GPS Antenna LNA

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Introduction

This application note is about LNA's used in GPS reception. The purpose of this application note is to give the reader an understanding of the basic properties of LNA's and help in defining the right amplifier for his or her application.

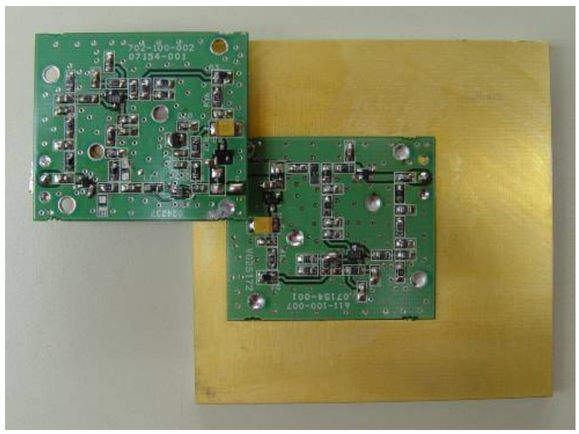


Figure 1: Single stage LNA
mounted to a GPS L1 antenna and a two-stage LNA

Basic LNA Terminology

Noise Figure (NF)
Noise Figure is a ratio that indicates how much noise power the LNA will contribute to the total receiver noise. The Minimum Discernable Signal (MDS) is the weakest signal a receiver can decode.
The more noise the LNA contributes, the higher the noise floor and the less sensitive the receiver is. At the systems level, a poor LNA degrades the MDS.
While LNA NF is not the only factor that drives the MDS, it is an important consideration since the noise figure of the first stage in a receiver chain is the single largest contributor to the system noise figure.
A typical state-of-the-art, single stage commercial grade LNA at L-Band (GPS) has a noise figure between 0.5 and 1 dB. A multi-stage GPS LNA with filtering has a noise figure between 1.0 and 2.5 dB.

Gain
Gain is the ratio of input to output power. For a single stage LNA, this is typically 15 dB. Typical GPS LNA's use two or three gain blocks and yield 25 dB to 50 dB of gain depending on the user's requirement. Unlike NF, a low or high gain does not indicate a good or bad LNA.
It is important to specify the amount of gain that is required rather than to go for the highest available gain: more gain will produce more intermodulation products in LNA and receiver. Not enough gain can cause the GPS signal to be below the MDS level of the GPS receiver.

Second or Third Order Intercept Point and 1 dB Compression Point
These terms define the LNA's behavior when either multiple (possibly strong) signals or at least one strong signal is presented at its input terminal. Multiple signals in an LNA can mix and generate a set of new signals. Some of these can fall inside the GPS passband and cause interference. A single strong signal that is fed into the LNA could drive the amplifier into compression and may suppress the GPS signal(s) at the output of the LNA. GPS reception may be lost. The theory of all of this is beyond the scope of this article, but a well-designed LNA should be able to keep going with as much as -15 dBm of power at its input terminal.

Supply Voltage
GPS receivers will put out a voltage to the RF input port to feed the LNA. The amplifier(s) inside the LNA typically operate at 3 V or 5 V. A voltage regulator inside the LNA enclosure will convert the 12 V or 24 V from the GPS receiver to whatever the amplifier(s) needs. Make sure the LNA can handle whatever voltage your receiver puts onto the coax cable.

Power Consumption
Power consumption is the current flowing through the LNA multiplied by the voltage coming out of the coax line. LNA typically have their current specified.
For a typical single stage LNA, the current is between 15 mA and 100 mA or more. Keep in mind that a really low current device means a poor intercept behavior of the LNA. While low power consumption is sometimes desirable, it is irrelevant because most GPS receivers can handle the current required.

Filtering
Connecting an antenna to a GPS receiver using an LNA without any filtering in between is not a good idea if reliability of the reception is of some value: all signals in a wide frequency range will enter the amplifier, generate spurious (unwanted) signals and degrade reception. In addition, strong out-of-band signals will degrade the sensitivity of the system by driving the LNA and possibly the receiver beyond their 1 dB compression point.

A wide range of filter options exists: SAW and ceramic are the typical choices. In the case of a combined L1/L2 antenna, we would use a duplexer to filter both bands. There are several ways to implement filtering: a single filter with a high out-of-band rejection but a relatively high insertion loss (2 dB) or multiple filters with less insertion loss (0.5 dB) but at the same time less rejection. As illustrated below, we can distribute filtering and reduce the impact of filter insertion loss on the noise figure while maintaining the out of band suppression.

Examples

Here are five configurations that illustrate what we have just discussed. Every example has specifications for the gain blocks and for the filters (if used), and the performance of the complete LNA is in the right hand column under total.

Example Number 1:

The first configuration shows an LNA with no filtering: this gives you the best possible noise figure and gain, the cheapest LNA but no out-of-band rejection and this is probably not what you want. Any strong interferer will cause compression and intermodulation. Multiple weaker signals will probably do the same because of intermodulation.

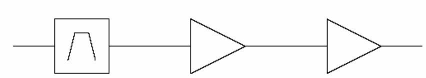
Note that even though the second stage of the LNA has a higher noise figure, the system noise figure is still pretty much that of the first stage. This is why you can install a lossy coax cable after an LNA and not kill your system noise figure.

			Total
NF (dB)	0.50	1.50	0.54
Gain (dB)	16.00	15.00	31.00
OIP3 (dBm)	36.00	39.00	38.73
OP1dB (dBm)	20.00	18.00	18.00

Input Pwr (dBm) -95.00 System Temp (K) 290.00

Example Number 2:

The second configuration has a filter with much rejection up front. If you are operating the LNA say next to a radar station, this is what you want. Your noise figure suffers but this system is very robust. If you wanted, you could use a mechanical filter (cavity or similar) to minimize insertion loss and still have much rejection. Be ready to accept that this unit is going to be heavy and costly.



				Total
NF (dB)	2.00	0.50	1.50	2.54
Gain (dB)	-2.00	16.00	15.00	29.00
OIP3 (dBm)		36.00	39.00	38.73
OP1dB (dBm)		20.00	18.00	18.00

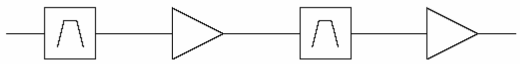
Input Pwr (dBm) -95.00 System Temp (K) 290.00

Figure 3: LNA with filtering

Note that whatever loss you put up front of the first stage of an LNA is added to the noise figure. A coax between the antenna and the receiver with no LNA gives you a similar result and this is why you want an LNA near the antenna in the first place.

Example Number 3:

In the next configuration, the filtering is distributed across the LNA. This is an excellent compromise between good rejection and best possible noise figure. This is what we would typically suggest. The noise figure is degraded with the insertion loss of the filter ahead of the LNA. We minimize that by selecting a filter with less loss and less rejection. The second filter adds rejection while the noise figure stays pretty much the same.



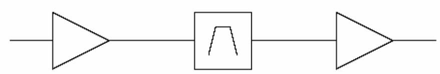
					Total
NF (dB)	0.50	0.50	0.50	1.50	1.06
Gain (dB)	-0.50	16.00	-0.50	15.00	30.00
OIP3 (dBm)		36.00		39.00	38.70
OP1dB (dBm)		20.00		18.00	18.00

Input Pwr (dBm) -95.00 System Temp (K) 290.00

Figure 4: Filtering distributed across the LNA

Example Number 4:

Here is a variation of example 2: still lots of filtering in a single filter but placed after the first gain block. The idea here is to pick a very robust (read high IP and high current) first stage so it will be ok with strong signals at its input.



				Total
NF (dB)	0.50	2.00	1.50	0.62
Gain (dB)	16.00	-2.00	15.00	29.00
OIP3 (dBm)	36.00		39.00	38.59
OP1dB (dBm)	20.00		18.00	18.00

Input Pwr (dBm) -95.00 System Temp (K) 290.00

Example Number 5:

And here is a variation of example 3: the filtering is distributed across the LNA but there is no filtering ahead of the LNA. This set-up behaves like example 4 and the same remark applies.

					Total
NF (dB)	0.50	0.50	1.50	0.50	0.56
Gain (dB)	16.00	-0.50	15.00	-0.50	30.00
OIP3 (dBm)	36.00		39.00		38.20
OP1dB (dBm)	20.00		18.00		17.50

Input Pwr (dBm) -95.00 System Temp (K) 290.00

Figure 6: Filtering distributed across LNA

Sample GPS LNA Data Sheet

Here is a typical spec sheet for a dual stage GPS LNA with no filtering built in. This unit is similar to example 1 above.

Parameter	**Specification**			**Unit**	**Remarks**
	Min.	**Typ.**	**Max.**		
Supply Voltage	7	12	24	V	Through Output RF Connector
Power consumption		<100		mA	
Frequency range	1,200		1,600	MHz	
Gain	32	35	38	dB	
Gain Flatness		+/- 1.5		dB	
Noise Figure		0.7	1.0	dB	
Output Third Order Intercept Point		38		dBm	
Output 1 dB Compression Point		17		dBm	
VSWR Input			2.0:1		
VSWR Output			1.5:1		
Temperature range	-40		+80	°C	

This is just the LNA without filtering. Consequently, adding filtering will degrade the noise figure by a fraction of a dB and decrease the gain by whatever insertion loss the filters add.

The figure to the right shows gain (top trace and scale on the right) and noise figure (bottom trace and scale to the left) versus frequency for a two stage LNA.

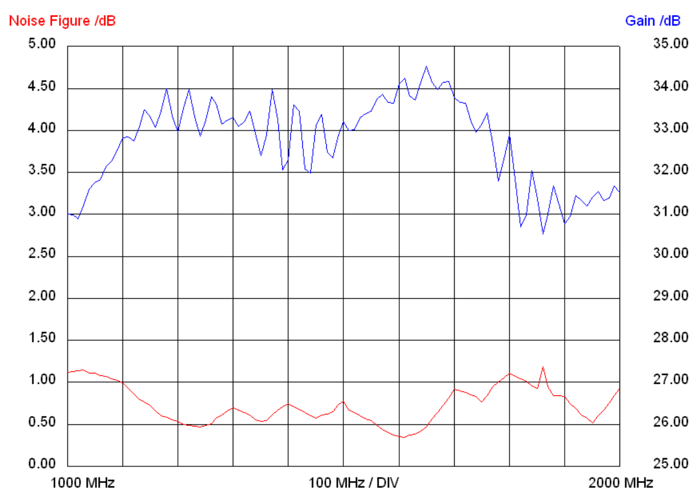


Figure 7: Noise figure and gain versus frequency for a two stage GPS LNA

Conclusions

When you specify a GPS LNA, you should define your requirements and then make a trade-off.

- If you need high gain, make sure the designer adds some filtering and, preferably, at least some of it ahead of the first stage of the LNA.
- If you need both filtering *and* a low noise figure (and you probably do) distribute the filtering across the LNA stages (filter, LNA, another filter, another LNA, etc).
- If current consumption is not an issue, don't specify low power consumption and allow the designer to select devices with a higher current; you will get a better intercept behavior.
- If the cost has to be really low, live with the compromise and accept the fact that GPS reception is going to be lost at times.
- If you are controlling some kind of machinery based on the location information, you might not want the system to use extrapolated position data and you should not compromise on the strong signal handling capabilities of the LNA.
- If you opt for lots of LNA gain, make sure the GPS receiver can handle the strong signals coming out of the LNA. Make sure the GPS receiver can supply the current the LNA requires.

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