Modification of a Goobay 67269 LNB for use in 10 GHz communication satellite reception

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Abstract

This article shows how to modify an inexpensive, commercial off-the-shelf low-noise block down-converter intended to be used for satellite TV to accept an external LO-reference signal. A LNB that has been modified in this manner is suitable for stable and reliable reception of K-band radiocommunications satellites such as QO-100 (Qatar Es'hail 2).

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1 Introduction

The commercial off-the-shelf (COTS) LNB chosen here is a Goobay 67269 LNB. The LNB by the German based company Wentronic GmbH was chosen primarily due to budgetary considerations. According to the manufacturer, it is suitable for reception from 10.7 to 11.7 GHz (low-band) and from 11.7 to 12.75 GHz (high-band). The intermediate frequency (IF) frequency range is 950 MHz to 1950 MHz (low-band) and 1100 to 2150 MHz (high-band). This corresponds to a local-oscillator (LO) frequency of 9.75 GHz (low-band) and 10.6 GHz (high-band).

According to the manufacturer ([2]), the operating voltage range is between 14 and 18 Volts DC. The applied DC voltage-level determines the receive-polarization of the LNB. 14 VDC selects vertical polarization, 18 VDC selects horizontal polarization. Switching between high- and low-band is achieved by an external 22 kHz control signal. If no 22 kHz control signal is applied to the LNB input, low-band operation is selected. If a 22 kHz signal is detected by the LNB, the mode is switched to high-band operation.

Figure 1: Unmodified Goobay 67269 LNB

The LO signal of the LNB is referenced to a 25 MHz crystal as the frequency-selective element. In low-band operation, the 25 MHz is multiplied by a factor of 390, in high-band operation the multiplication factor is 424. While a standard 25 MHz crystal reference is stable enough for broadband satellite TV reception, it is insufficient for the reception of narrow-band signals commonly found on radiocommunication satellites such as the popular, geostationary QO-100 (Qatar Es'hail 2). Therefore, the desire arises to lock the LO to an externally provided reference.

Being able to inject an external reference signal also opens the possibility to change the LO-frequency. This is particularly useful if existing communications receivers designed for the 2 m or 70 cm amateur radio bands are supposed to be used to receive satellite communications signals. For instance, the narrow-band transponder of the QO-100 satellite has a downlink frequency range of 10489.5 to 10490.0 MHz. The standard LO-frequency of 9750 MHz results in an intermediate frequency (IF) range of 739.5 to 740 MHz.

Reference	LO	IF (10489.5 MHz)	IF (1049.0 MHz)
25.000 MHz	9750.00 MHz	739.50 MHz	740.00 MHz
25.780 MHz	10054.20 MHz	435.30 MHz	435.80 MHz
25.788 MHz	10057.32 MHz	432.18 MHz	432.68 MHz
26.526 MHz	10345.53 MHz	144.36 MHz	144.86 MHz

Table 1: Possible reference frequencies, their corresponding LO-frequencies and resulting IF frequency range for reception of the QO-100 narrow-band transponder

A literature research showed that the Goobay 67269 LNB has been subject to previous modification attempts ([1]). However, the images of the PCB shown in the cited research differ significantly from the current PCB layout of the LNB. Since the literature source is from 2019, it can be assumed that the manufacturer has changed the design of the LNB in the meantime. Therefore, this modification is started from scratch.

2 Theory of Modification

The first step of the modification, the removal of the internal 25 MHz crystal, is self-explanatory.

The next goal is to implement a suitable series LC circuit to pass reference signals from the external F-connector to the correct pin of the internal PLL. A LC series circuit was chosen due to its band-pass characteristic.

With the commonly known equation

$$f_{res} = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

, where f_{res} = 25 MHz, L = inductance in Henry and C = capacitance in Farad, standard component values of 18 pF and 2,2 µH were chosen for the series LC circuit.

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With the impedance of a LC circuit being described by

$$Z_{LC} = |2\pi f L - \frac{1}{2\pi f C}| \tag{2}$$

, with Z_{LC} = impedance in Ohms, f = frequency in Hertz, L = inductance in Henry and C = capacitance in Farad, this results in an impedance of ≈ 8.1 Ω at a frequency of 25 MHz. At 26 MHz the resulting impedance is ≈ 19.32Ω, at 27 MHz this value further increases to ≈ 45.74Ω.

Any modifications of the voltage regulator circuitry is disregarded in this modification. However, a modification of the voltage regulator stage of the LNB would allow to use a significantly lower drive-level of the externally injected LO-reference signal.

3 Modification

After removing the plastic cover using a flat screwdriver (Fig. 4), the metal cover for the PCB housing can be removed after loosening two screws (Fig. 3 and 4). The required screwdriver is of type Torx T8.

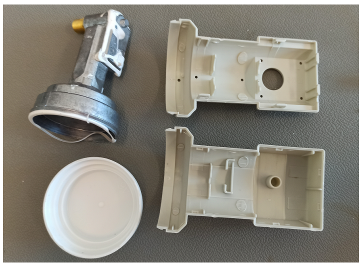

Figure 2: Plastic cover of the LNB removed

Figure 3: Removal of the PCB housing screws

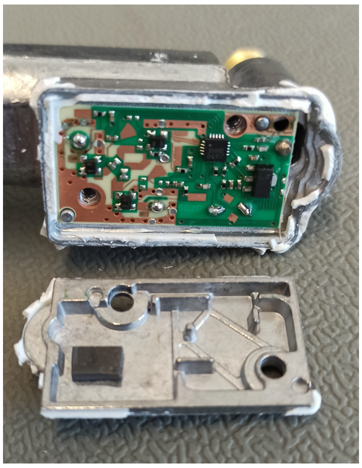

Figure 4: Metal cover of the LNB removed

After removal of the metal cover, the top-side of the LNB's PCB is accessible.

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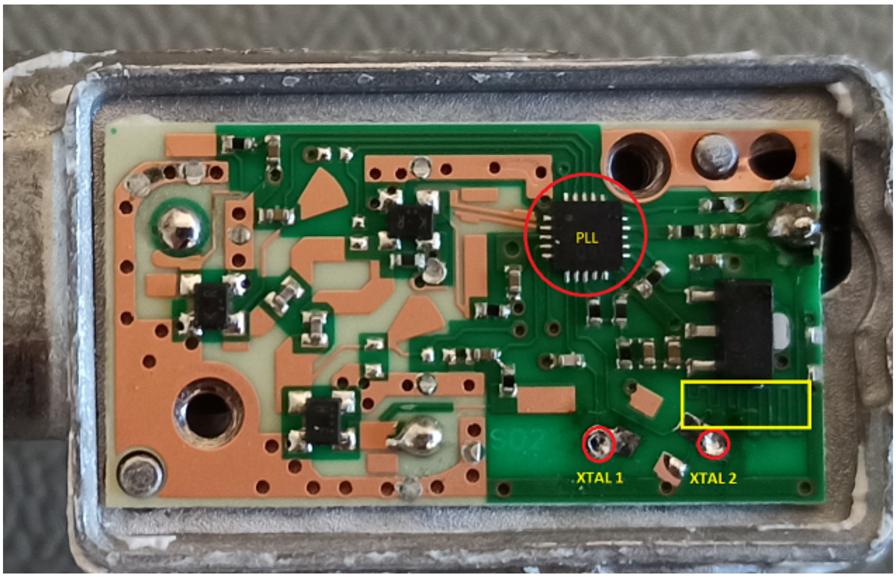

Figure 5: Closeup of the PCB with markings for the PLL, crystal pins and the printed circuit board inductor choke in front of the voltage regulator (yellow rectangle)

The main function blocks of the LNB's PCB can easily be identified (Fig. 5). The circuit design is centered around a fully integrated PLL-/LO-/Downconverter-chip marked 3566E. Even after a thorough search, very little information on this chip can be found. However, knowing the general working principle of such a chip, the relevant parts of the circuit can be reverse engineered without specific device information at hand.

The DC supply-voltage from the F-connector is passed to a 7806-type voltage regulator through a printed circuit board inductor (Fig. 5, yellow rectangle), supplying the 3566E with stable 6 V DC. The pins marked ẌTAL1änd ẌTAL2c̈onnect to a 25 MHz crystal located on the backside of the PCB.

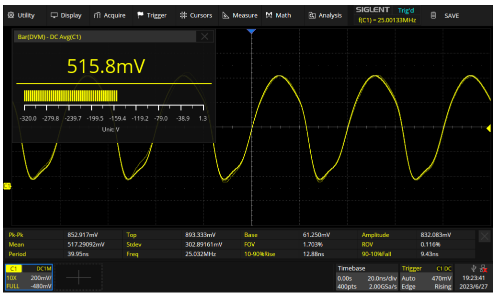

Figure 6: Signal measured on PIN 1 of the 3566E PLL chip

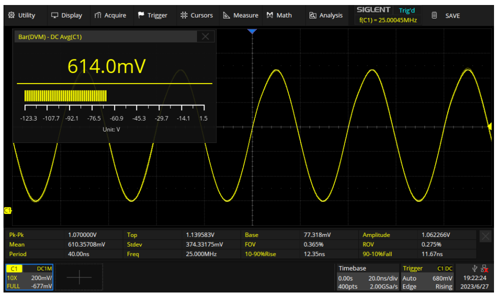

Figure 7: Signal measured on PIN 2 of the 3566E PLL chip

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In order to identify the proper input pin for injection of an external LO-reference-signal, the waveforms on pin 1 and pin 2 where examined using an oscilloscope (Fig. 6 and 7). Pin 2 of the 3566E (Fig. 5, XTAL2) was consequently identified to be the most suitable pin for injection of an external reference signal.

After desoldering of a single solder joint right above the F-connector, the PCB can be removed from the casing. It was found to be best to apply a slight upward pressure to the PCB while heating the solder joint (Fig. 8).

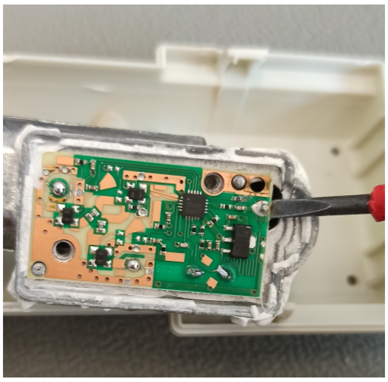

Figure 8: Applying slight upward pressure right next to the solder-joint

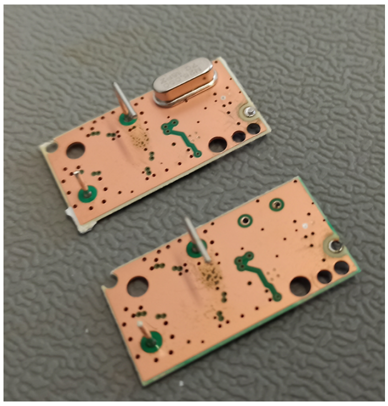

Figure 9: Two of the LNB PCBs before the modification (top) and after the removal of the 25 MHz crystal (bottom)

The 25 MHz, through-hole crystal on the back of the PCB was removed using a soldering iron and solder wick. A 2.2 µH inductor was then installed instead of the previously removed crystal. In order to protect the leads of the inductor from unintended contact with the grounded enclosure, it was covered with a small piece of Kapton tape (Fig. 10). The PCB was then re-installed inside the metal enclosure and soldered back in place.

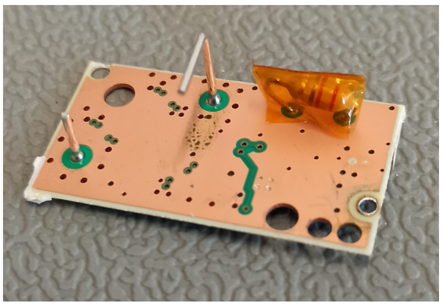

Figure 10: 2.2 µH inductor installed in lieu of the removed 25 MHz crystal

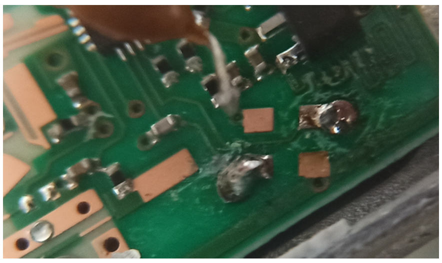

Figure 11: The PCB-trace connected to pin XTAL 1 has been cut using a sharp tool

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The now unnecessary and hindering PCB trace connecting the crystal socket pin XTAL and the 3566E PLL was cut using a sharp object (Fig. 11). Lastly, the 18 pF capacitor has been soldered between the input connection pin (from the F-connector) and the XTAL 1 pin.

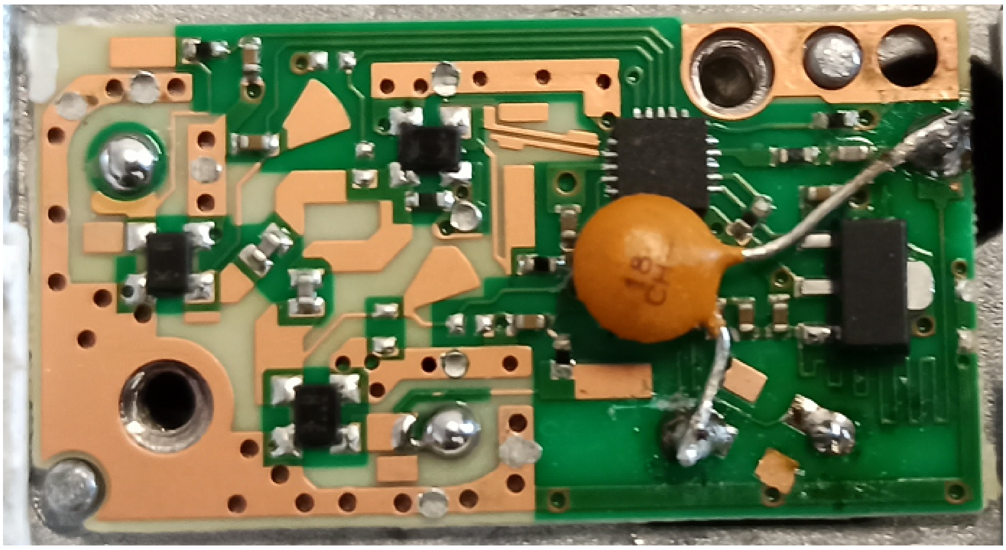

Figure 12: A 18 pF capacitor has been installed between the F-connector input pin and the XTAL 1 pin, connecting directly to the 2.2 µH inductor

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4 Functional Test

In order to test the functionality of the performed modification, the LNB was connected to a makeshift diplexer with an integrated bias tee. Absolutely no care was taken to match the LNB's input impedance of 75 Ω to the 50 Ω impedance of the equipment used in this test.

The low-pass path of the diplexer ($f_c = 30MHz$) was connected to a RTL2832 SDR through a 10 dB attenuator. The high-pass path of the diplexer ($f_c = 100MHz$) was connected to a signal generator. The signal generator was then set to a frequency of 25.78 MHz, resulting in a LO-frequency of 10054.2 MHz if locked-on correctly by the PLL. 14 VDC were then supplied to the LNB through the bias tee of the diplexer. It was observed that the LNB draws a current of ≈ 60 mA when unlocked. This value jumps to ≈ 90 mA when the PLL has properly locked onto the reference signal. Lock was observed at a signal amplitude of $3V_{pp}$ into the diplexer. According to the equation

$$P = 10log_{10}(\frac{(V_{rms})^2}{Z}) \tag{3}$$

, with P = power in dBm, V_{rms} = rms voltage of the signal amplitude in millivolt and Z = impedance (50 Ω), this corresponds to a drive level of ≈ 13.27 dBm.

Two signals of 3496 MHz and $3496.\overline{3}MHz$ were generated using an ADF4351 evaluation board from Analog Devices. The third harmonics of said signals serve as test signals with frequencies of 10.488 GHz and 10.489 GHz. The ADF4351 evaluation board was set to hop between both frequencies at a rate of 500 ms.

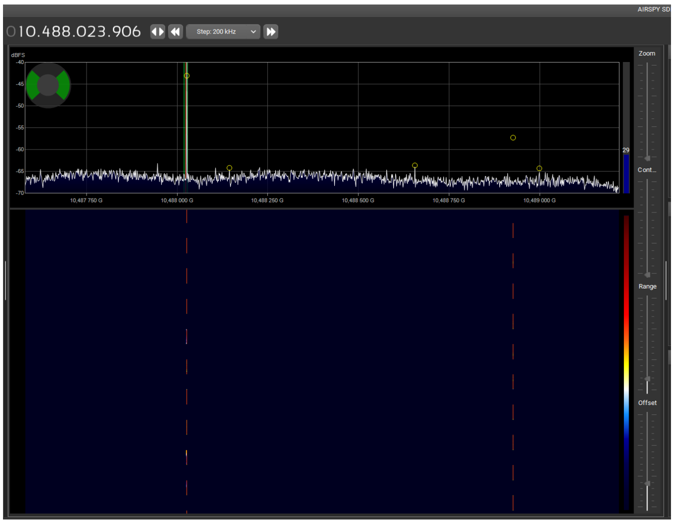

Figure 13: LNB signal output viewed in SDRSharp

The resulting output spectrum was viewed in AirSpy SDR# Studio (Fig. 13). The two test signals were clearly visible and the alternating 500 ms hops confirmed their identity. It was noted that due to the high gain of the LNB, it was very easy to overdrive the LNB. Despite using the third harmonics of signals with an amplitude of -4 dBm, the LNB had to be pointed away from the signal source in order not to cause distortion. Further, the 10 dB attenuator in front of the RTL2832 SDR was absolutely necessary in order not to exceed the full-scale dynamic range of the receiver.

It was further observed that varying the frequency of the reference signal between 24 MHz and 27 MHz does indeed change the LO-frequency without a visible change in IF output power or spurious frequency components.

5 Conclusion

This article shows that it is possible to successfully modify an inexpensive Goobay 67269 LNB to accept an external reference signal. Furthermore, the experiments in section 4 demonstrate that the LNB is capable of down-converting K-band signals outside of the manufacturer's specified frequency range.

The exact performance in regards of gain and frequency response will have to be determined in future experiments.

The necessary signal amplitude of the external reference signal could probably be reduced significantly by increasing the reactance of the inductor in front of the voltage regulator (Fig. 5, yellow rectangle). In future experiments, the PCB inductor will be interrupted and a SMD inductor of proper size will be installed instead.

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Author Contribution Statements

S.W. devised the project, the main conceptual ideas and theoretical framework. C.M. worked out almost all of the technical implementations, performed the experiments and validated the results. S.W. wrote the draft of this document with input from C.M. All authors discussed the results and commented on the manuscript.

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