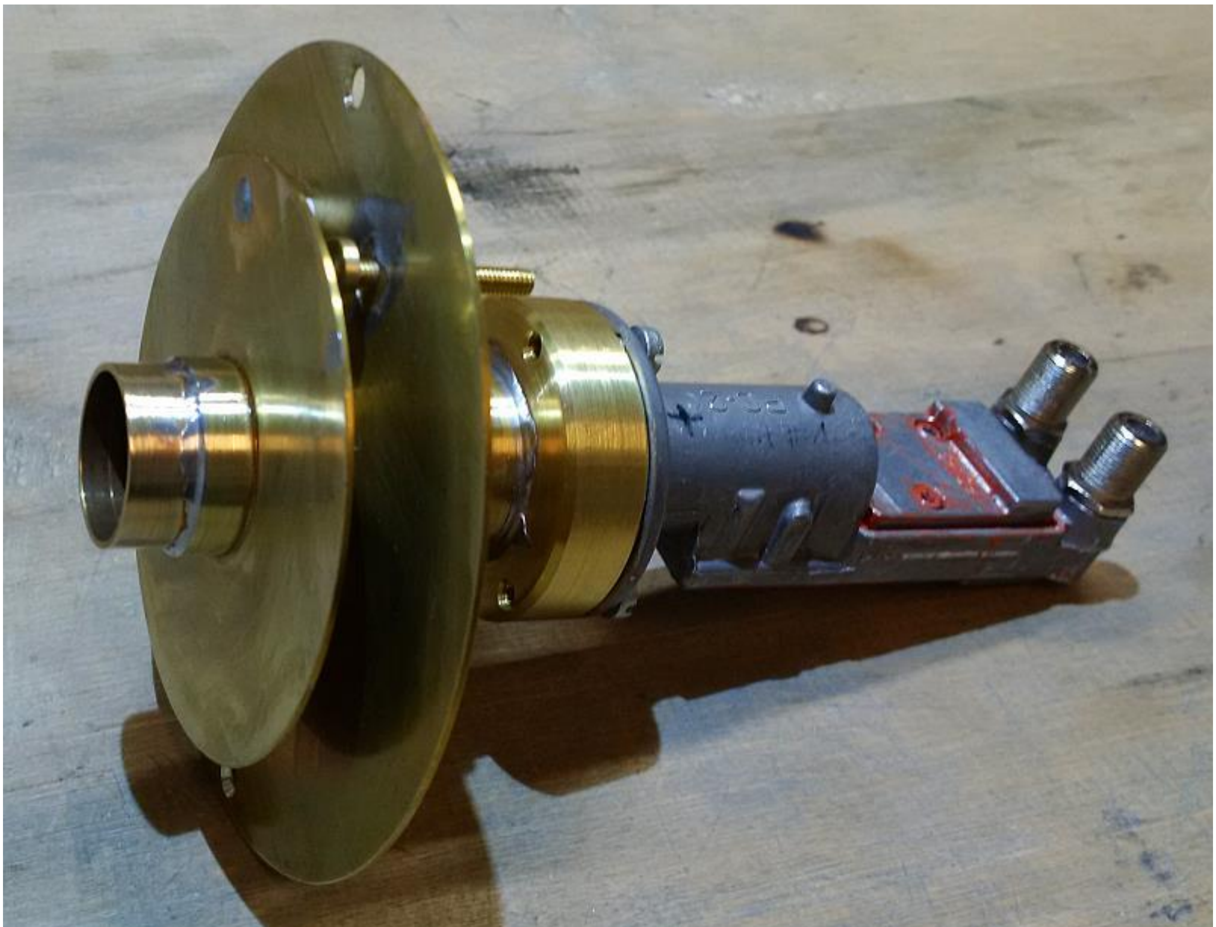
Here are pictures of the LNB with the assembled TCXOs:



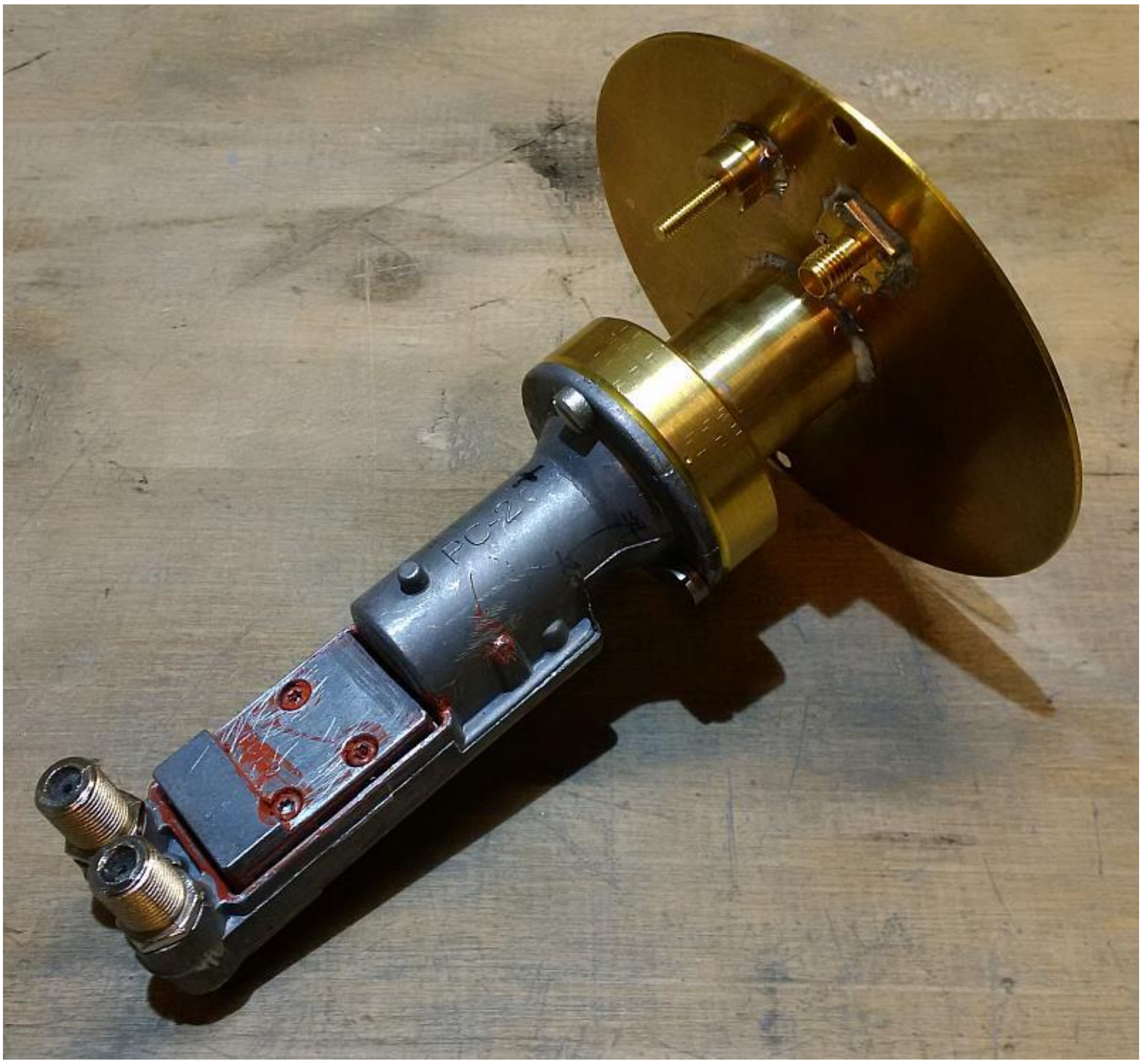


Next you will find some pictures of the LNB adapted to the dual band feed which was built according to the description of DJ7GP:

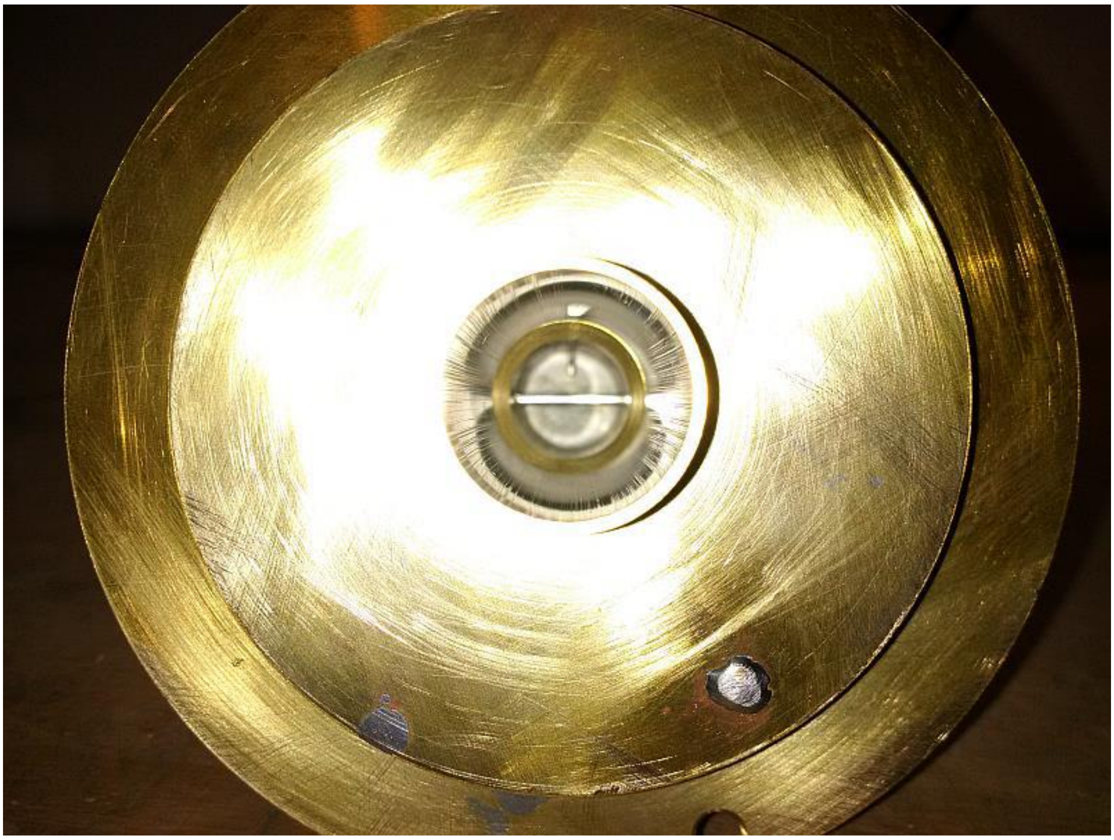


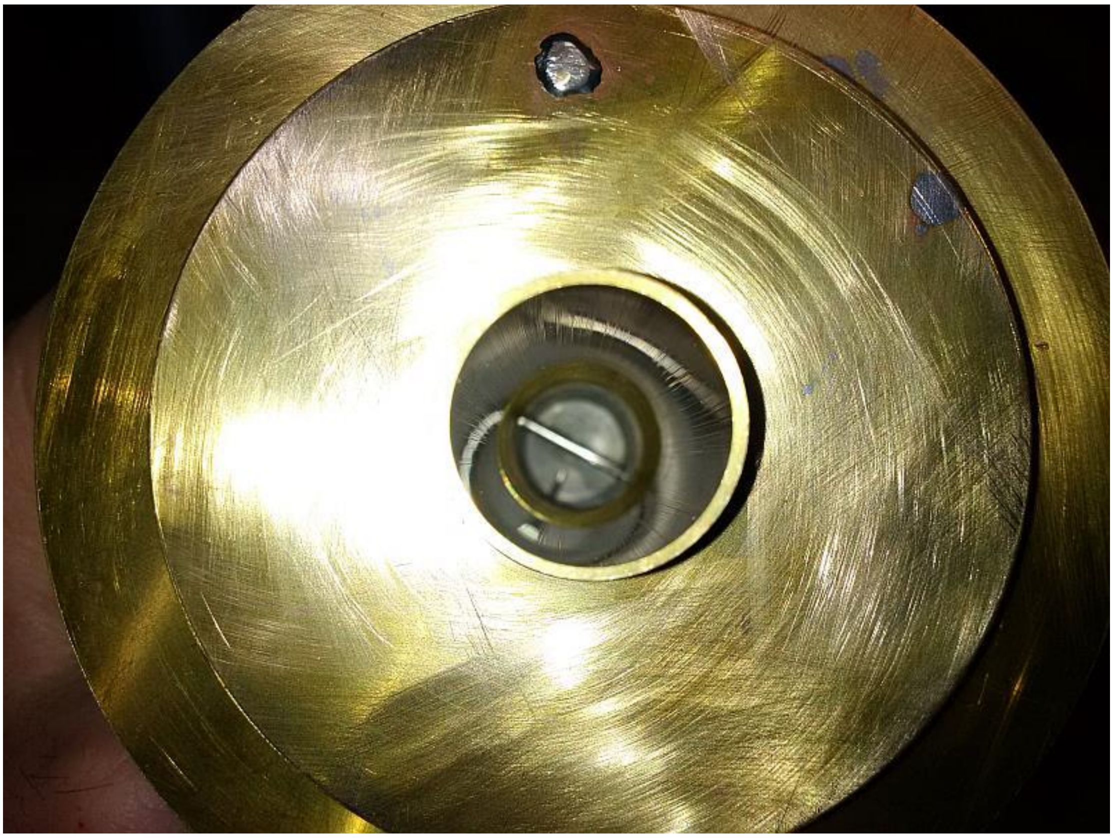



PC-2C

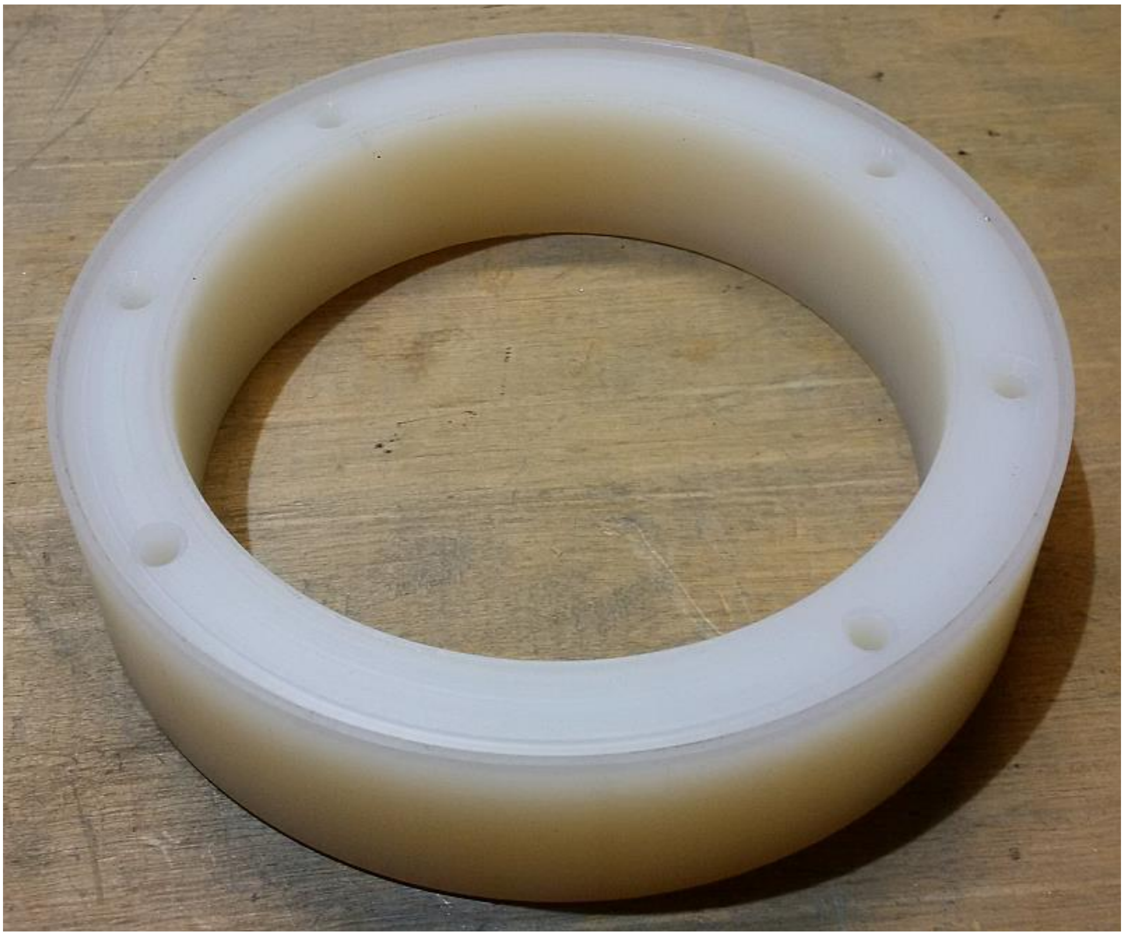


The feed is connected to the LNB with a brass adapter, which is soldered to the feed's circular waveguide. The adapter is conical on the inside and provides a tapered transition from the slightly larger inside diameter of the feed to the inside diameter of the LNB. The adapter is bolted to the remaining flange of the LNB. Here's a look from the front into the circular waveguide.

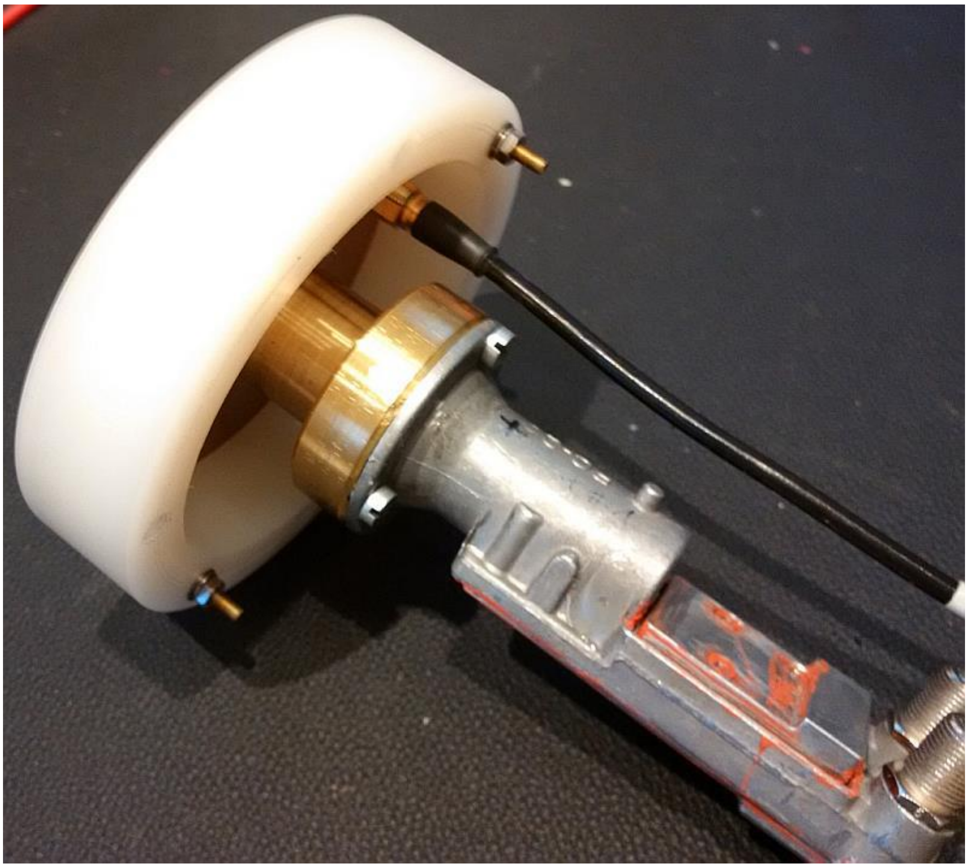


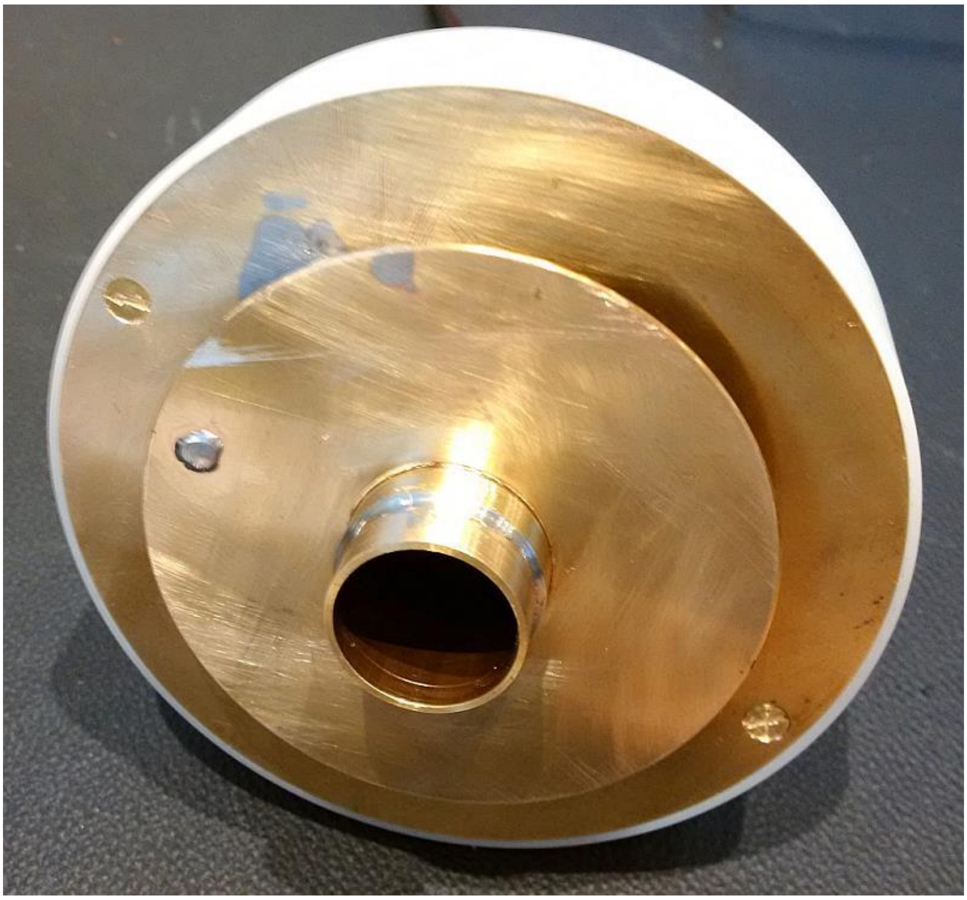


The feed is held in a plastic tube (with an inner diameter of 100mm) by means of a Teflon ring:



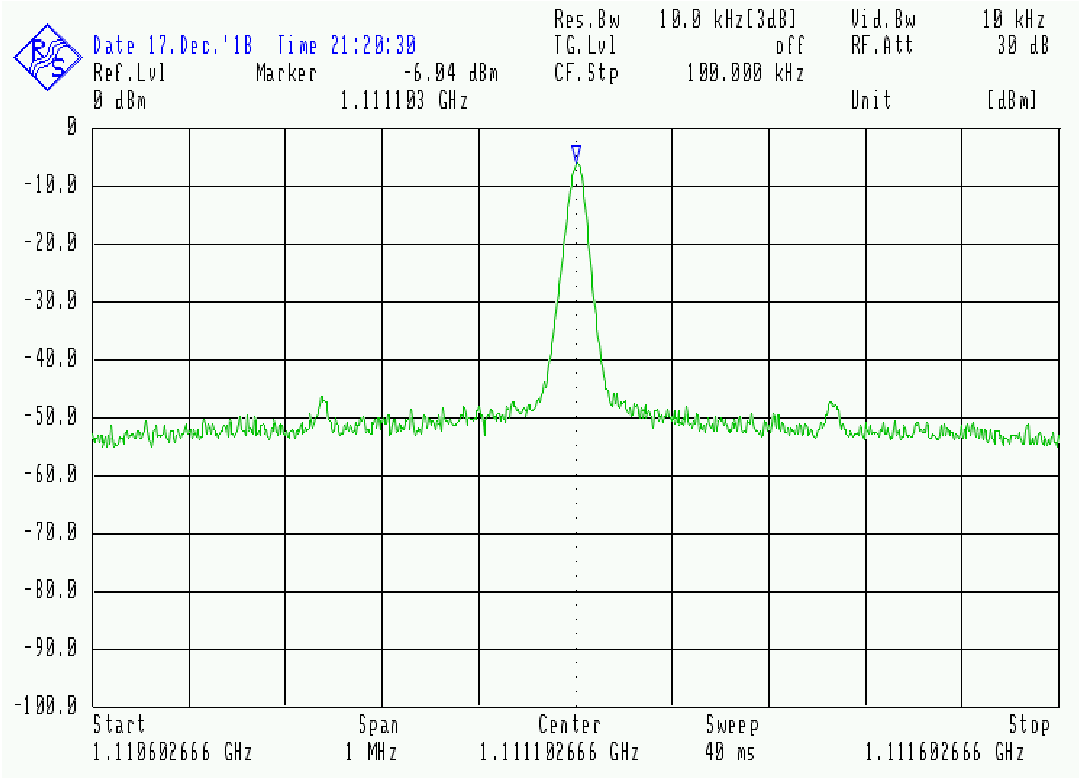
Here you can see the feed attached to the Teflon ring:

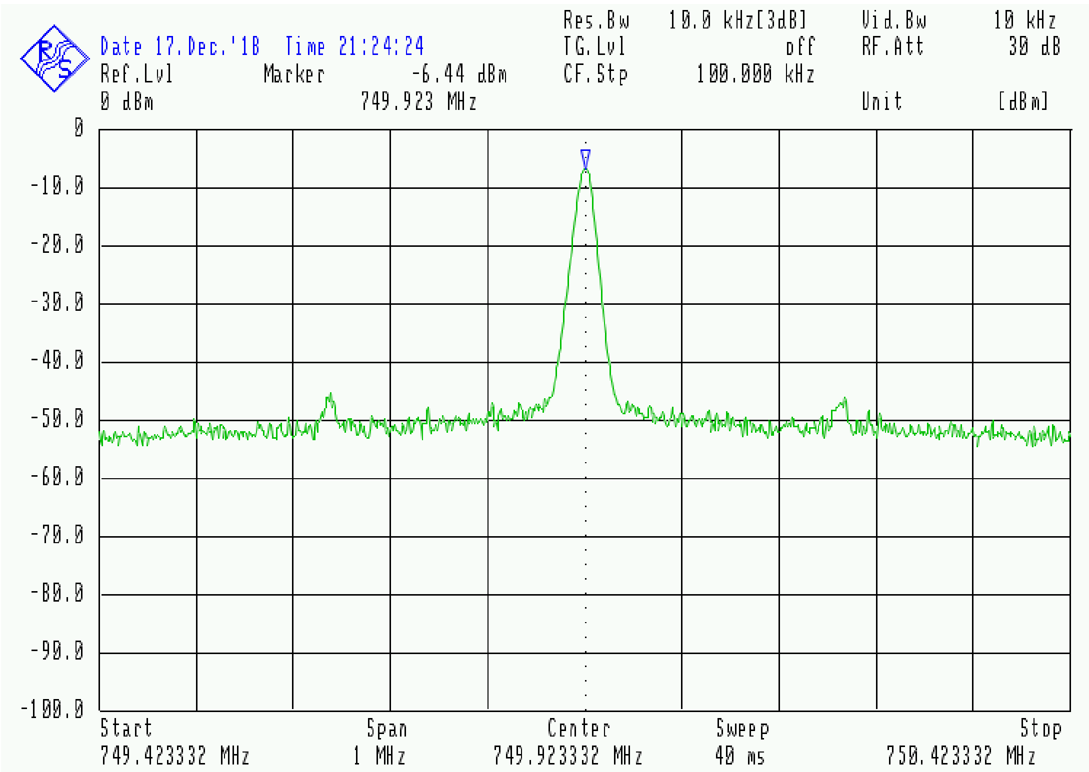




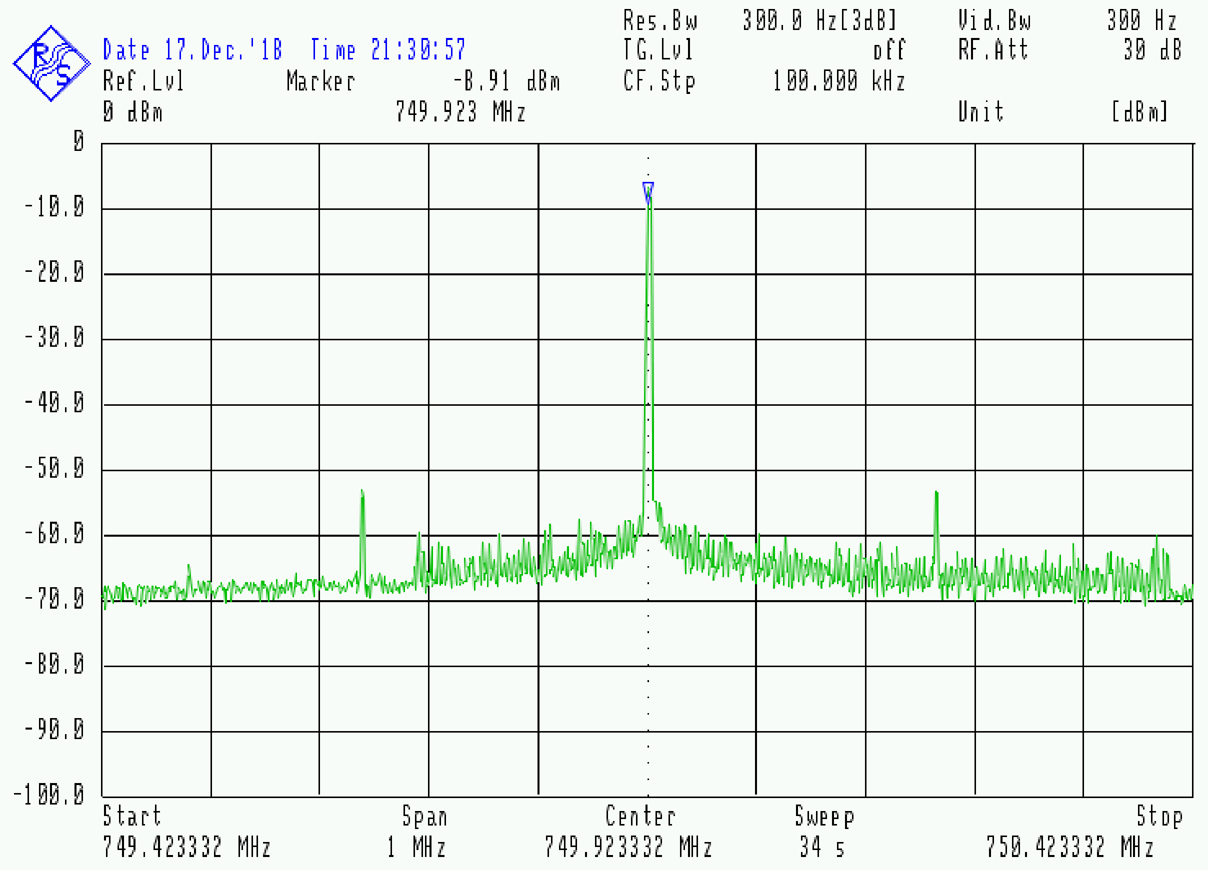
Next, I measurements the IF output signal with the same measurement setup as it was described before. I compared the output of the modified LNB branch A with the unmodified branch B to see if replacing the quartz with a TCXO did result in any unwanted side effects.

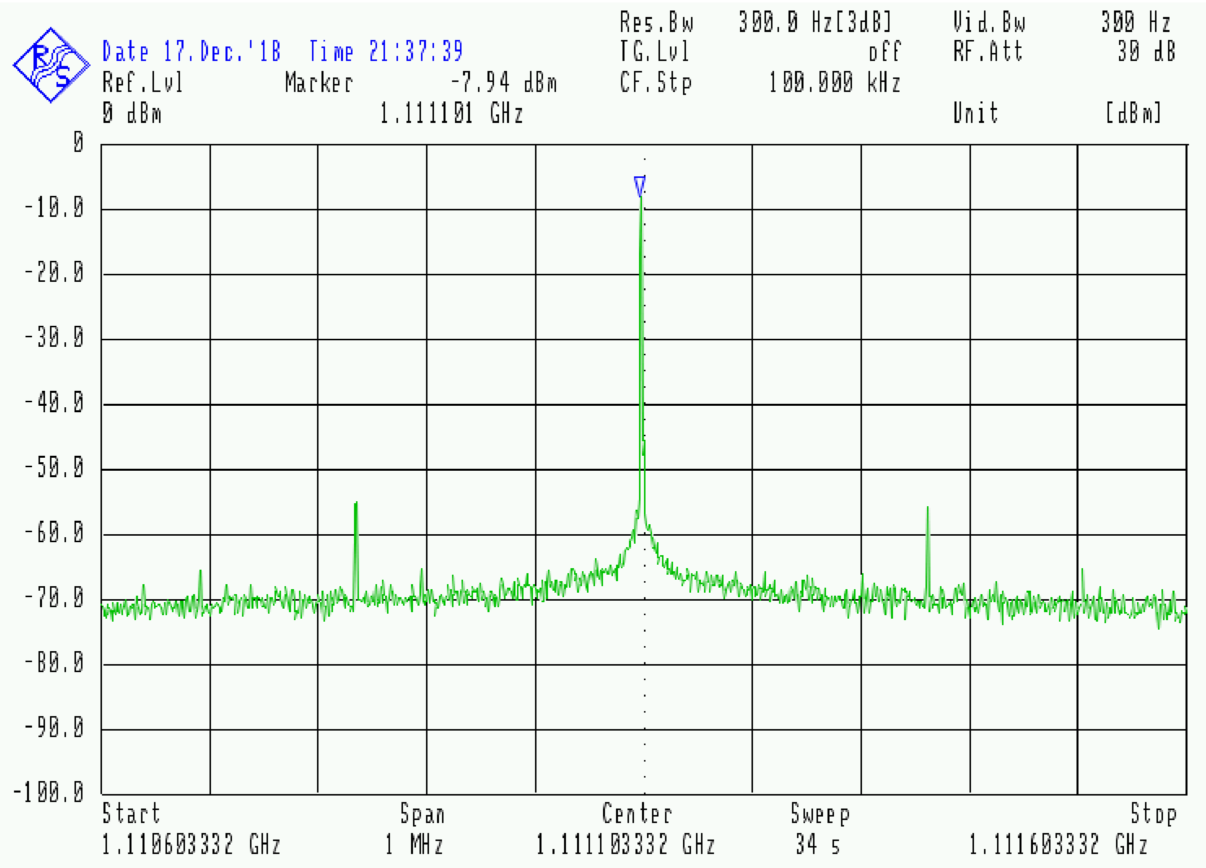
Here are the spectra of output A and B measured at a resolution bandwidth of 10 kHz and a span of 10 MHz.



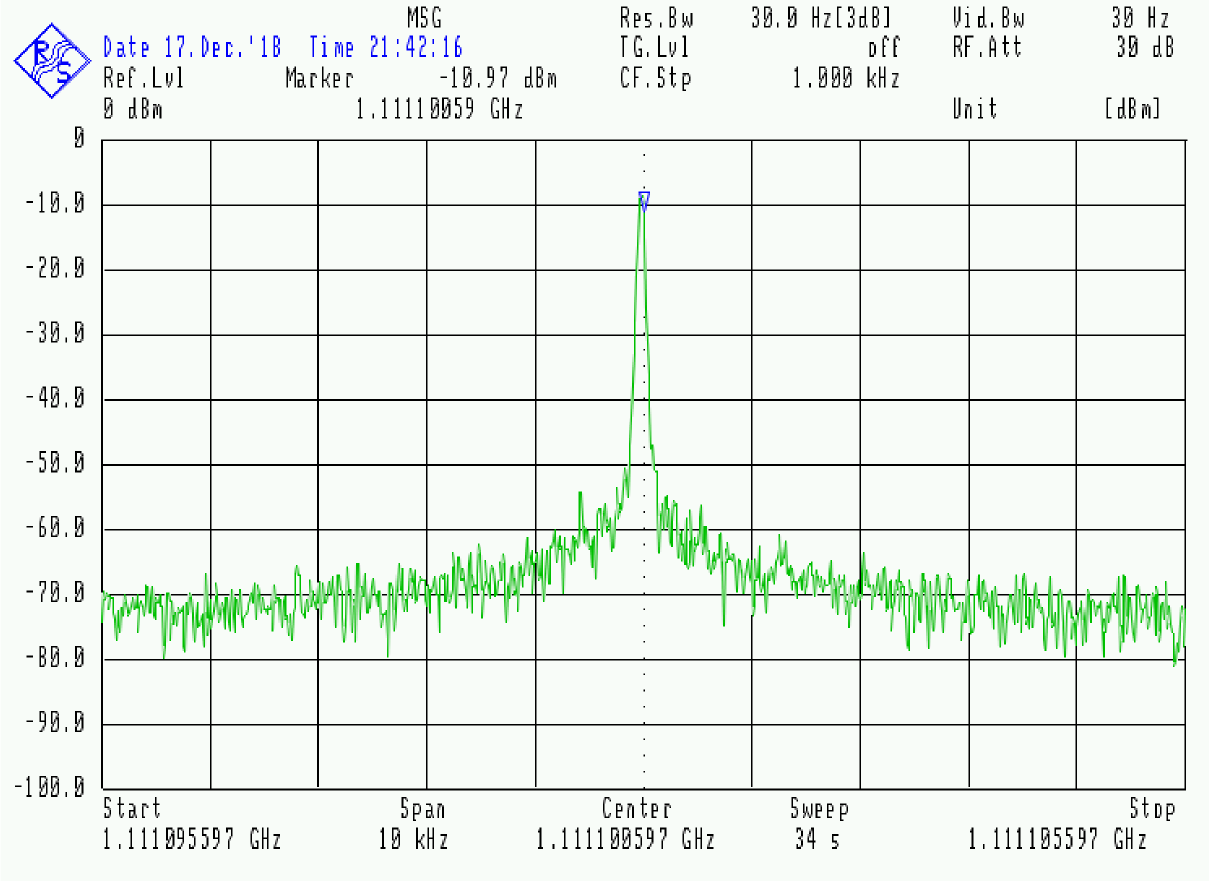


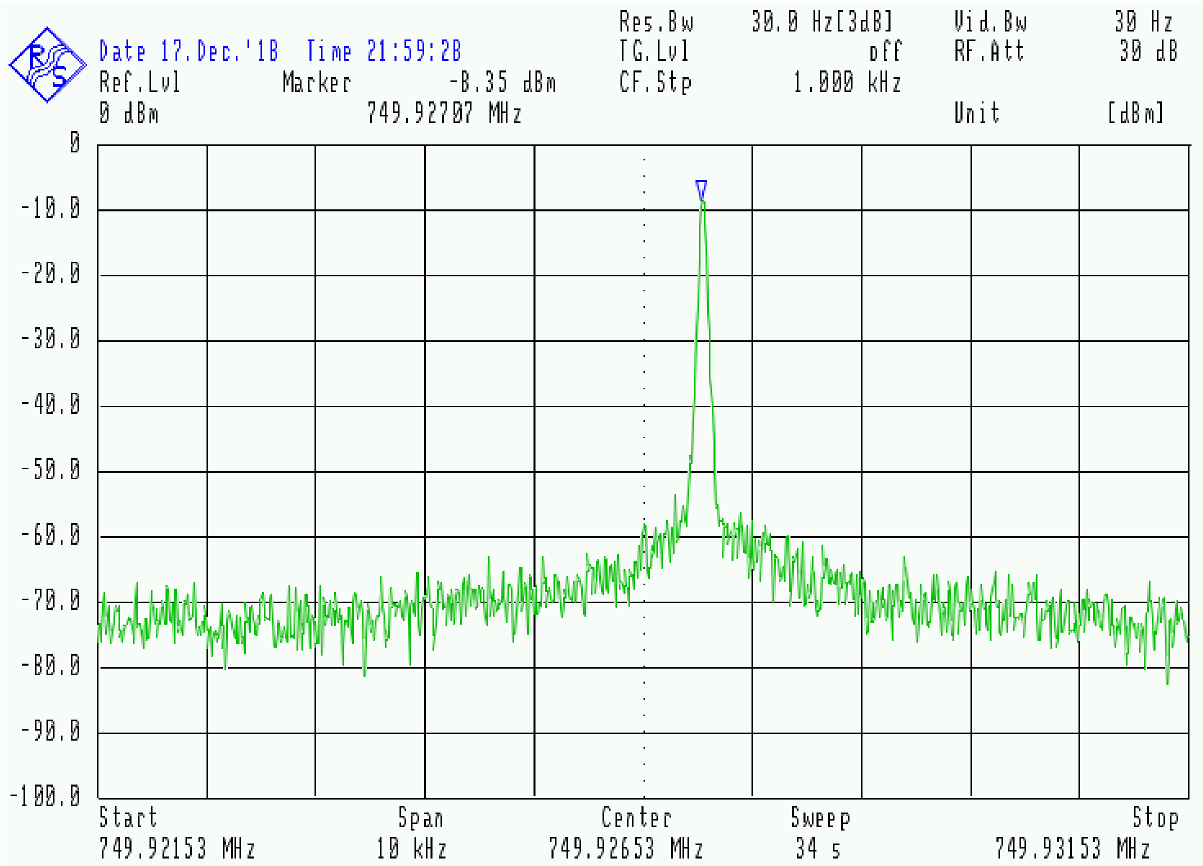
Next, the measurement was repeated with a resolution bandwidth of 300 Hz and a span of 1 MHz:



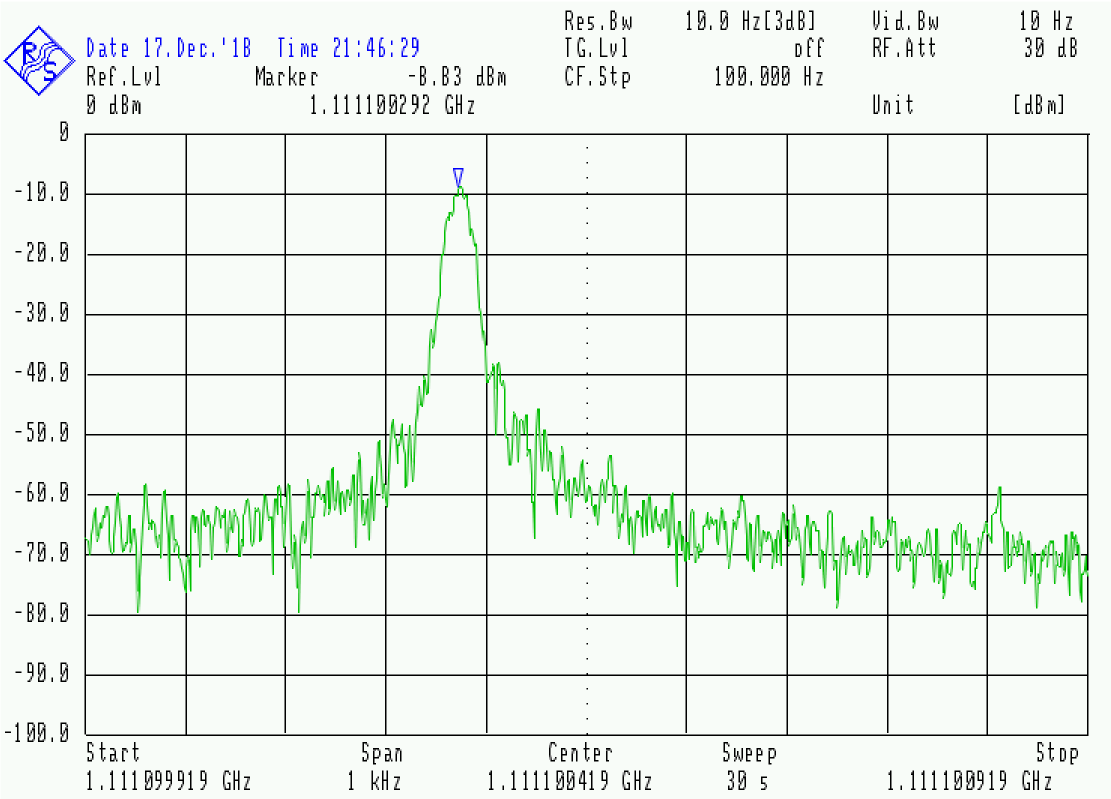


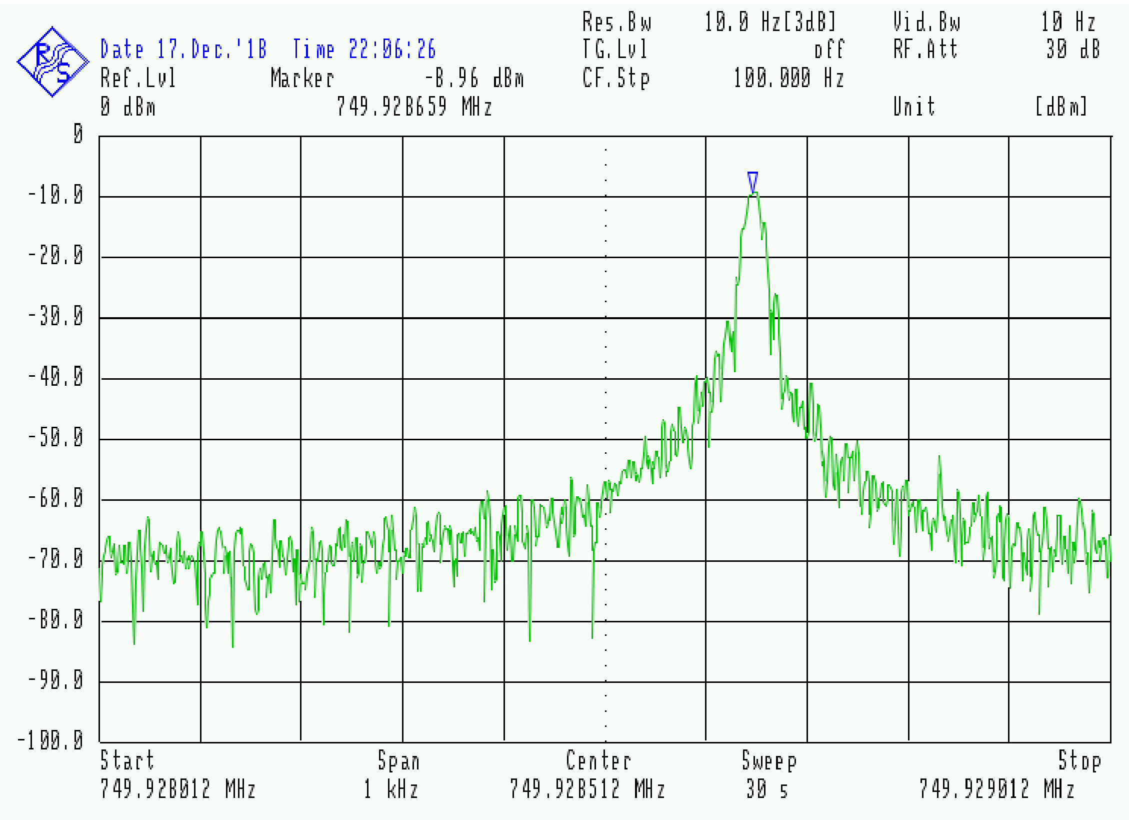
In the next measurements, the resolution bandwidth was further reduced to 30 Hz and the span was set to 10 kHz.



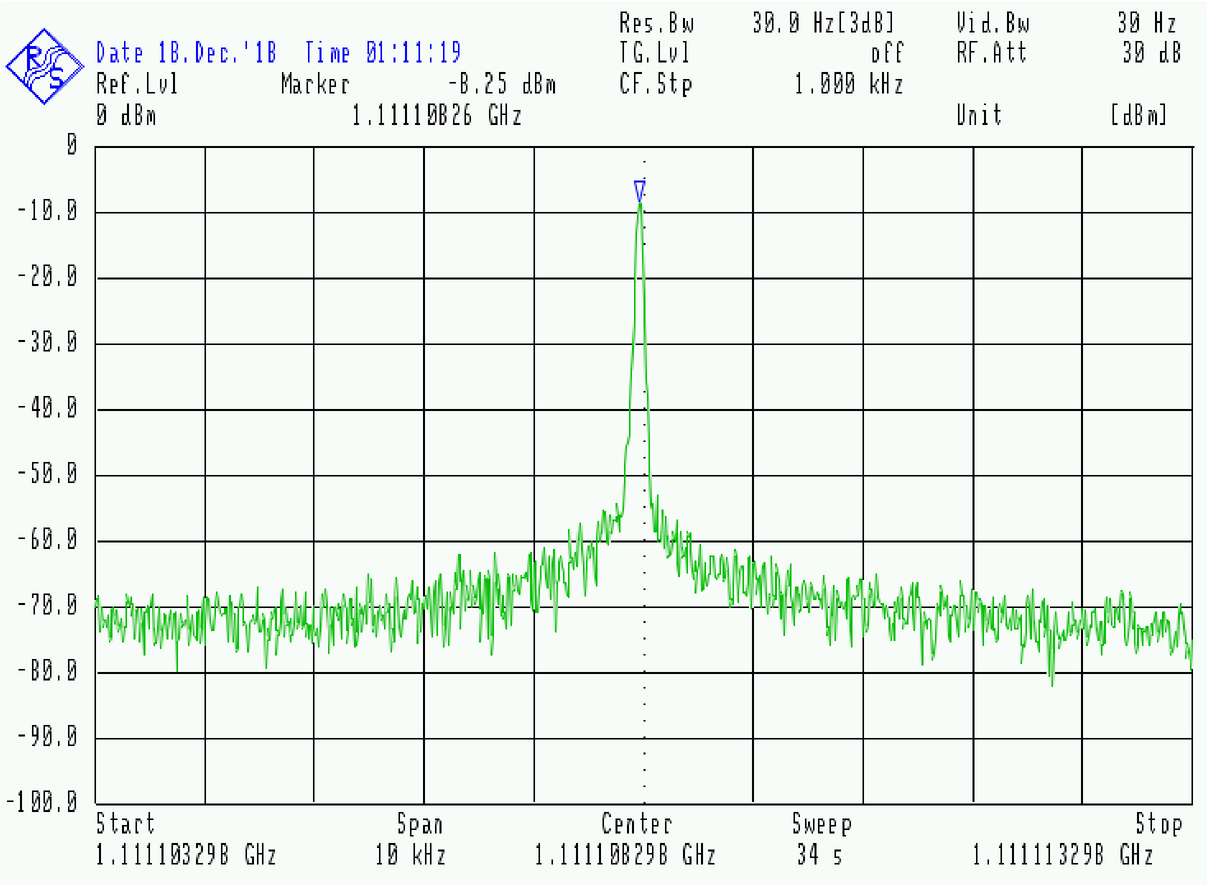


Finally, the resolution bandwidth was reduced to 10Hz and the span set to 1kHz. Due to the high drift of the unmodified LNB branch, the measurement was of the first graph was a bit tricky.





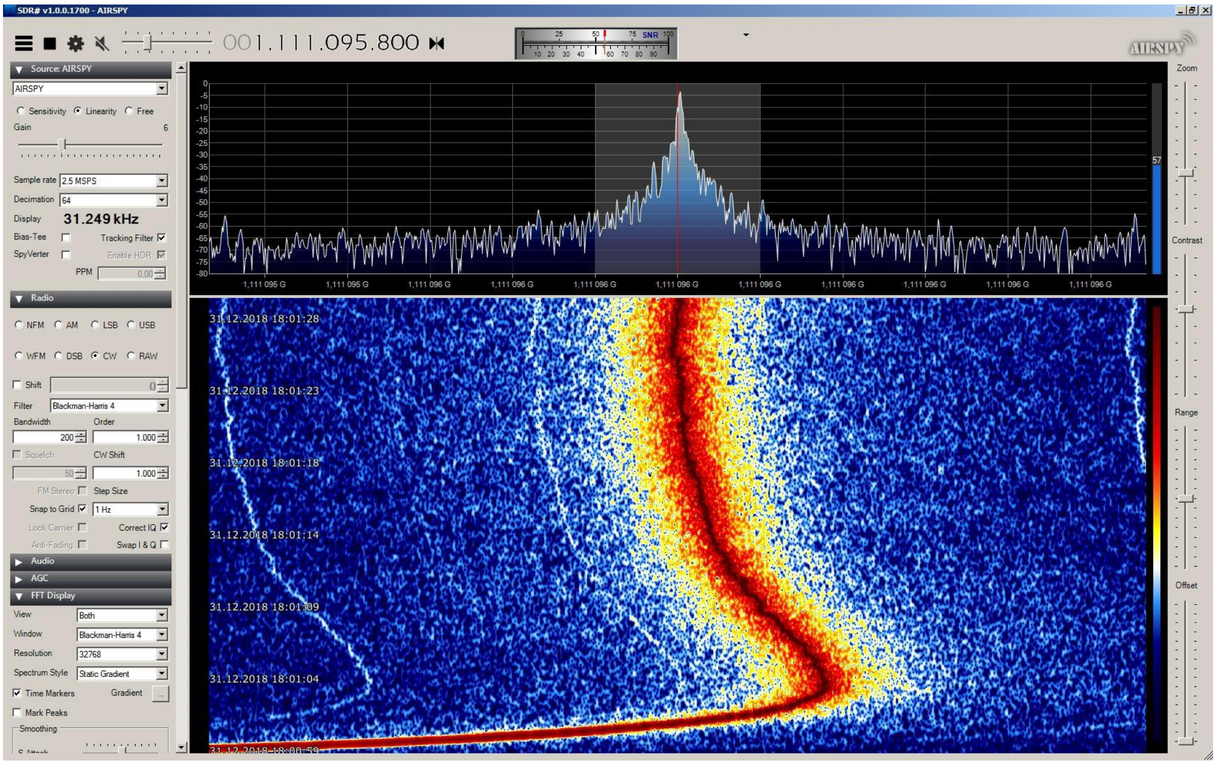
After the modification of branch B of the LNB, the measurements were repeated also for branch B. There was no significant difference to branch A. Therefore, I refrain to represent all traces here. For reference you find next only one of the measured spectra from branch B:



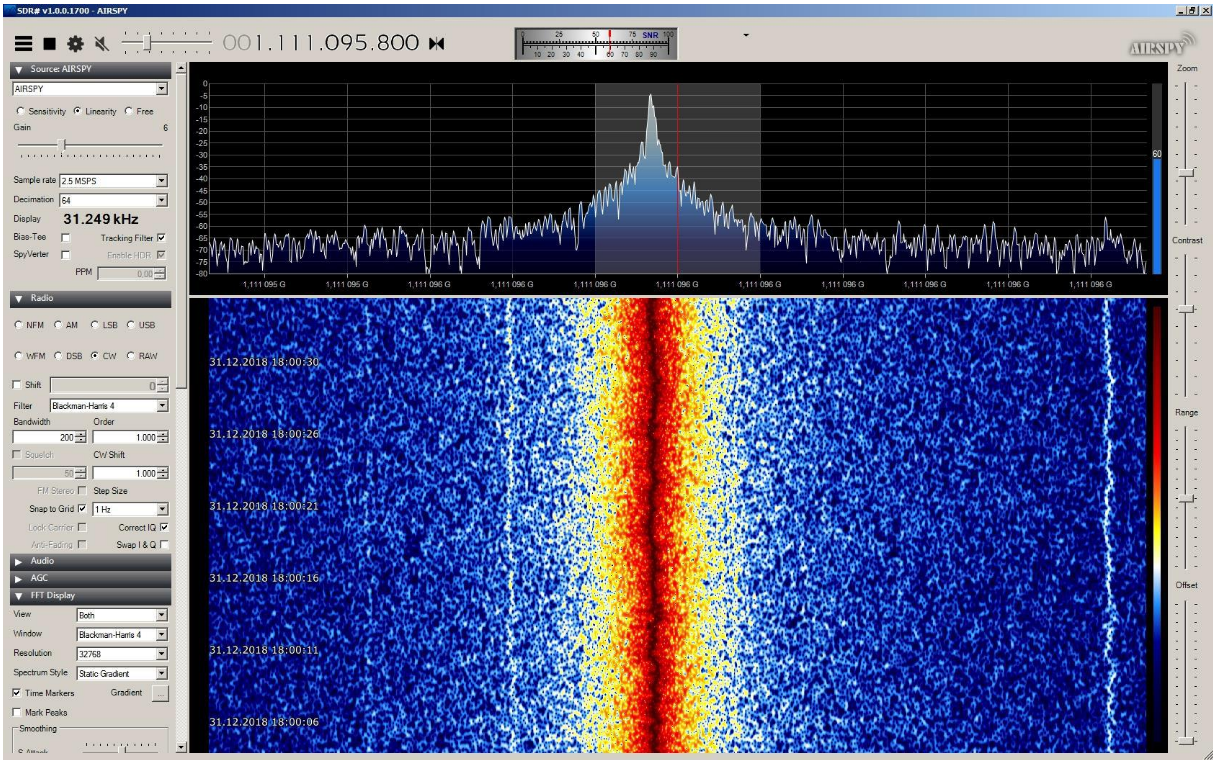
Finally, below you will find measurements, which were carried out at the IF output using an Airspy SDR. The measurements were done after the modification of both LNB branches A & B and the final installation of the feed in the weatherproof housing. The horizontal scaling in the graphs is 100 Hz per division. The spectrum as well as the waterfall diagram are in each measurement 1 kHz wide.

First, output A was measured. A supply voltage of 17 V was used. The input signal was 10500 MHz.

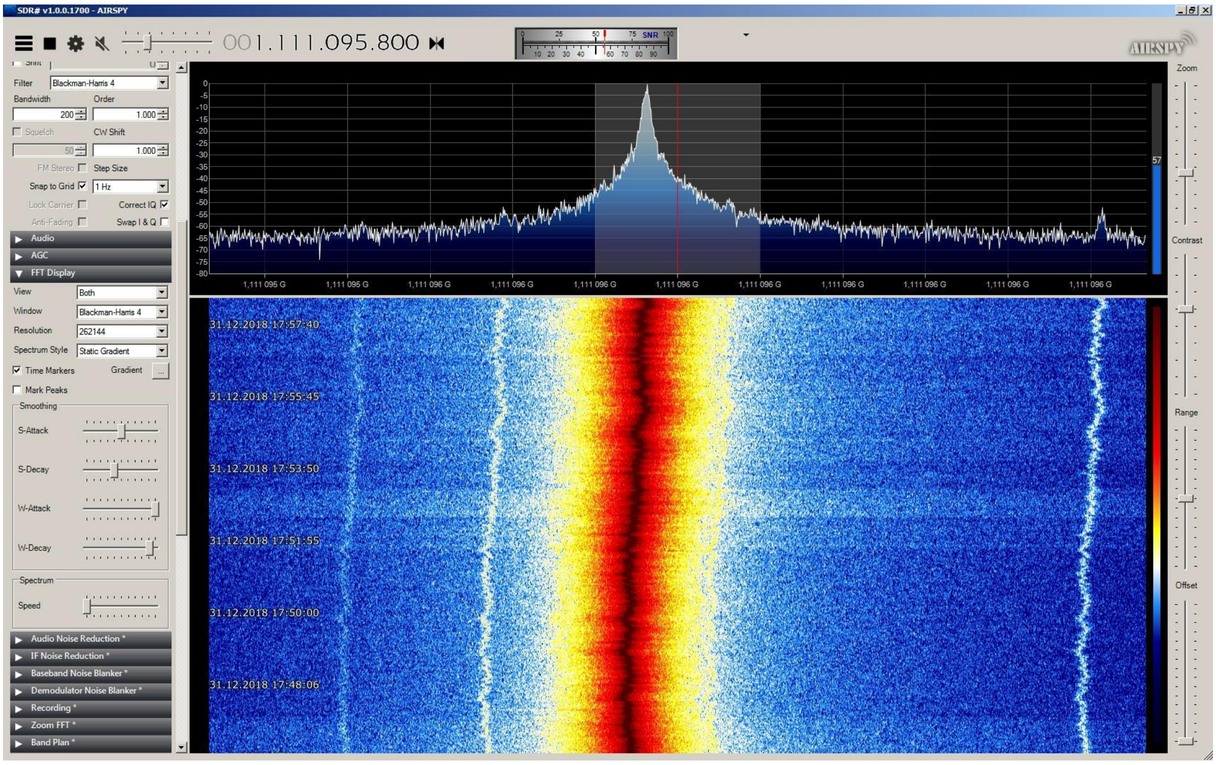
Transient response of the LNB within the first 30 seconds after applying the supply voltage:



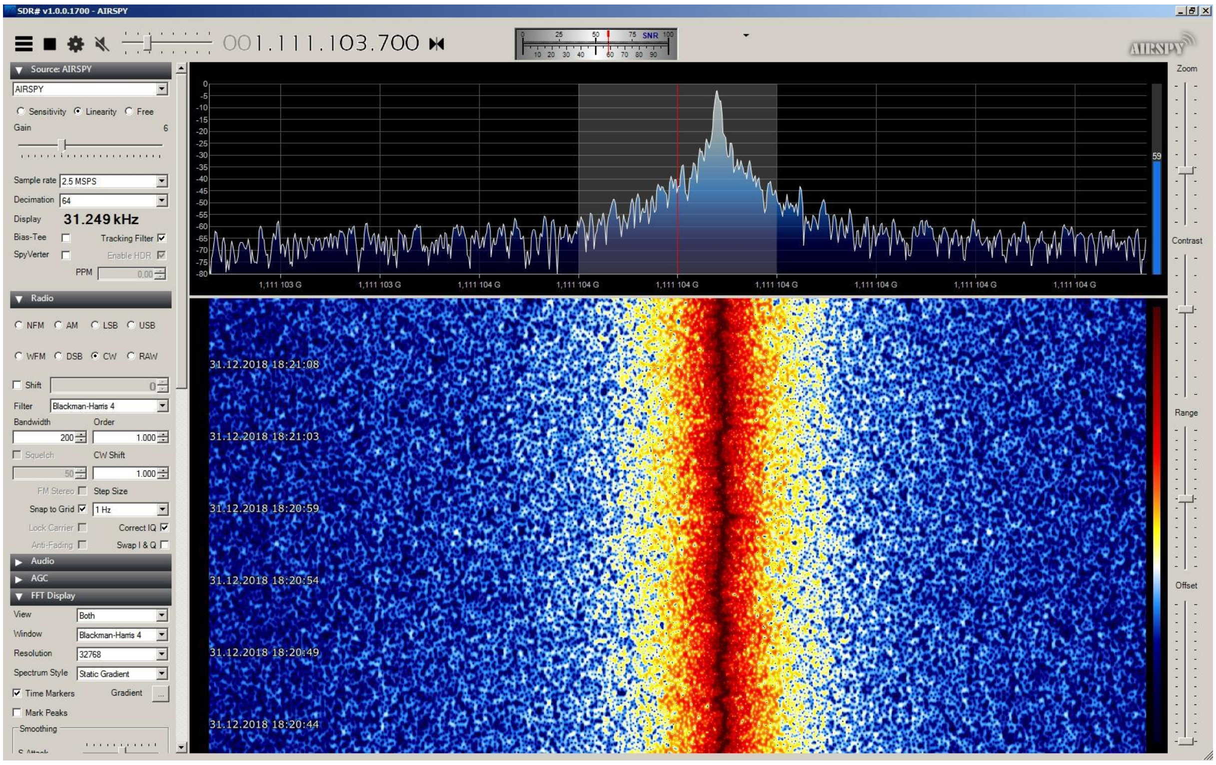
Here the same measurement after the oscillator has settled:

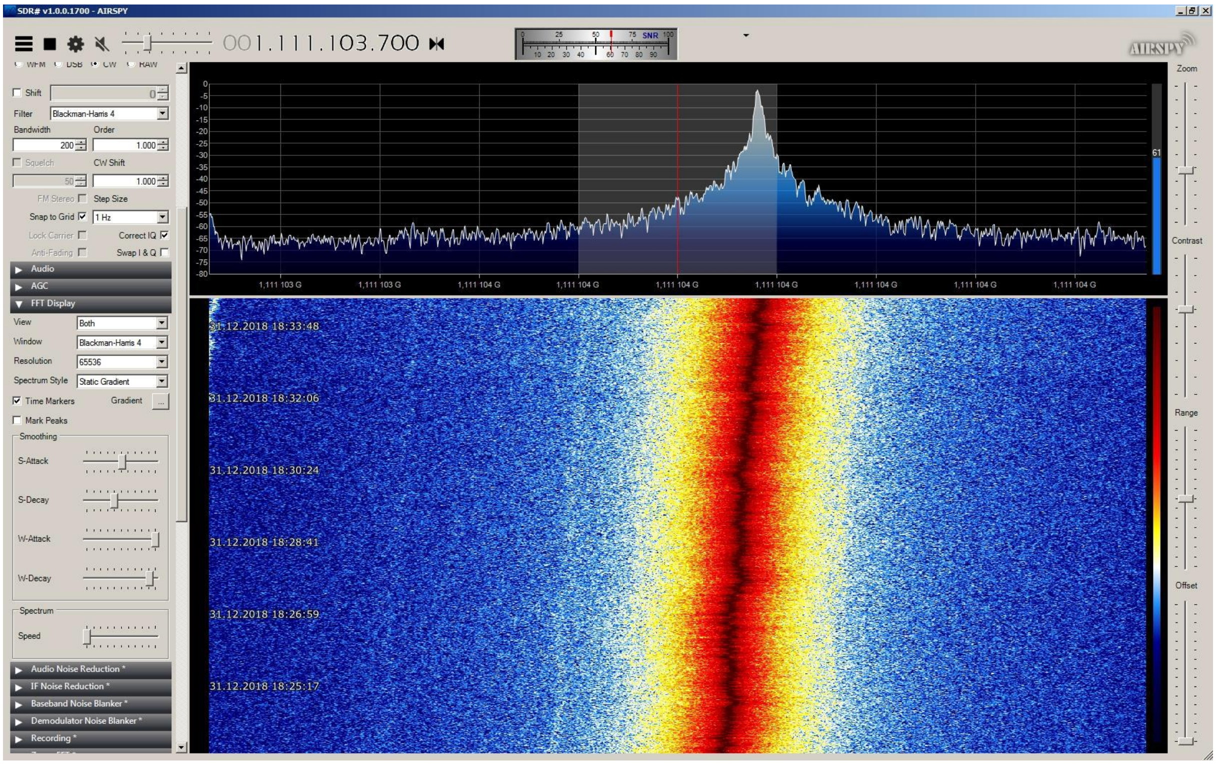


In the diagram below, the waterfall chart was taken over a longer time period (in total 12 minutes):



Next, output B was measured using the same methodology.





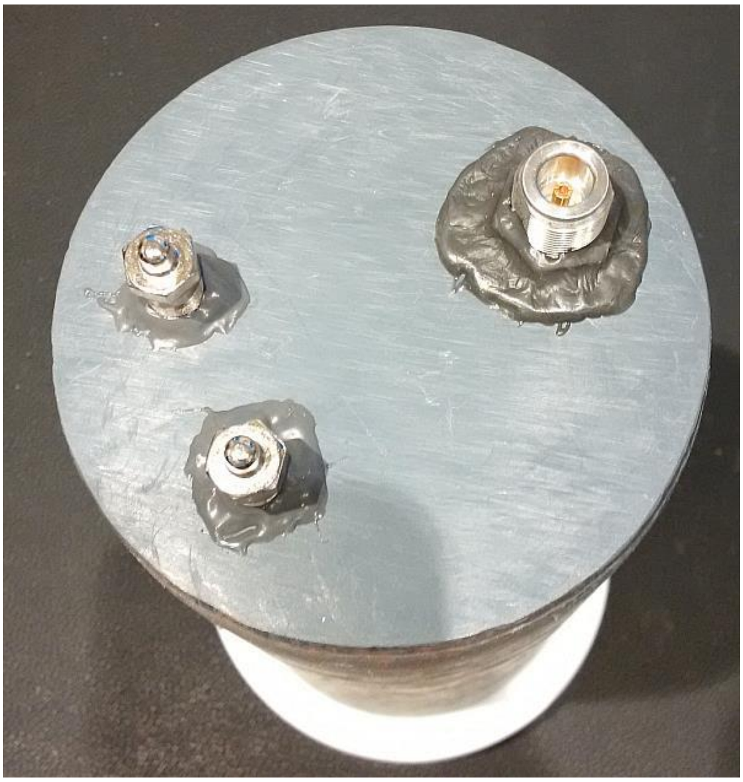
As you can see the two branches behave almost identically. The only difference is the frequency offset: the LOs (local oscillators) of the two LNB branches differ by 7.9 kHz.

I would like to point out that during these measurements I did not synchronize neither the SMIQ06 signal generator (with self-made frequency doubler) nor the Airspy SDR with an external reference frequency. The measured frequency drifts are therefore the sum of the entire measurement setup. Furthermore, everything was measured here in the shack at constant ambient temperature. However, since the structure is in a hermetically sealed weatherproof housing and the power dissipation is about 1.8 watts, it can be assumed that the LNB has warmed over time.

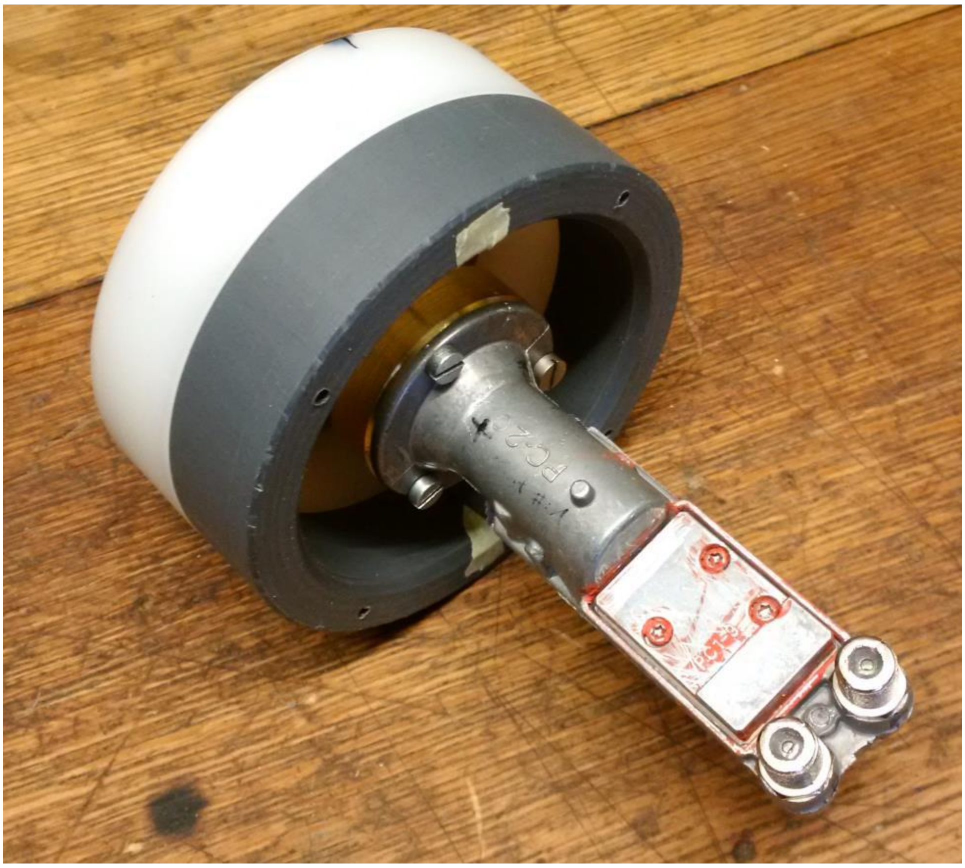
I am quite satisfied with the results. I have listened to the received signal in CW and it sounds very clean. The remaining drift is about 10 Hz in the short-term range, about 50 Hz over a period of 10 minutes. The drift is obviously continuous which again confirms that the TCXO contains an analogue control loop. Measured over an hour, drift was always below 100Hz. After about 3 hours, the offset was still well below 200Hz. This can be easily compensated for in practical QSO operation, whereby a higher long-term drift is certainly to be expected in outdoor use.

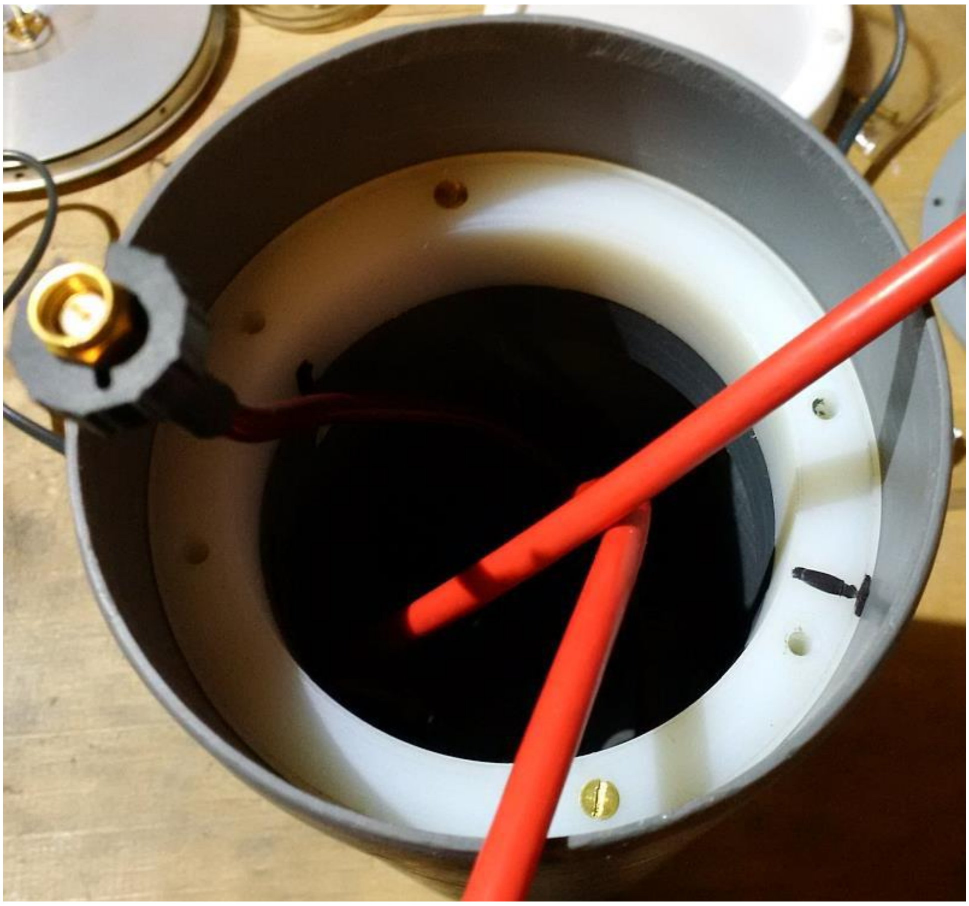
When conducting QSOs on EsHail-2 / Qatar-OSCAR 100 with the feed outside, the above measurements were confirmed. The Octagon Dual PLL LNBs with the TCXOs performs very well.

To protect the feed against the weather I used a 100mm water pipe, on which I glued a bottom plate made of PVC. In this bottom plate the coaxial cable jacks are screwed. The connections are sealed with Spinner Plast2000. So far, I have had very good experiences with this sealing and I intend to seal also the LNB with it when all further tests have been successfully completed.

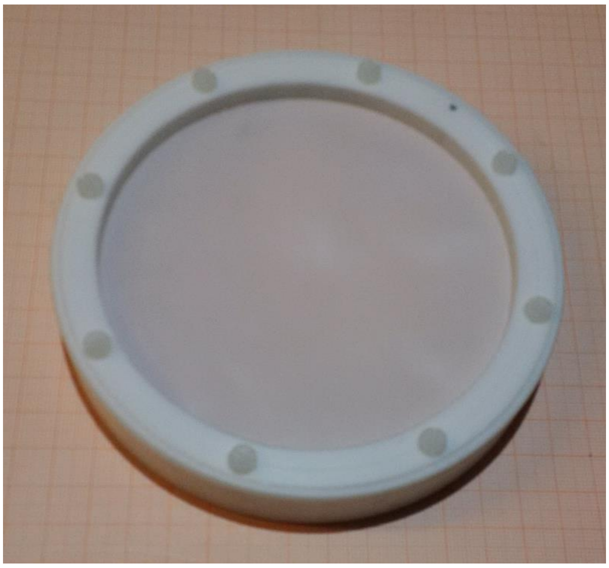


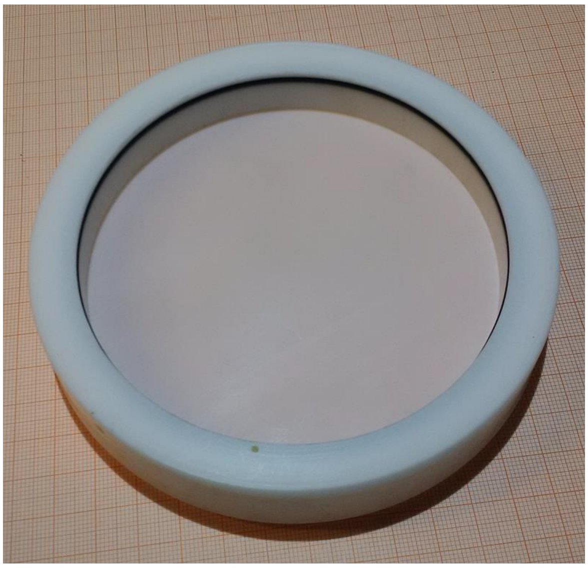
To fix the feed in the tube, another ring of plastic was turned, which was glued into the tube. In this ring M3 threads were cut so that the feed with the Teflon holder is screwed to this ring. Thus, the feed is fixed in the tube and cannot slip neither axially nor radially.



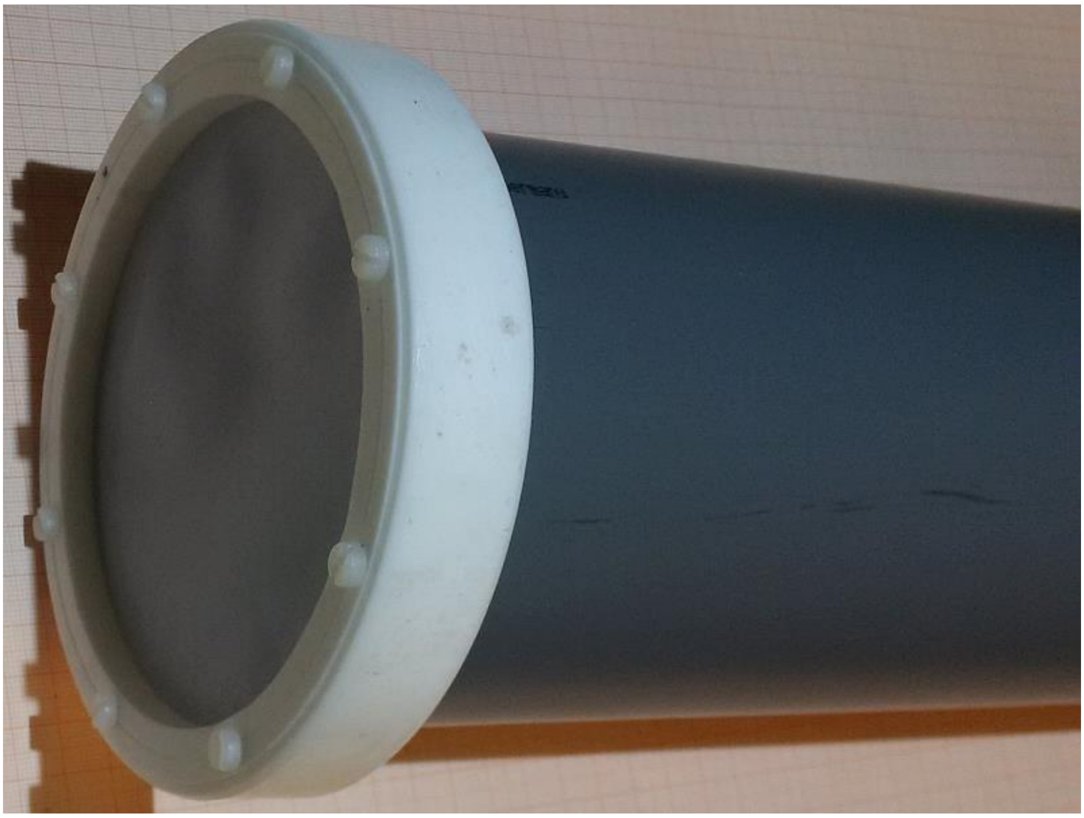


An attachable Teflon cover protects the front of the feed. A Teflon ring holds a thin Teflon foil. A rubber seal is embedded in the Teflon ring.

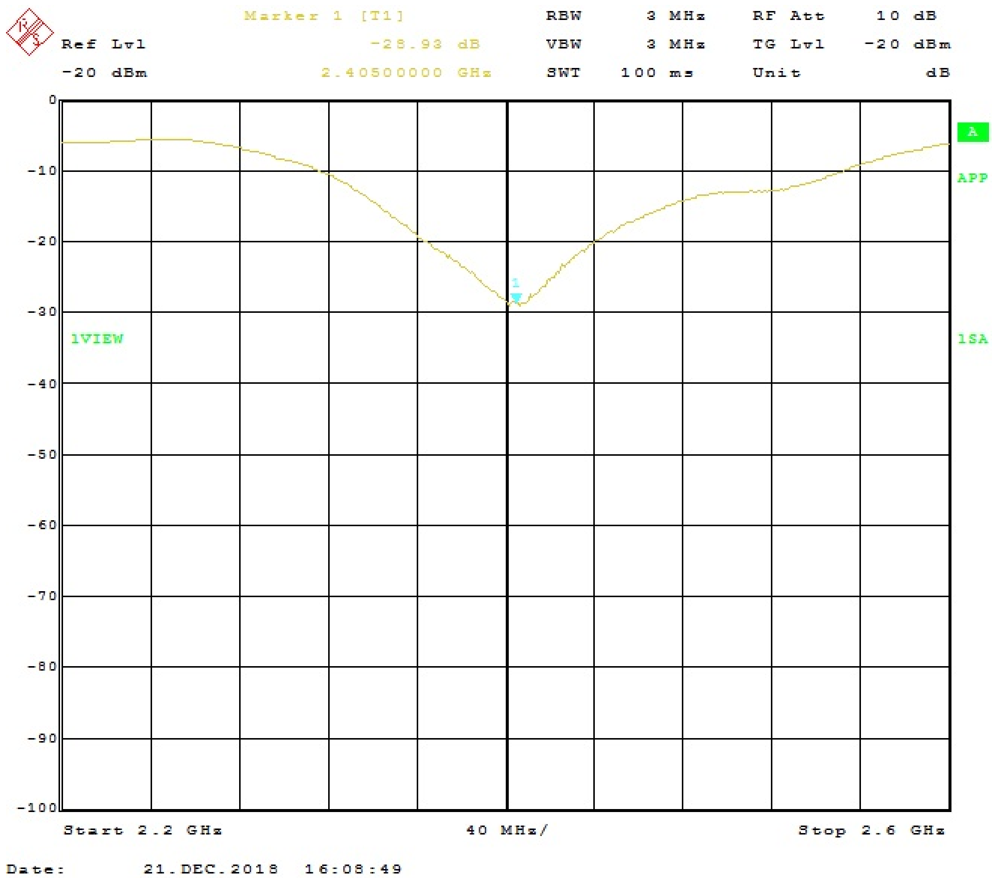




This is the feed after everything was assembled:



Adjusting the 2.4 GHz patch feed is quite easy with the capacitive probe which can be adjusted with a screw on the back of the patch-feed. The final tuning should be done, when the feed is mounted in the weatherproof housing. Due to the housing and the front cover, the resonance frequency shifts slightly downward. The return loss at 2405 MHz is about 28dB, which corresponds to a VSWR of 1.08.

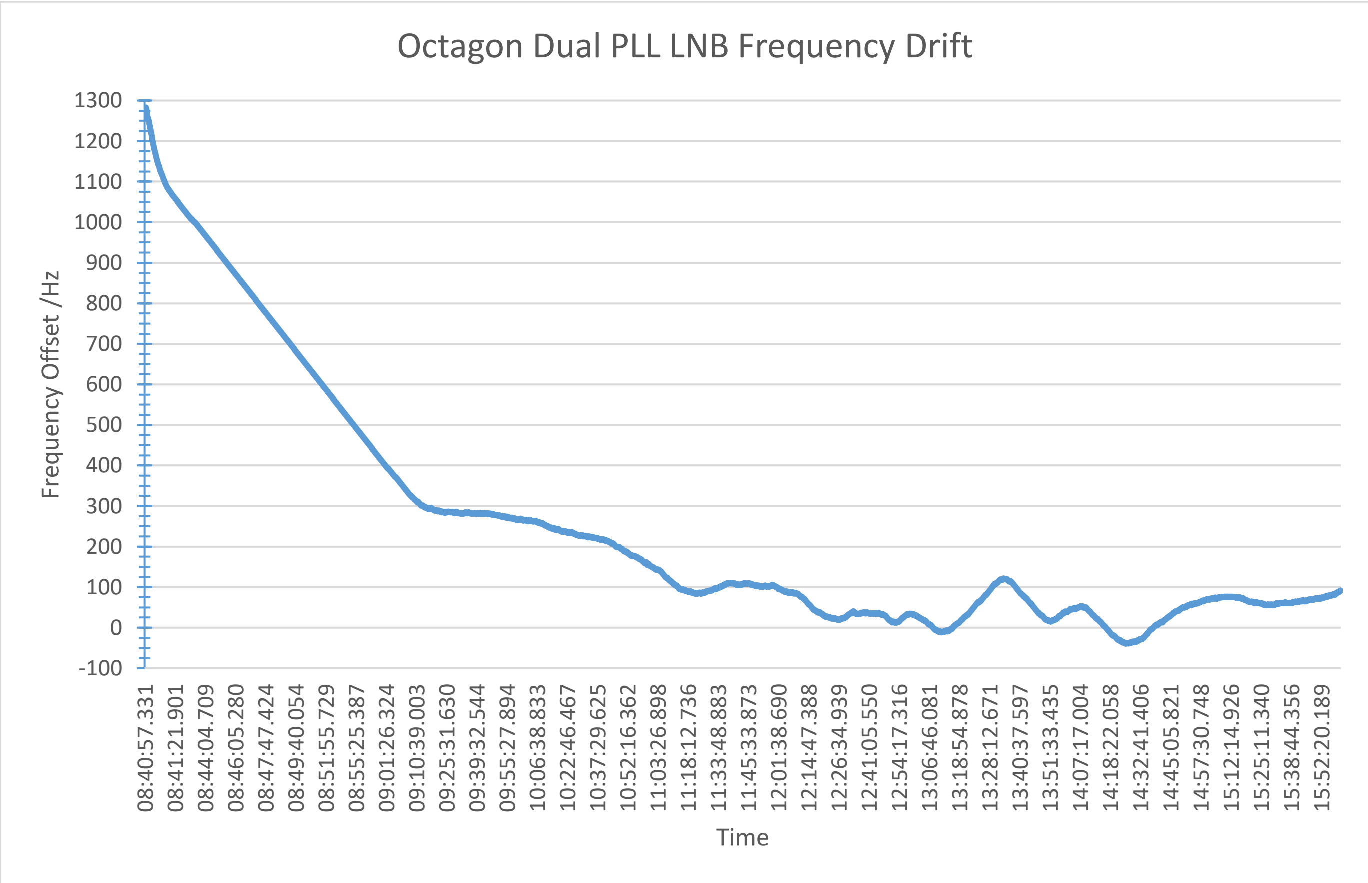


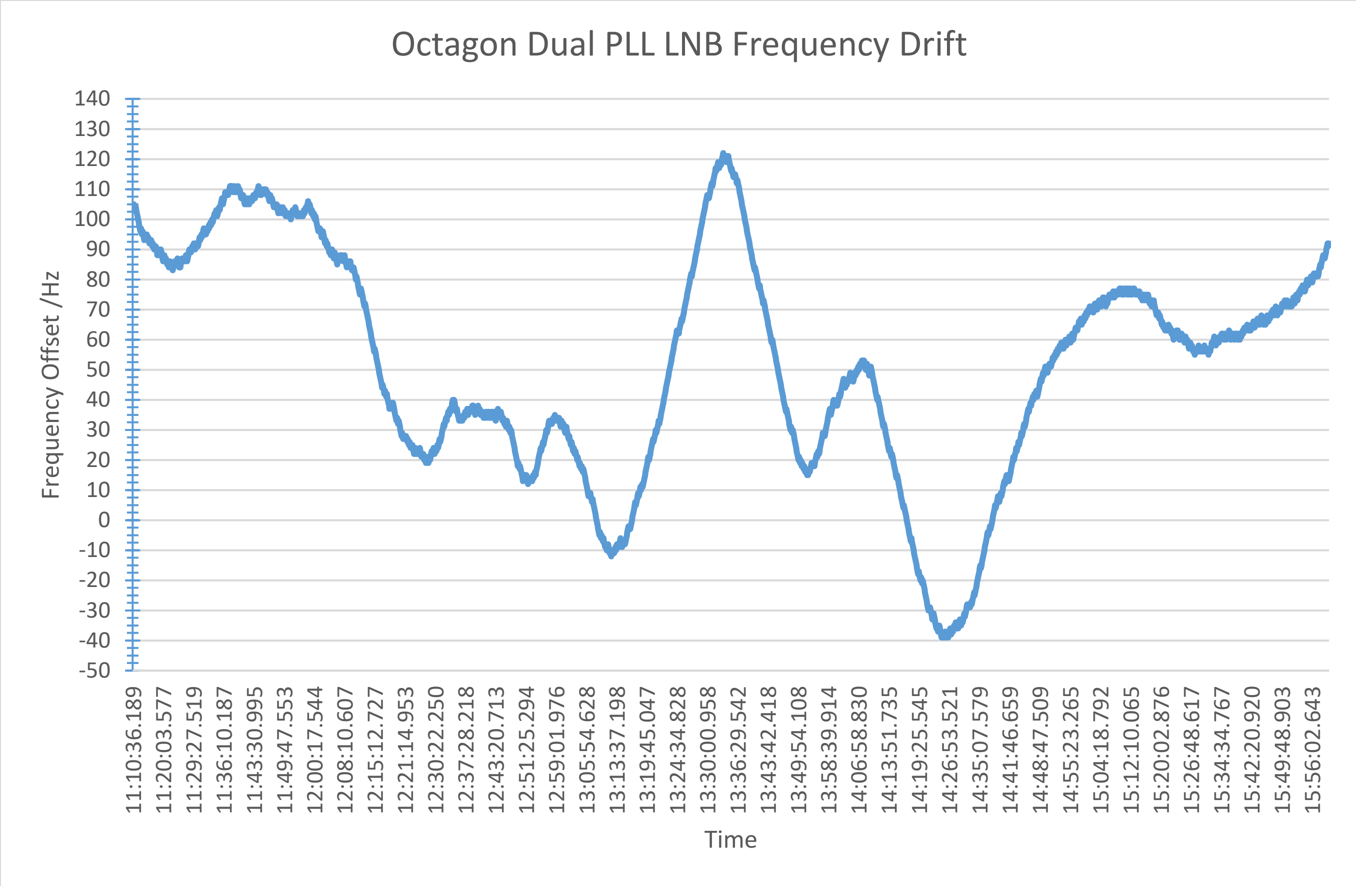
Finally, here are pictures of the feed mounted in the quick-change bracket of the parabolic dish.

This setup has proven to work very well on QO-100. With a transmit power of 300mW at the feed my signal is about 30dB above the transponder noise floor. More uplink power is not recommended, in order to avoid triggering the AGC of the satellite.

I have been using the LimeSDR-USB with SDR-Radio to operate via QO-100. It works very well. In the latest version Simon has implemented a nice feature which allows SDR-Radio to lock to the PSK beacon of QO-100 and automatically correct the frequency drift of the LNB. In addition, the compensated offset can be recorded in a CSV file. Here are some me measurements I made on March 25th 2019 from 8:40h to 16:00h. The measurement started exactly when the LNB was first time powered on after being switched off for about 8 hours. As can be seen the LNB started with an offset of 1.3kHz and after about 30 minutes the offset was down to 300Hz. In the next 7 hours the offset varied by about 350 Hz.

I would like to reemphasize, that the offset was always compensated by SDR-Radio and this just shows the drift of the modified LNB (i.e. the drift which would have existed if there was no compensation by SDR-Radio). Clearly this drift would have been good enough to operate SSB and CW without having to readjust the frequency frequently. By the way my LimeSDR is locked to a GPSDO, thus we only see the drift of the LNB and not of the whole receiver chain.





Meanwhile a new feed from DJ7GP is available with an improved circular polarization of the 2.4 GHz patch. This new version 2.0 is available through Bamatech and is also available with a readily adapter LNB.

I am always happy about feedback or question. Please send them preferably by Email to the address given below.

Best regards

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