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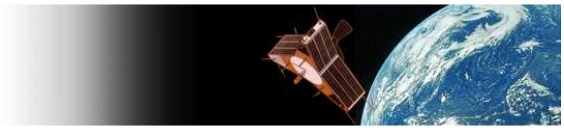


Universal receiver mixer for QO-100 (AMSAT P4-A)

While in the past we were able to make experiences with AO-40 operating on 13 cm, 10 GHz reception will be new territory for most of us. Commercial TV-Sat hardware cannot be used with a conventional SSB transceiver without modifications. In this article we present a downward mixer that can close this gap.

circumstances

Due to the wide distribution of commercial receivers for satellite television, antenna systems for 10-11 GHz with corresponding Low Noise Blocks (LNBs) are available at very low prices. LNBs are generally formulated as preamplifiers with down mixers that convert the Ku band between 10.7-12.75 GHz to the IF of 950-2150 MHz used by TV receivers. Usually two separate LO frequencies are used (9750 MHz or 10600 MHz), which are switched with a 22 kHz signal on the coaxial line. The switching between the two linear polarization planes (vertical/horizontal) is done with the operating voltage (14V or 18V). For the downlink frequencies of 10489 MHz (narrowband/NB, 250 kHz) and 10495 MHz (broadband/WB, 8 MHz) used by Phase 4A, only the LO frequency of 9750 MHz makes sense. This results in intermediate frequencies of 739 MHz (NB) and 745 MHz (WB). Unfortunately these frequencies cannot be reached by conventional SSB transceivers or satellite receivers. Here a SDR stick would be necessary which is not desired by many OMs.

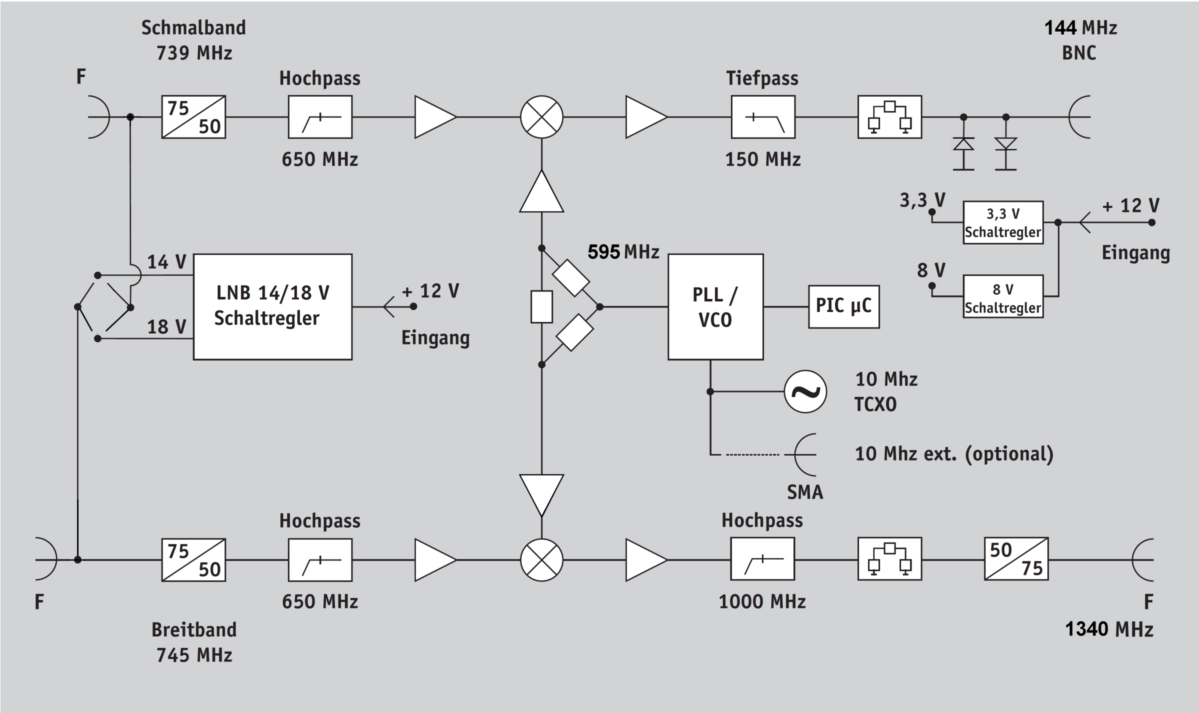
approaches

One of the first ideas was the modification of commercial LNBs. In the past, the local oscillators of LNBs were so-called dielectric resonance oscillators (DRO): small ceramic pills on the LNB board, which could be shifted down in frequency by placing further ceramic discs on the board. Not only was this method relatively inaccurate: the DROs are sufficient in terms of phase stability for television signals, but completely unusable for SSB or even CW signals. Modern LNBs have a voltage controlled oscillator, which is locked to a reference oscillator (usually a quartz, approx. 25-27 MHz) by means of a phased locked loop (PLL). These PLL LNBs are much better in phase noise and suitable for narrow band signals. The necessary modification means only the exchange of the quartz oscillator. Experience shows that working with SMD components and selecting the right quartz is not everyone's cup of tea and so there are now several OMs which offer modified LNBs.

New approach: downstream mixer

David Bowman G0MRF published a downward mixer in the OSCAR NEWS (September 2016) which mixes the narrow band signal down to the 2m band based on a SI590 oscillator at 595 MHz. Regardless of this design (which we didn't know at the beginning), we within AMSAT-DL were of the opinion that a solution had to be created to enable the radio amateur an easy access to Phase 4A with as much commercial technology as possible. We also opted for a down mixer with 595 MHz, resulting in a IF of 144 MHz. At the same time our mixer should also use the LO to mix the WB signal. This signal, originally at 745 MHz, would be at 1340 MHz after an upward mix, suitable for conventional satellite receivers. In order to further simplify the use of this module, the coaxial inputs should be directly compatible with an LNB, i.e. F standard and 75 Ohm. The necessary supply voltages of 14/18V should also be generated locally. This was about our wish list, which was created at the beginning of June 2017 during the EME experiments. The aim was to present a prototype at the Hamradio in Friedrichshafen (middle of July!)...

draft



The block diagram of the high-frequency part was drawn relatively quickly. Companies such as Analog Devices or Mini-Circuits offer various modules in the GHz range, which are all internally already adapted to 50 Ohm and can be operated with minimal effort. Not unexpectedly the generation of the LNB supply voltages was somewhat more complex. Somewhat surprisingly, we quickly found highly integrated switching regulator ICs, which come directly from television technology and are specially designed for feeding such LNBs. Two additional switching regulators generate the additional voltages from 12V: 3.3V for the local oscillator (in our case an ADF4360-7) and the microcontroller required for initialization and 8V for the RF amplifiers. The frequency synthesizer of course still needs a reference, which was realized with a 10 MHz TCXO. For most users this will be by far stable enough as the thermal drift of the oscillator in the LNB will dominate the overall frequency (in)stability. However, if someone uses a phase-locked LNB, the possibility of connecting an external 10 MHz reference to stabilize the entire receiving system is provided on the mixer.

realization

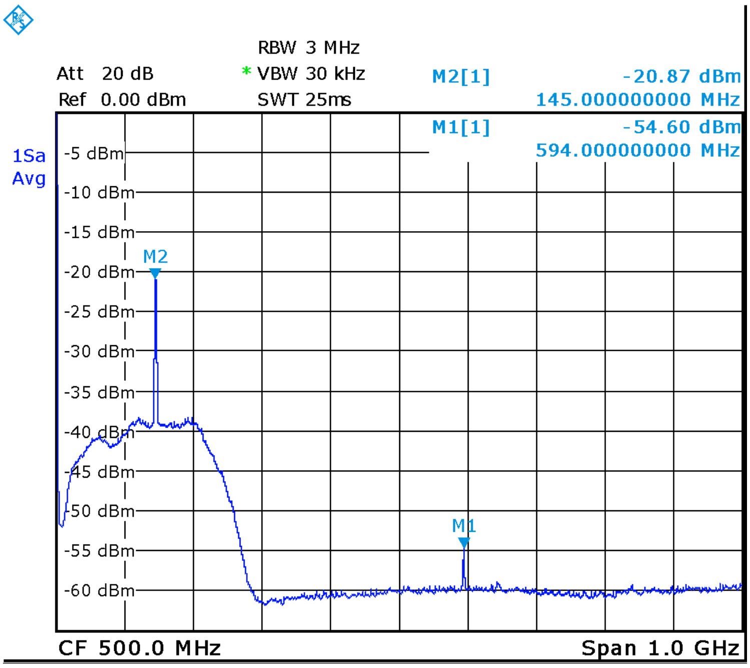
A tinplate housing with the dimensions 111mm x 74mm was chosen as the form factor. As already mentioned, all 75 Ohm connectors are designed as F-sockets. Only the connection for the 2m ZF is a BNC socket. The optional reference input is designed for an SMA socket. In order to adapt the 75 Ohm connections internally to 50 Ohm, a broadband and therefore lossy resistor network was chosen. The noise figure of the whole board is therefore not very low (NF approx. 10 dB), but this is not really critical either, since the LNB provides enough gain and therefore the noise figure of the mixer does not weigh heavily.

A microchip controller (PIC18F2520) is used to program the ADF4360-7 synthesizer. Since only the I2C interface for the LNB switching regulator and a few digital pins for programming the oscillator are *used* here, a simpler controller (*'used because available'*) would certainly have done the trick. The 595 MHz signal is fed to two MMIC amplifiers via a resistive divider, which raise the level to the +7 dBm required by the following mixer.

On the NB side the 739 MHz signal is amplified after a high pass filter at 660 MHz and fed to the mixer. The filter is necessary for the suppression of the mirror frequency and also prevents the LO from being guided in the LNB direction. After the mixer, the signal is amplified again and the unwanted mix product is suppressed with a low-pass filter. For protection against inadvertent transmission power on the 2m output there is a 10dB attenuator followed by two antiparallel connected diodes. On the WB side there is also a high pass filter followed by an amplifier and the actual mixer. After a further amplification a high pass filter follows, which isolates the WB useful signal.

The LNB switching regulator generates both 14 V and 18 V on its two channels. Normally the switching is done by the microcontroller via the I2C interface. For the sake of user-friendliness, however, this is not used here and the selection is made using standard 2.54 mm short-circuit bridges. Two additional switching regulators generate 3.3 V for the synthesizer and the controller as well as 8 V for the amplifier stages.

First results



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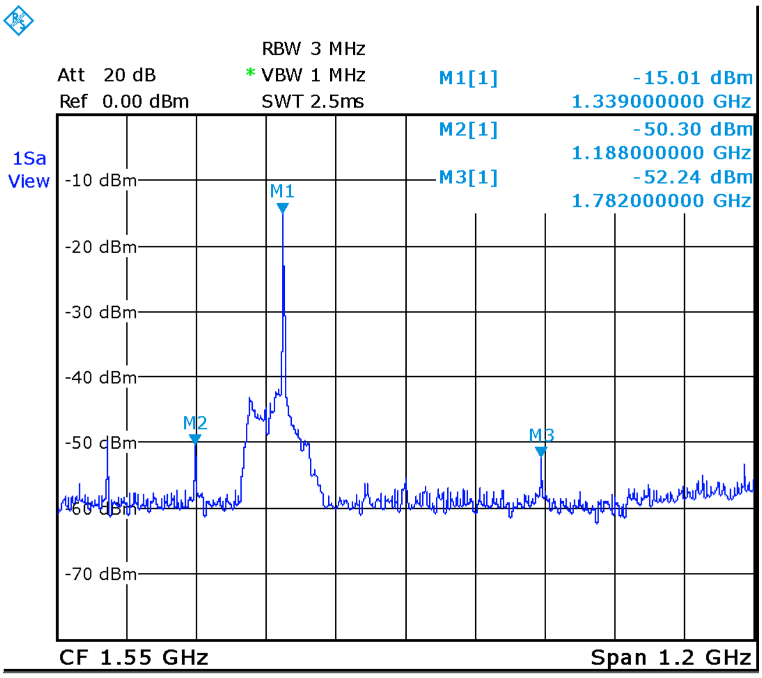
(Note April 15, 2019: The following measurements were made with the LO at 594 MHz, see below for instructions on optional conversion).

After loading (which can only be done with a microscope, more on this later) the first voltage measurements were made on the regulators. As expected, everything went as planned right away. The subsequent development of the controller firmware was made much easier by earlier projects and correspondingly existing code segments, and both the LNB controller and the synthesizer could be successfully put into operation within a few hours. Finally, the mixer went to the measuring station where the functionality was verified using a signal generator and spectrum analyzer. "Surprisingly, the mixer worked right away, which was anything but a matter of course given the short development time. The NB path is even so far within the planned performance that no changes are necessary here. Unfortunately, on the WB path, both the double LO frequency (1188 MHz) and the triple LO frequency (1782 MHz) very prominent. These are generated in the mixer due to its non-linear characteristic and are not eliminated by the following high-pass filter at 1000 MHz. Here, however, there is a danger that the input stage of the following satellite receiver would be overdriven by these two strong signals, which are within its reception range. In a test, this high-pass filter was replaced by a surface acoustic wave (SAW) filter, which has a bandwidth of 80 MHz at 1330 MHz. The interfering signals could thus be sufficiently reduced, so that a SAW filter will be used in the next version.



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What's the next step?

At HAMRADIO in Friedrichshafen, only two questions were asked about the assembly group: "Does it exist as a kit?" and "Where is the price? We can answer the kit question with a clear 'yes'. Finished devices must receive certain standards and declarations (even in amateur radio) and AMSAT-DL cannot and does not want to operate this effort. However, a kit in the classic sense is not possible due to the size of some components (0402 coils and 0.5 mm pitch of the ICs) and the QFN package of some semiconductors (no more pins at all...). Also, the costs of a machine assembly have to be set in relation to the necessary support which AMSAT-DL would have to provide to the buyers of a kit. The possible intermediate route here consists of the mechanical assembly of all SMD components, whereby the end user is then left with the remaining wired components, e.g. the coaxial sockets and jumpers. As far as the possible price is concerned, we are in discussions with corresponding companies. This raises the question of the quantity required. Usually, economies of scale are effective from approx. 100 assemblies, so that this should be regarded as a minimum lot size for a reasonable price. After initial discussions, we are confident that a price of less than 150 euros should be possible for such quantities. Whether the community of satellite radio operators will show sufficient interest in this module will become apparent in the coming months, but at the latest the start and commissioning of the Phase 4A transponders in 2018 will still take place.

Achim Vollhardt, DH2VA

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Assembly instructions (Update 2019-03-09)

Note: kit comes without tin box (111x74mm), photo only for illustration

<u>Hint:</u> The kit is delivered without tin can (111x74mm), photo for illustration only.

Description

The universal down mixer is proposed for use with an unmodified Twin Ku band PLL LNB with a low band LO of 9750 MHz. The two AMSAT transponders on Qatar-OSCAR-100 (Es'hail-2) will be down-converted to the center frequencies of 739.675 MHz (narrow band, NB) and 745 MHz (broadband, WB). The described RX converter converts both signals into frequency bands which are better suited for use by radio amateurs. It is based on a local oscillator that generates a frequency of 595 (standard) or 594 MHz (optional). The signal is connected to two separate receiving paths. The narrow band receive path has a 600 MHz low pass, followed by an amplifier and a mixer with 739.675-595 = 144.675 MHz, which is separated from the mix by another low pass filter. The broadband reception path has the same 600 MHz low pass followed by an identical mixer. Here the upper mix image (745 +595 MHz = 1340 MHz) is selected with a SAW filter.

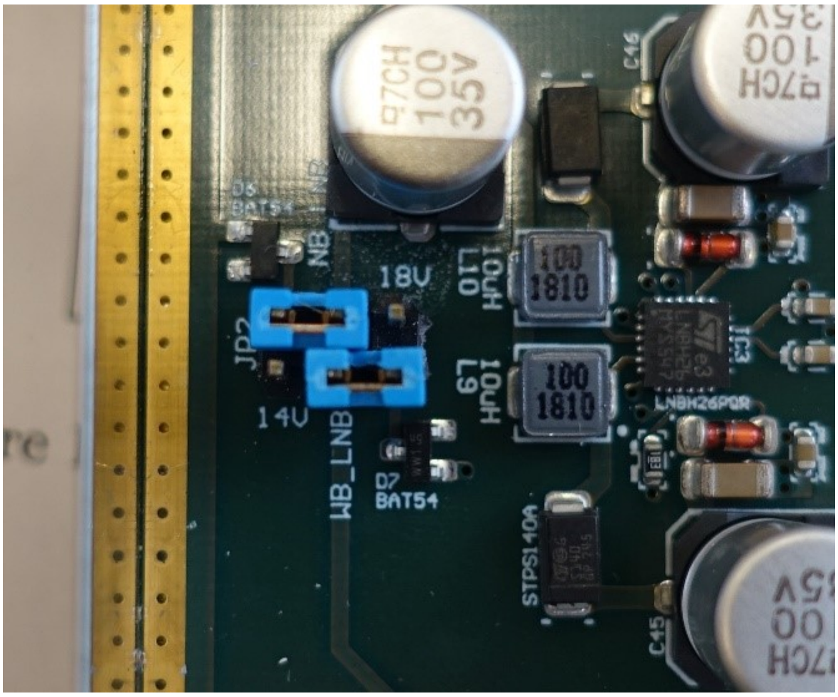
A further feature of the RX converter are integrated 14/18V power supplies for the supply and switching of the Twin LNB to the H and V polarisation levels.

final assembly

4 Coaxial sockets must be installed by the user. Assuming that the AMSAT-DL logo is upright, F jacks must be installed in the upper left and lower left and right corners. The fourth socket in the upper right corner is a BNC socket for the 2m narrow band signal. Normally the earthing pins of all sockets are nickel plated and must be removed with a file or sandpaper for easier soldering. Use a hot, powerful soldering iron as each socket takes some time to heat up due to its thermal mass.

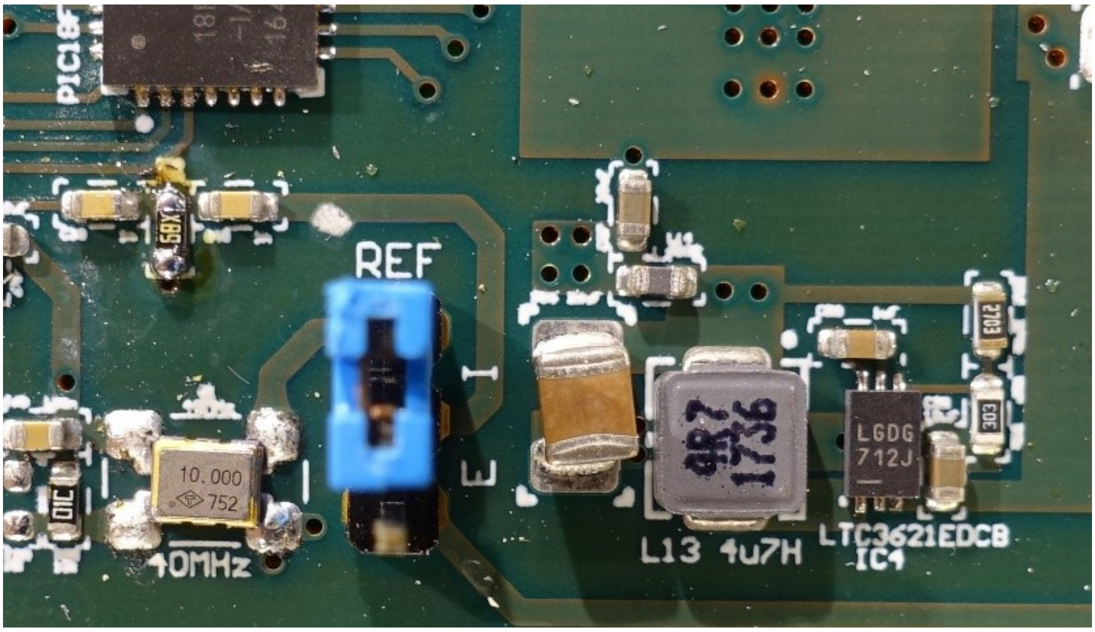
In addition, 2 pin strips must be mounted, a 2×3 pin strip on the left side (JP2) and a 1×3 pin strip on the right side (REF). Do not heat them too long, as they easily melt away. After installation, place the jumpers on the pin headers as shown:

JP2:



This sets the narrowband LNB channel (upper jumper, left position) to vertical polarization (14V) and the broadband LNB channel (lower jumper, right position) to horizontal polarization (18V). This should be sufficient for most users in Europe. Users in South America or Southeast Asia can exchange this configuration.

REF:



The REF jumper in the upper position connects the internal TXCO with the LO. This should be fine for most users. Users with extremely stable references (Rubidium or GPSDO) can use the lower position and add an SMA jack on the right side of the PCB.

ATTENTION, PLEASE: The specification for the 10 MHz input is 1-10 dBm at 50 Ohm (max. 3.3 Vpp). Pay attention to an especially low jitter (excellent phase noise) of the external 10 MHz reference, as all impurities are amplified by 595 / 10 MHz = 59.5 !

Connect the positive power supply 8-16 V (type 12 V / 110 mA without connected LNB) to the lower hole in the upper right corner below the BNC socket. Connect GND to any point on the board edge.

operation

When switching on, you should see 3 LEDs directly to the left of the BNC socket.

From left to right:

status	LNB Power Good	PLL Locked	Power present
OK	ON	ON	BLINK
digestion	OFF	OFF	OFF

So in one sentence: If everything is okay, the left and middle LED lights up and the right LED flashes.

When the left LED is off, check the LNB power connections. Probably a short circuit in the coaxial cable or faulty LNB.

When the center LED is off, check that the REF jumper is in the upper position.

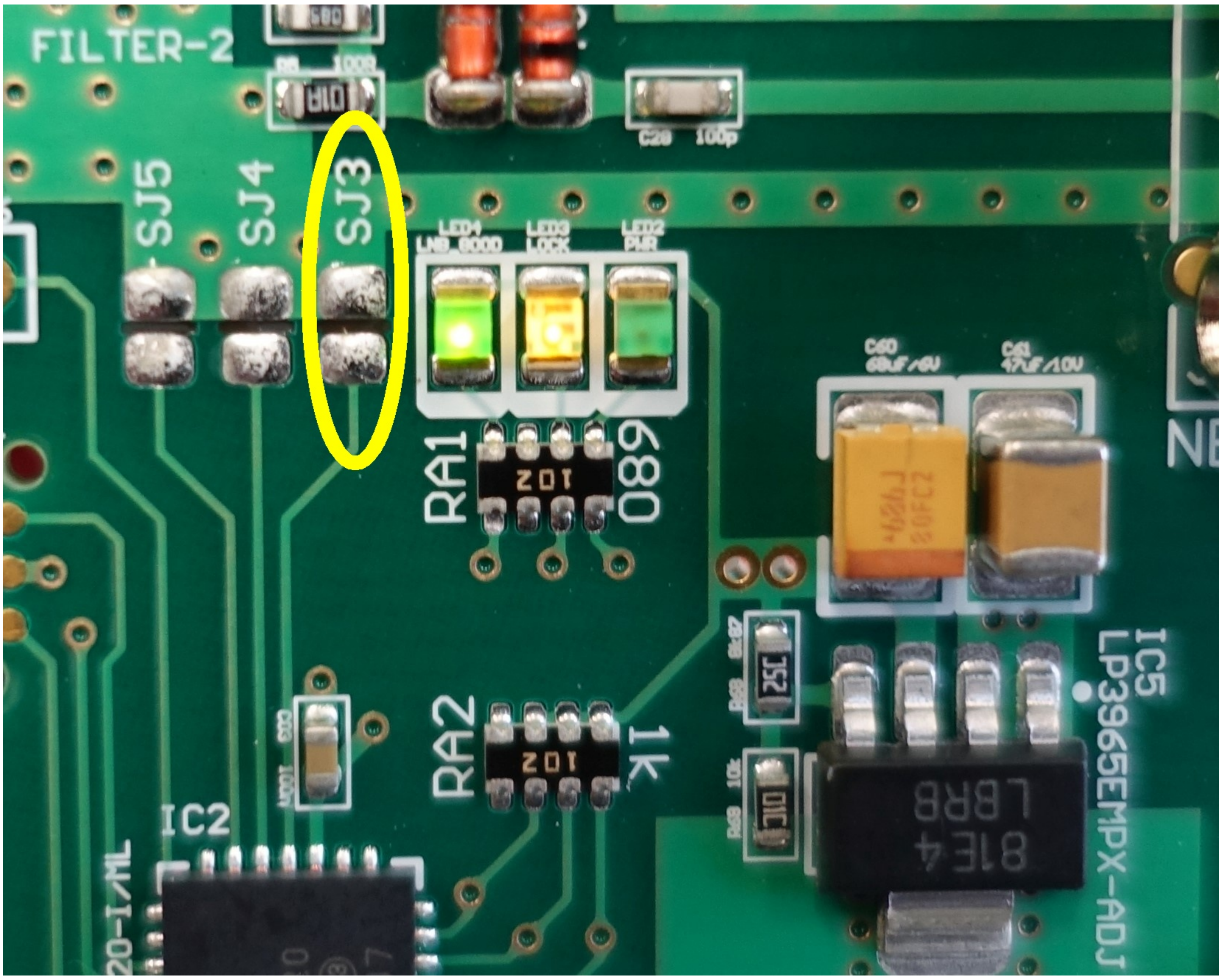
If the right LED is off, check that the power supply is connected (other LEDs are also off).

OPTION: Change LO to 594 MHz

In special cases, the user may prefer a LO of 594 MHz, which results in the NB signals being placed at 145.675 MHz and the WB signals at 1339 MHz.

To use the 594 MHz LO frequency:

- interrupt the power supply
- Short-circuit the solder joint SJ3, directly to the left of the LED, with a soldering iron and a solder blob.
- Switch on power again



The LO frequency should now be 594 MHz.

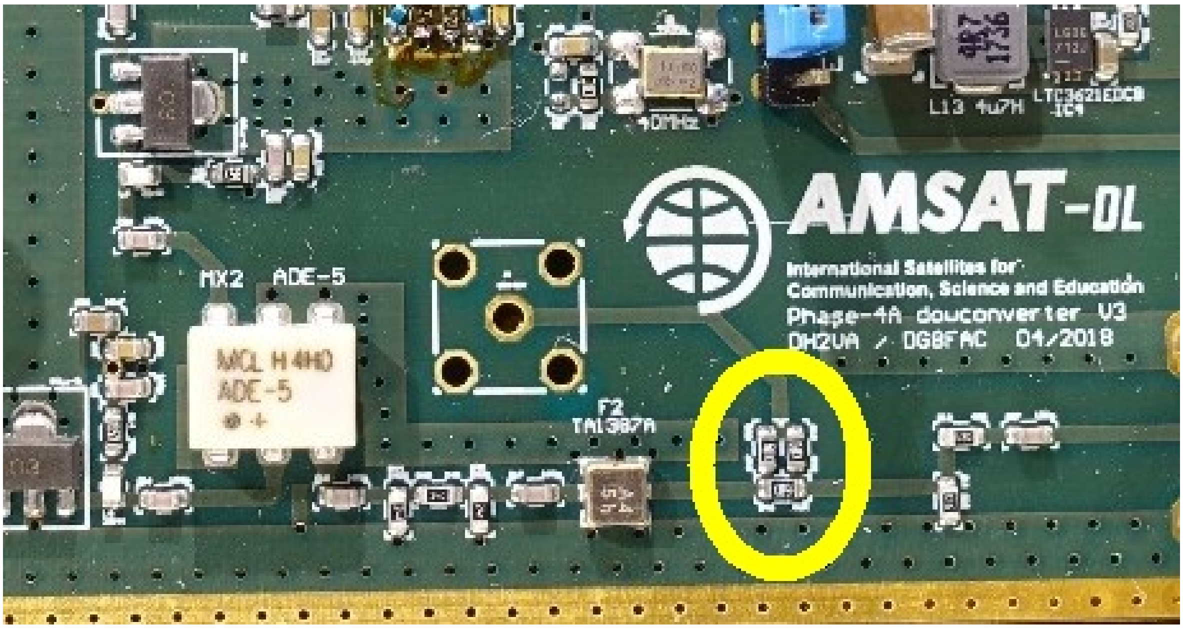
ADDENDUM: Fix for downconverters shipped before March 1, 2019 (conversion gain improvement)

This section describes how to troubleshoot the problem with the reduced conversion gain for the WB path in the Downconverter.

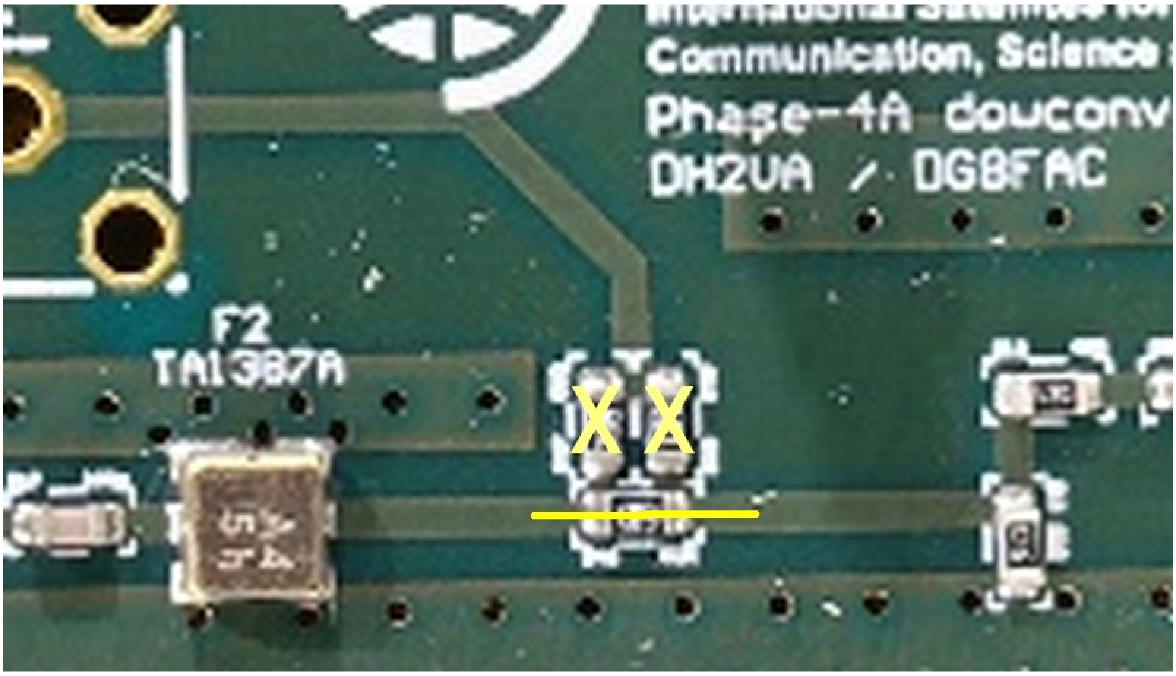
Only downconverters are affected that before 1 March 2019 have been delivered! All kits delivered after this date have already implemented this fix!

If you don't use the WB path anyway, but only the NB path, no change is required either.

Behind the SAW image rejection filter F2 a resistive 6dB splitter in down converter design was introduced. It has been shown that this significantly reduces the overall gain gain, especially when there is no SMA socket and no 50 Ohm termination attached to the empty SMA socket.



This can be easily fixed by removing all three 50 Ohm resistors in the yellow circle area. This can be done with a soldering iron and a large amount of solder, so that all parts can be heated at the same time and pushed to the side with the soldering iron. It is then necessary to reconnect the SAW filter output to the conductive path leading to the F connector using a short piece of wire or a large solder blob.



Further improvements for the use of the AMSAT-DL receiver converter on the WB transponder

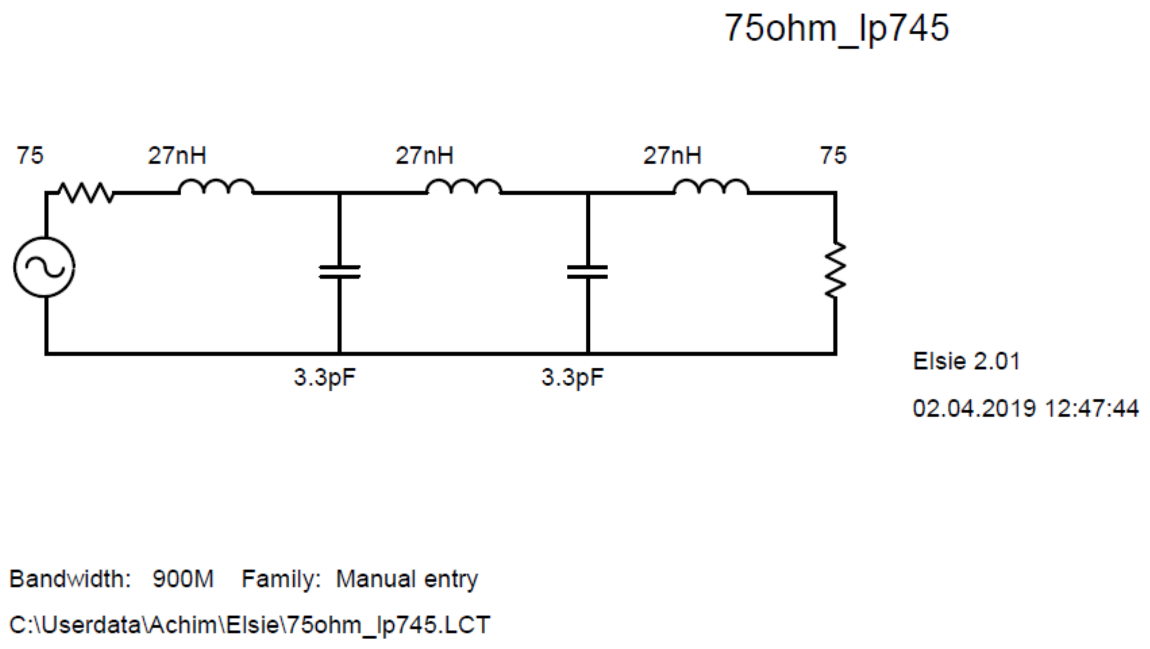
(Achim Vollhardt, DH2VA/HB9DUN, 2019-05-02)

introductory remarks

In the summer of 2017, we introduced a receiver converter that converts signals from an unmodified LNB to easy-to-reach frequencies. The NB transponder will be moved to the 2m band and the WB transponder range to approx. 1339 MHz, suitable for commercial satellite receivers. The converter is used in our QO-100 ground stations and manufactured by AMSAT-DL in small series and offered as a kit to interested OMs via the webshop. When commissioning the ground stations with the satellite, the WB beacon signal was not optimally set. At the same time we received feedback from some OMs about similar experiences.

A first guess

Both the author and Stefan DG8FAC had looked at several converters again exactly on the measuring station and with satellite signals, but could not reproduce the situation. Assumptions that poor phase noise or insufficient conversion gain were the cause were not confirmed, and we were also able to exclude the SAW band filter. After a few weeks in the dark, Mario DL5MLO suggested in one of the regular teleconferences of the project team that they look at the suppression of the mirror frequencies. This would be at the WB path of the converter at a LO frequency of 595 MHz at 745 MHz + 2x 595 MHz = 1935 MHz. Although this was far outside the specifications of the mixer used, it was still in the middle of the IF range of normal satellite LNBs. So a 75 Ohm low pass filter for 900 MHz corner frequency was calculated and built with F-sockets, which was sent to Martin DL9SAD for tests (he was one of the affected OMs).



Martin was able to quickly confirm that the reception quality was significantly improved: the MER values displayed by the Minitioune software were in the expected range with the filter for an 80cm mirror of approx. 7 dB. Without a filter the reception of the beacon was not possible or only hardly possible.

Measurements again

Now we took a closer look at the mirror frequency suppression on the measuring station. We fed the converter on various frequencies and compared the measured output levels with the input levels used.

- 745 MHz: conversion gain -22 dB
- 1339 MHz: conversion gain -36 dB
- 1933 MHz: conversion gain -31 dB

Note: the LO frequency is 594 MHz for the used pattern and the 50 Ohm branch has already been deactivated (see web page).

745 MHz is the actual useful frequency, which leads with a LO of 594 MHz to a IF of 1339 MHz. A direct feed of 1339 MHz is suppressed by only 14 dB, the upper mirror frequency (1933 MHz - 594 MHz = 1339 MHz) by only 9 dB. This is admittedly very little, but would not be bad for pure noise contributions on these frequencies, since the signal-to-noise ratio would only deteriorate by 0.7 dB.

Satellite reception and the solution

Unfortunately we do not have pure noise contributions in our situation, but further satellites, which radiate their own signals. An IF of 1933 MHz corresponds to a reception frequency of 11683 MHz for a low-band LNB with 9750 MHz mixing frequency. Relatively close to it Astra-2G transmits on 11671 MHz (also with horizontal polarization) and a high-power spotbeam towards Central Europe. Due to its position at 28.2 degrees East it can hardly be separated from the QO-100 at 25.9 degrees East by small mirrors and therefore leads to disturbances which prevent the reception of the QO-100 WB beacon. A similar situation arises with NB reception, where 2xLO-IF results in a further receiving point at 1043 MHz (X-band frequency 10793 MHz), which is suppressed by 23dB compared to the main receiving frequency. With Astra-2E (28.5 degrees East) there is also a strong signal on 10788 MHz, which should still be clearly visible in Germany and could cause interference.

A real remedy here is an improved filtering of the frequencies above the 745 MHz we use. In an upcoming new version of the converter the filters will be installed directly, for the converters used so far a solution suggestion of Jürgen DF1EO offers itself. He has successfully used an F low pass for DVB-T (Goobay 67511, available from Reichelt and Pollin, among others) which allows the clean reception of the WB video beacon from Doha.