White Paper
Title: Low Noise Micro-Mini Active Antenna Modules for Modernized GNSS
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Background

Antennas play a more important role than ever in IoT equipped with modernized GNSS receivers. Conventionally, the key metrics for assessing the GNSS antenna performance is generally characterized by efficiency/efficacy, gain, the overall signal carrier-to-noise ratio and user domain solution errors. At the component level, once satisfactory performance is achieved on the antenna design, it passes onto the next system-level of applications. Many discrete GNSS antennas are sold in the market in this approach and leave it to the design engineers to determine how the input impedance, standing wave ratio, and reflection coefficient versus frequency are associated with the rest of the sub-circuitries.

Parsec micro-mini active antennas satisfy the efficacy of modernized GNSS receivers.

Nowadays, the GNSS is simply one among several RF systems in a radio cohabitation environment – a mix that includes new added GNSS frequencies and non-GNSS signals such as cellular or Wi-Fi. A new requirements-level assessment is required to determine that the GNSS antenna performance can be accomplished within both physical constraints (e.g., size, budget, and weight) and operational environment for an intended application.

Radio Cohabitation Environment

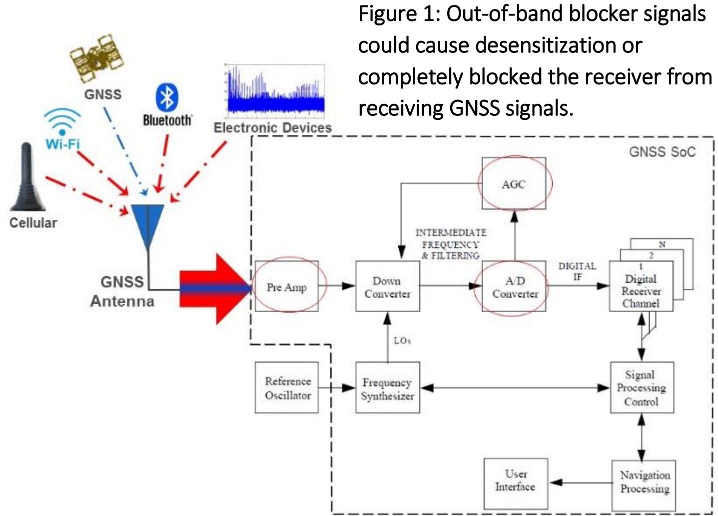


Figure 1: Out-of-band blocker signals could cause desensitization or completely blocked the receiver from receiving GNSS signals.

An inadequate use of a GNSS antenna can mess everything up. The antenna can easily pick up unwanted blocking RF power from other sources in a compact product design. Fig. 1 explains the radio cohabitation environment in a modernized GNSS receiver. Out-of-band blocker signals could cause the GNSS pre-amp, AGC, and A/D converter to compress, desensitizing or

Radio cohabitation requires low noise and high linearity active GNSS antenna.

completely blocking the receiver from receiving GNSS signals as illustrated in the fig. 2a. Under compression, spurious signals are generated.

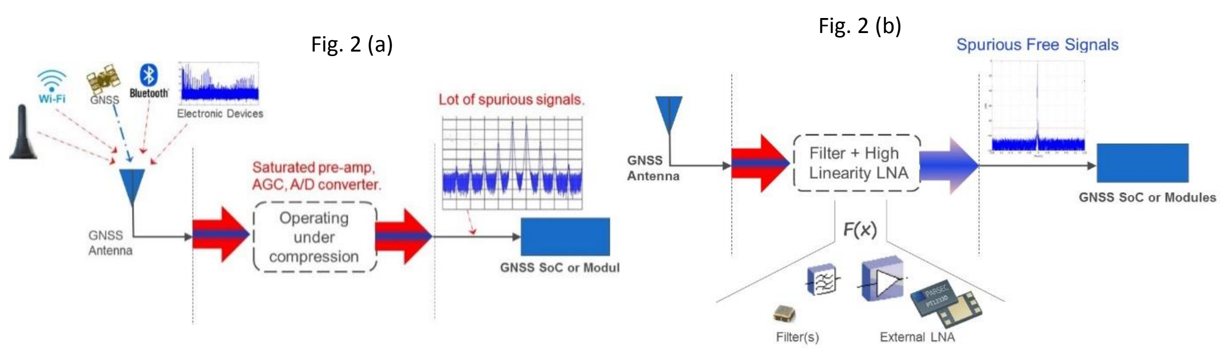
GNSS Signals Integrity

Using an active GNSS antenna is becoming popular to enhance the signal's quality. Figure 2(b) illustrates the configuration of an antenna element, filter and LNA prior to the input of a GNSS SoC or module.

$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + ... + \frac{F_n - 1}{G_1 G_2 ... G_{n-1}}$$

According to the Friis formula as described above, the noise figure of the first stage noise (F_1) determines a larger extent than the final noise contribution of receiver to the signal. In additional to the requirement of low noise, the active antenna must exhibit high linearity to prevent compression in the presence of unwanted out of band RF signals power. This ensures spurious free and boosted GNSS signals under hostile radio environment.

Figure 2: (a) Spurious signals are generated under compression. (b) Proper design of active GNSS antenna is essential to produce spurious free GNSS signals.

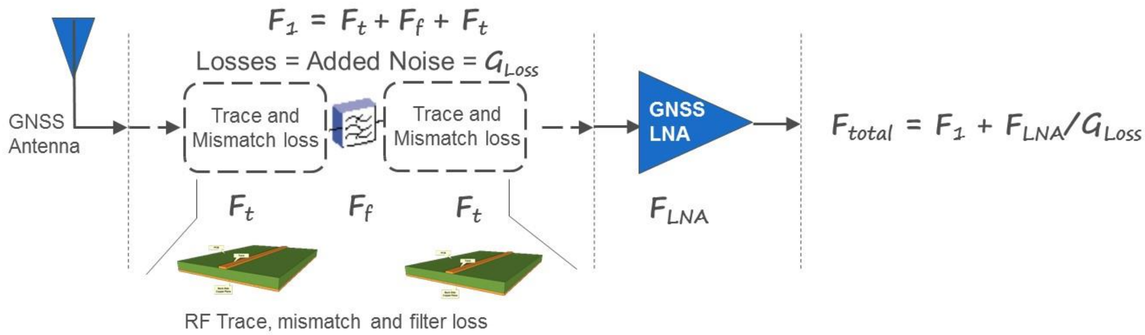


The new Parsec PTA1.5M-9 micro-mini GNSS active antenna exhibits low 1.8dB NF at a high gain of 15dB, while consuming current as little as 4mA at 1.8V.

Active GNSS Antenna Implementation

Implementation loss of using discrete GNSS antenna, filter and LNA contributes major degradation for the overall system noise factor. Referring to the Friis formula again, the first stage noise F_1 in fig. 3 should be considered as the aggregated noise contributed from dielectric losses on RF traces, filter and mismatch losses between antenna, filter and LNA. Without a proper RF design and tight production control, the loss in F_1 typically wipes out the low noise benefit given by the external LNA.

Figure 3. Implementation loss between the GNSS antenna and LNA.



GNSS LNAs with noise contribution of less than 1dB are easy to realize today. But it is difficult to maintain a low noise level in the first stage when discrete antenna, filter and LNA are put together on a mass produced FR-4 PCB panel. The dielectric loss at GNSS frequency is about 0.2dB/inch. Table 1 explains the differences of NF in mass production with different realization method. Additional mismatch losses between the antenna, filter, and the LNA are hardly to be controlled in mass production with a typical production variation at 20%. Thus, it is difficult to achieve less than 1dB board-to-board variation. The best solution to eliminate the large board-to-board variation is by modularizing the antenna, filter and LNA in a very close proximity on a tightly controlled microwave substrate. This production method will realize the lowest noise level in the first stage with external LNA. However, this area is often an overlooked or undervalued aspect of GNSS antenna and LNA implementation. Many designs take discrete GNSS antenna, filter and LNA for granted because they are almost always readily available parts or many mass-market GNSS receivers typically have built-in LNA offering "no-choice" for the buyers. In reality, not all design implementations are able to maintain the need of low noise, high gain and high linearity requirements altogether to provide high quality and spurious free GNSS signals.

Table 1. NF in mass production

Larger system NF due to board-to-board variation based on discrete components on FR-4 PCB panel			
Trace and Mismatch Loss	Filter Insertion Loss	LNA Noise Factor	LNA Gain
1dB	0.8dB	0.8dB	15dB
F_1 = 1 dB + 0.8 dB = 1.8 dB F_{total} = 2.6 dB			

Lower system NF in mass production based on modularization on microwave dielectric laminate			
Trace and Mismatch Loss	Filter Insertion Loss	LNA Noise Factor	LNA Gain
0.2dB	0.8dB	0.8dB	15dB
F_1 = 0.2 dB + 0.8 dB = 1.0 dB F_{total} = 1.8 dB			

Proven Advantages with Micro-Mini Active GNSS Antenna Modules

The Parsec micro-mini PTA1.5M-9 and -16 active GNSS antenna modules have integrated the antenna, filter and LNA on a military grade low loss dielectric substrate. They provides very low noise factor, high gain and high linearity altogether in a single package. The total implementation loss (F_t) is less than 0.2dB as shown in the figure 4. This guarantees the highest quality, possible sensitivity as well as high out-of-band input 3rd order intercept point (OOB IIP3).

Proven antennas performance with live GNSS satellite signals in the characterization process.

Figure 4. Parsec PTA1.5M-9 Active GNSS Antenna

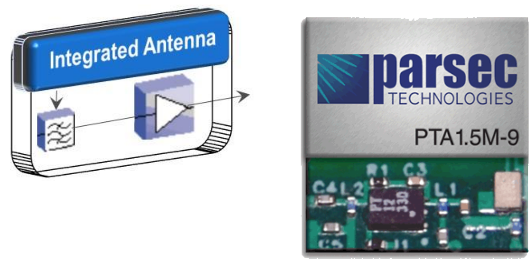
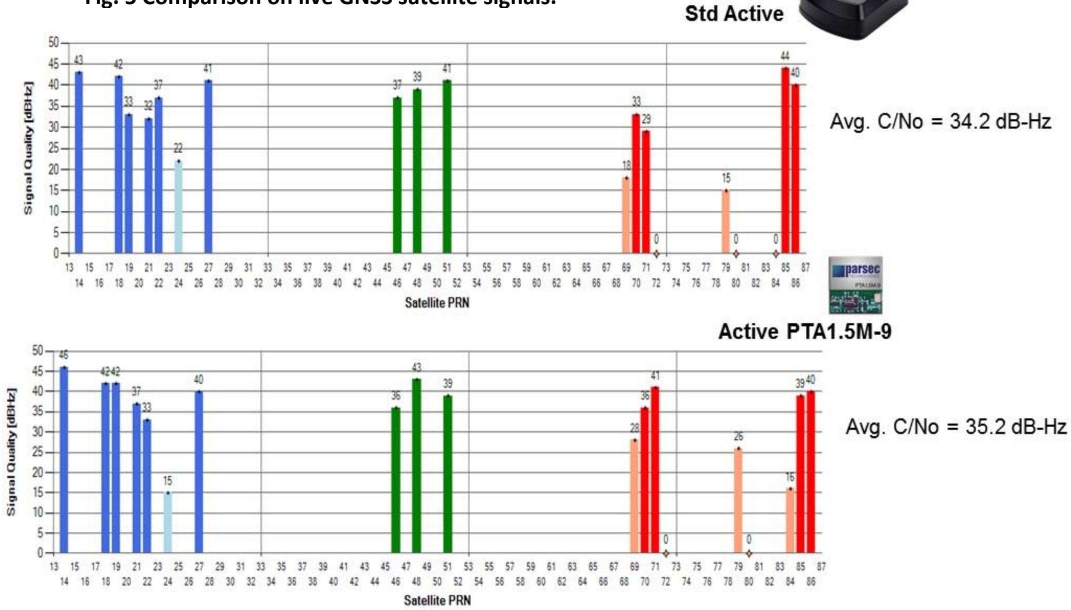


Table 2. Comparison of C/No with live GNSS satellite signals.

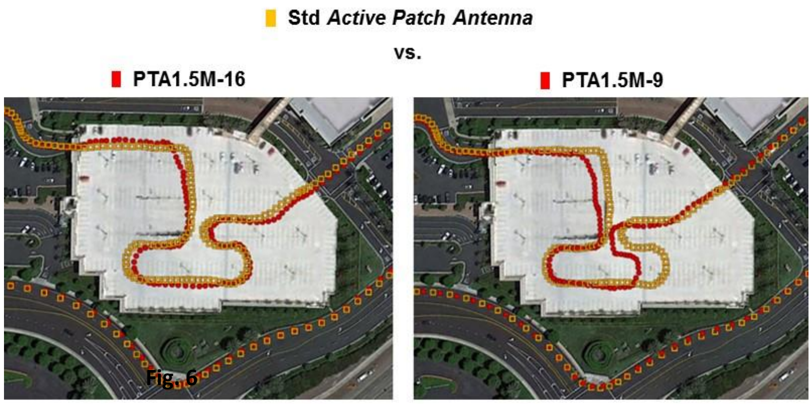
From a product design prospective, system-level characterization of the PTA1.5M-9 and -16 active GNSS antennas involve the use of the antenna with the GNSS receiver in an operational environment with live GNSS satellite signals. Table 2 and figure 5 compared the average C/No between a standard GNSS active ceramic patch antenna and Parsec's micro-mini active antennas based on a leading commercial GNSS receiver, which were done in parallel with live GNSS satellite signals.

Parsec PTA1.5M-16 	Parsec PTA1.5M-9 	Standard GNSS Ceramic Patch Active Antenna 
16 x 9.17 x 1.3 mm	9 x 9.17mm x 1.3mm	25 x 25 mm
34.5 dB-Hz	35.2 dB-Hz	34.2 dB-Hz

Fig. 5 Comparison on live GNSS satellite signals.



Other than comparing the efficacy of the GNSS active antennas, the key aspect is to compare the user domain solution errors to assess the difference between a standard active patch antenna and the Parsec micro-mini antennas. Fig. 6 is the drive test results done in covered parking garage.



Drive Tests Done in Covered Parking Garage

Summary

Direct integration of micro-miniaturized GNSS antenna, filter and low-noise high-linearity LNA with a low-loss microwave dielectric substrate provides significant improvement in noise factor for a mass-produced active antenna module. This approach eliminates implementation loss which commonly exhibits with discrete antennas, filter and LNA on a FR-4 PCB board. The Parsec PTA1.5M-9 and -16 active GNSS antennas contain low-noise and high-linearity active amplifier and filter in an ultra-compact form-factor to boost and filter the GNSS signal spectrum before it is passed to the GNSS receiver for processing. Significantly, the performance of the micro-mini active antennas are comparable to the large and bulky standard patch active antennas, which leave a lot of rooms for designers to accomplish a compact product design within physical constraints.

- *Significantly reduces system noise due to FR-4 board-to-board variation in mass-production for the cable/wiring loss and antenna mismatch to the input of the GNSS system.*
- *Reduces the desensitization due to crowded spectrum.*
- *Ultra-compact to accomplish within physical constraints (e.g., size, budget, and weight).*
- *High performance design comparable to standard patch active antenna.*