The Effect of LNBs Modification on Their Noise Properties

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Introduction

I would like to estimate the noise parameters of modified LNBs for my future project on small parabolic antenna for QO100 satellite. The antenna gain, parallel with the system temperature can be expressed as their ratio – G/T_s . This ratio is called quality factor of the receiving chain The recommended value for QO100 is higher than $G/T_s = 13.98\text{dB/K}$.

System Temperature and Noise Power

The system temperature is a linear combination of the antenna noise temperature and the receiver noise temperature:

$$T_s = T_A + T_{Rx} \tag{1}$$

To achieve best reception parameters, both the antenna noise temperature and the receiver noise temperature should be as low as possible. The noise figures of well-performing professional LNBs for X – band are around 0.7 dB (50.7 K). However, I was curious, how modification of LNB (lowering its IF frequency) effects the system noise temperature.

A good LNB consists of a low noise amplifier – (LNA), an input RF filter, a mixer + a local oscilator – (LO) and a selective amplifier - (IF). The suppression of the mirror frequency usually LO – IF (also referred to as LSB) must be performed before mixer, otherwise the noise power of a mirror signal is added to the wanted signal LO + IF (also referred to as USB). The total noise power is then:

$$P_N = P_{NUSB} + P_{NLSB}/b \tag{2}$$

where,

P_N is the received noise power,
P_{NUSB} is the noise power of the wanted band
P_{NLSB} is the noise power of the mirror band (unwanted band)
b is the attenuation of the mirror signal [ratio]

Noise power, P_N can be expressed as:

$$P_N = \mathrm{k}T_s B_n \tag{3}$$

where,

k is the Boltzmann constant (1,380 649×10^{-23} J·K^{-1})
T_s is the system tepmerature [Kelvin]
B_n is the bandwidth [Hz]

Based on the equations 2 and 3, we can express the system temperature as:

$$T_s = (1 + 1/b)(T_A + T_{Rx}) \quad (4)$$

Suppression of the Mirror Signal

The selectivity of the input RF filter of a cheap LNBs is usualy quite low. The IF frequency of a TV satellite systems (950 up to 2150 MHz) is relatively far from their Rx frequencies (10700 up to 12500 MHz) and even a suppression of a few dBs can improve the LNBs noise parameters. Unfortunately, some low cost LNBs don't have any input RF filter. In the worst case scenario, when the input filter does not stop the mirror signal, the system temperature is doubled. This fact may have a negative effect on the noise power received by the receiver and negatively affects the G/T_s ratio. This can be especially critical for small antennas.

Measured Results

I have measured two LNBs. The first one is the SPCR5300 by SPC Electronics, the second is the NORSAT 1107HC by Norsat International Inc., see Fig. 1 - 3. Both LNBs are fitted with the UBR120 waveguide flange for the WR75 waveguide. I used wide band coaxial to waveguide transition - SMA to WR90, plus a Waveline WR90/WR75 adapter. A PICO Technologies VNA106 was employed as the generator fitted with a 16x frequency multiplier. A Rohde & Schwarz FSP38 analyzer was used to measure signals on the IF output. Results are displayed in Fig.4

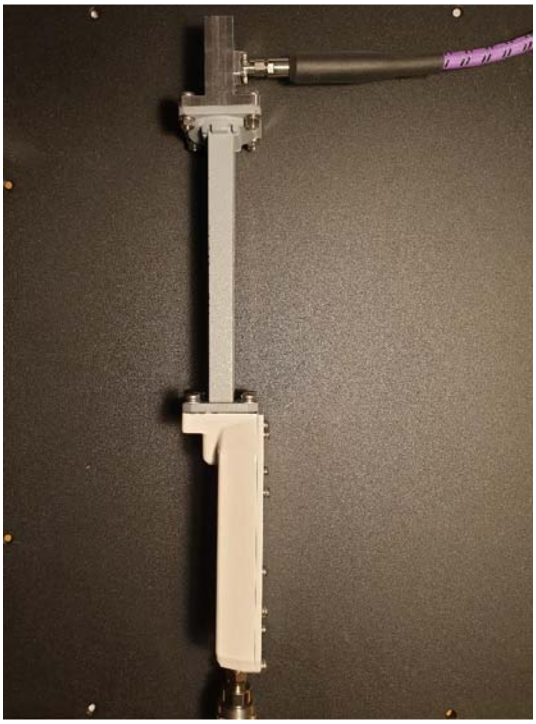

Fig 1 and Fig 2 - The SPCR 5300 LNB under test

Fig. 3 – Measurement setup with the LNB NORSAT 1107HC

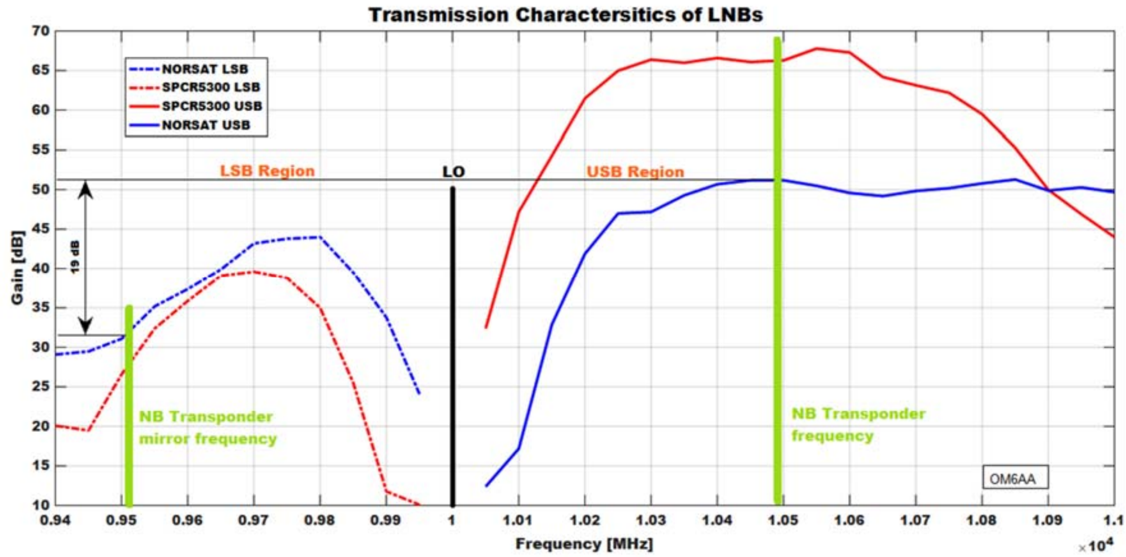

Fig. 4 – Transmission characteristics of measured LNBs

Example 1

Calculate the system temperature and the G/T_s ratio of the system created with the LNB with 0.7 dB (50.7K) noise figure, antenna with a 30 dB Gain and 50 K antenna temperature. Suppression of the mirror band is 1 dB ,19 dB and 60dB.

1 dB is 1.259 in a ratio, 19 dB is 79.43 in a ratio, 60 dB is 1 000 000 in a ratio

Using equation (4), for 1 dB:
T_s= (1 + 1/1.259) * (50 + 50.7) = 180.7 K
G/T_s = 1000/180.7 = **7.43 dB/K**

for 19 dB:
T_s = (1+1/79.43) * (50 + 50.7) = 101.97 K
G/T_s = 1000/101.97 = **9.92 dB/K**

For 60dB
T_s = (1+1/1000000)*(50+50.7) = 100.7 K
G/T_s = 1000/100.7 = **9.93 dB/K**

Example 2

The primary antenna has a diameter of 0.75 meter (d_1). The system temperature of the primary system is 176.5 K (T_{s1}) Its quality factor is $G/T_s = 13.98$dB/K .
The system temperature dropped to 88.23 K (T_{s2}), thanks to the feed optimization, and a better LNB of the modified system.
Calculate a new diameter of the parabolic dish antenna (d_2) for the same quality factor G/T_s

We can write:

$$\frac{G_1}{T_{s1}} = \frac{G_2}{T_{s2}}$$

Where:

G_1 is the gain of the primary antenna, $G_1 = \eta\,\pi^2 d_1^2/\lambda^2$
G_2 is the gain of a the new antenna, $G_2 = \eta\,\pi^2 d_2^2/\lambda^2$

Let assume the same efficiency for both antennas.

After a substitution and an adjustment:

$$d_1 = d_2\sqrt{\frac{T_2}{T_1}} = 0.75\sqrt{\frac{88.23}{176.5}} = \mathbf{0.53\ m}$$

Conclusion

The LNB with low suppression of unwanted mirror band can significantly downgrade quality factor of the receiving chain. This can be compensate by enlargement of an antenna diameter.

Properly selected LNB, fitted with an appropriate feed (optimized for a low antenna temperature), can achieve the same G/T_s quality factor as a bigger reflector. Thus, it is possible to significantly decrease the Rx antenna size. A small downlink antenna, parallel with a simple (helical or X - Yagi) antenna for the uplink can be used for portable operations, DX expeditions and places with a space constraints.

Acknowledgements

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