

Reducing the impact of RF interference to improve GNSS performance.



Abstract

GNSS receivers are finding their way into an ever-growing variety of devices, from connected wearables, homes, and vehicles to people, vehicles, and asset trackers. Often, they are tightly co-packaged with cellular and short-range modems that wirelessly transmit location data obtained using the global navigation satellite system (GNSS) receiver to the cloud for processing, storage, and visualization. Such designs are challenging to GNSS receivers, whose performance can be degraded by RF signals emitted by the wireless modem during transmission. In this white paper, we present strategies to reduce the impact of RF interference in order to improve GNSS performance.

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The essential role of GNSS in tracking and telematics



Because GNSS receivers depend on extremely weak satellite signals to determine their location, they are potentially subject to interference from nearby radio-frequency (RF) transmitters. **RF interference can reduce the sensitivity and accuracy of GNSS receivers**, potentially leading to interruptions in service and directly impacting power requirements, a vital factor in battery-powered devices.

Reducing the effects of RF interference is particularly critical in vehicle tracking and telematics, just one of many well-established industries that are being transformed by the widespread adoption of Internet of Things technology. Thanks to wireless data exchange over cellular networks, vehicle data can be transmitted directly to the cloud and made visible to fleet operators in near real-time. This brings countless advantages for fleet managers to optimize their operations.

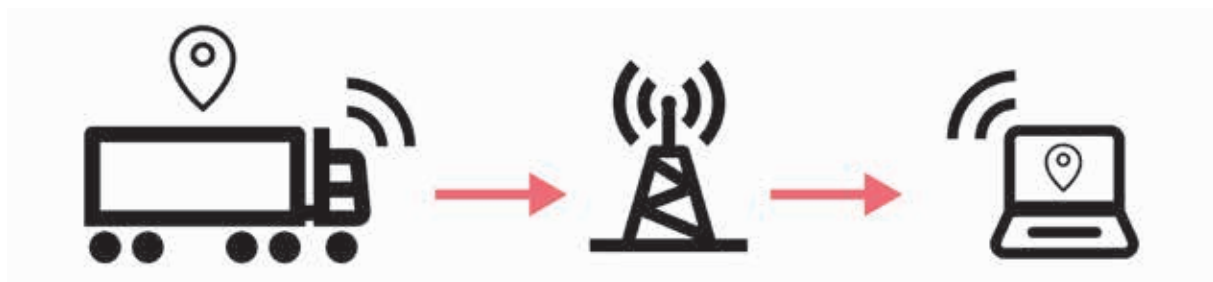


Image 1: IoT has transformed fleet management, vehicle tracking, and telematics.

RF interference caused by the **proximity of the GNSS and cellular antennas**, as well as the reduced liberty to optimally place the antennas, pose significant challenges for applications that require reliable, robust, and power-efficient GNSS performance. In this white paper, we present

strategies used by the u-blox GNSS receivers to reduce the impact of RF interference in order to improve GNSS performance as well as general design strategies device developers can adopt to optimize their products.

General threats to achieving accurate time and position information

A GNSS receiver's position accuracy can be affected by a multitude of factors. Some are caused by propagation delays of GNSS signals from the orbiting satellites to the receiver. Others are

caused by the quality of the signals emitted by the satellites. Others still come down to how, precisely, the positioning solutions are implemented.



Image 2: RF interference is one of many factors impacting the performance of GNSS receivers.

The most common source of GNSS signal delays are **adverse meteorological conditions** in the ionosphere and the troposphere.

Closer to the ground, **multipath effects** become more prevalent, as satellite signals bounce off solid structures such as cliffs and buildings.

Poor satellite selection can pose an additional threat to GNSS performance, as not all satellite constellations and all satellites within each constellation provide the same level of signal quality at any given location.

Satellite availability is directly influenced by the number of GNSS constellations a receiver can track. And the performance of the GNSS receiver can further depend on the quality of the **satellite selection algorithms** it uses.

Poor antenna design and placement are another common cause of poor positioning performance. Antennas must be narrowly tuned to the frequencies tracked by the GNSS receiver, which continues to be particularly challenging for multi-band GNSS receivers. The placement of an antenna influences its antenna pattern, i.e. the angular dependence of the strength of incoming signals. In already poor signal environments, antennas with non-homogenous antenna patterns caused, for example, by nearby metal parts can lose their GNSS signal reception altogether.

Similarly, **low GNSS receiver sensitivity** means that receivers have less margin to deal with low signal levels caused by bad weather or bad antennas.

Jamming and spoofing are two approaches used to intentionally interrupt a GNSS receiver or hijack its operation. While technically also a form of RF interference, they lie beyond the scope of this white paper.

And finally, **unintentional RF interference** can limit a GNSS receiver's performance by degrading the quality of the signal it receives.

How RF interference impacts GNSS performance

Common culprits behind unintentional RF interference include co-located RF transceivers such as cellular modems used in combination with GNSS receivers in tracking and telematics solutions. That said, any type of nearby RF transceivers transmitting in the frequency bands close to those used by GNSS satellites can deteriorate the positioning performance of a GNSS receiver.

There are two categories of RF interference: **inband interference** caused by signals that overlap with the frequency spectrum used by GNSS signals, making mitigation difficult, if not impossible, and **outband interference** from outside the GNSS frequency band.



Image 3: How RF interference impacts GNSS performance in real-world scenarios.

RF interference impacts GNSS performance in several ways. By degrading the quality of GNSS signals, RF interference prolongs signal acquisition, causing GNSS receivers to spend **more time trying to establish a position**. In some use cases, failure to get a position fix within a specified time can undermine the business case for GNSS-based solutions. For example, pay-as-you-go applications such as dynamic road pricing schemes that rely on GNSS tracking to monitor consumption depend on the data collected by the receiver to determine pricing. In these types of applications, delays in acquisition translate directly to lost revenues.

Prolonging the signal acquisition phase adversely impacts **power consumption**. Because signal acquisition draws significantly more power than tracking once a position fix has been established, RF interference can lead to a hike in power demand,

ultimately shortening the power autonomy of battery-powered solutions. Mitigating RF interference is, therefore, particularly relevant in power-constrained applications such as asset trackers that cannot be plugged into an external power source.

In some cases, RF interference can cause **loss of GNSS signals**. Although modern GNSS receivers concurrently track many satellites from several GNSS constellations, temporarily losing some of the tracked signals can lead to a reduction in position accuracy. In the worst case, the consequence can be a full loss of the position fix. The consequences are the same as detailed above, including interrupted service and increased power consumption the GNSS receiver reacquires the lost signals and establishes a new position fix.

Strategies to mitigate RF interference

RF interference comes in many flavors. That's why any successful solution to mitigate RF interference needs to combine several strategies. The first point to consider is whether the RF interference overlaps with the GNSS signal, as mitigating inband and outband interference require **separate approaches**.

Outband interference can leak into the frequency spectrum that the GNSS receiver is tuned to. As a result, it can be mitigated using bandpass filters designed to minimize the amplitude of signals outside of the desired frequency band.

Rejecting **inband interference** is much more difficult, as any manipulation of RF signals within the band will not only affect the interfering RF signals, but the desired ones as well. **One approach to remove interference caused by cellular transmission, for instance, is to alternate between GNSS reception and cellular data transmission.**

Another approach to reduce inband RF interference is using a software-based filter. This technique is most promising when the RF interference is a pulsed signal emanating, for example, from a clock generator or a DC/DC converter.

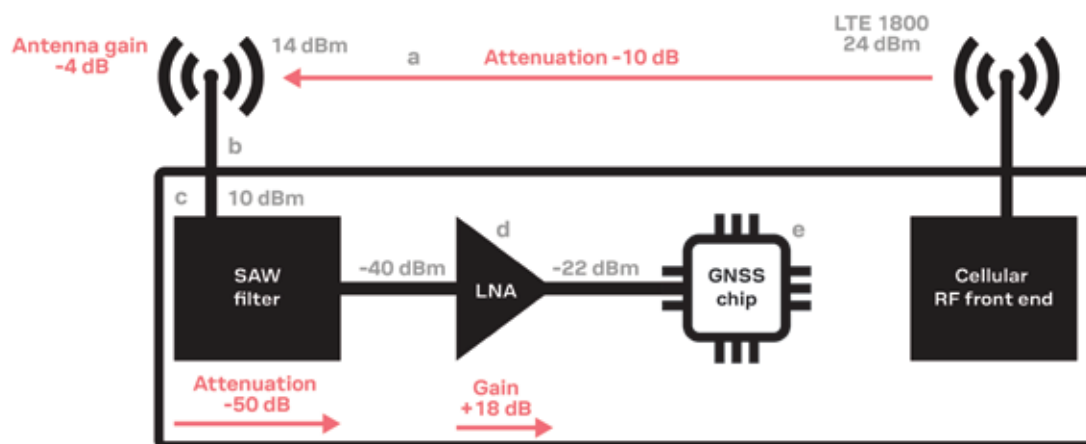


Image 4: Strategies to reduce unintentional RF interference on the GNSS receiver exemplified with 24 dBm cellular transmission at 1800 MHz. Quantities in red illustrate possible amplification and attenuation along the RF signal path.

a: Separating the antennas for GNSS signal reception and wireless data transfer addresses the root cause of RF interference coming through the RF path, as RF signal strength attenuates significantly in air.

b: Narrowband antennas form the first line of defense against RF interference along the RF path. Selectively tuning antennas to the frequency bands they are tracking is key to filtering out any unwanted noise and interfering signals.

c: Band-pass filters, such as surface acoustic wave (SAW) filters, can then be applied to remove outband interference picked up by the antenna.

d: Low-noise amplifiers (LNA) finally amplify the resulting signal with minimal additional noise, increasing the GNSS receiver's sensitivity. Because the LNA can get saturated by strong input signals, disabling the GNSS receiver's normal operation, the RF path upstream of the LNA is critical for the GNSS receiver to operate optimally.

e: Software-based filters in the GNSS receiver firmware remove unwanted inband signals based on prior knowledge. Effectively tuning a software-based filter requires a thorough understanding of the RF interference a device is exposed to.

Specific impact of the LTE 1800/1900 frequency bands

Devices that combine a GNSS receiver and a cellular modem are particularly exposed to RF interference due to the proximity of the upper L band (1559 – 1610 MHz) with the 1800/1900 MHz frequency bands, which are the most used bands for cellular communication networks. The problem is compounded further by the more recently introduced LTE700 band, which creates inband interference near to the 1574 MHz GNSS band.

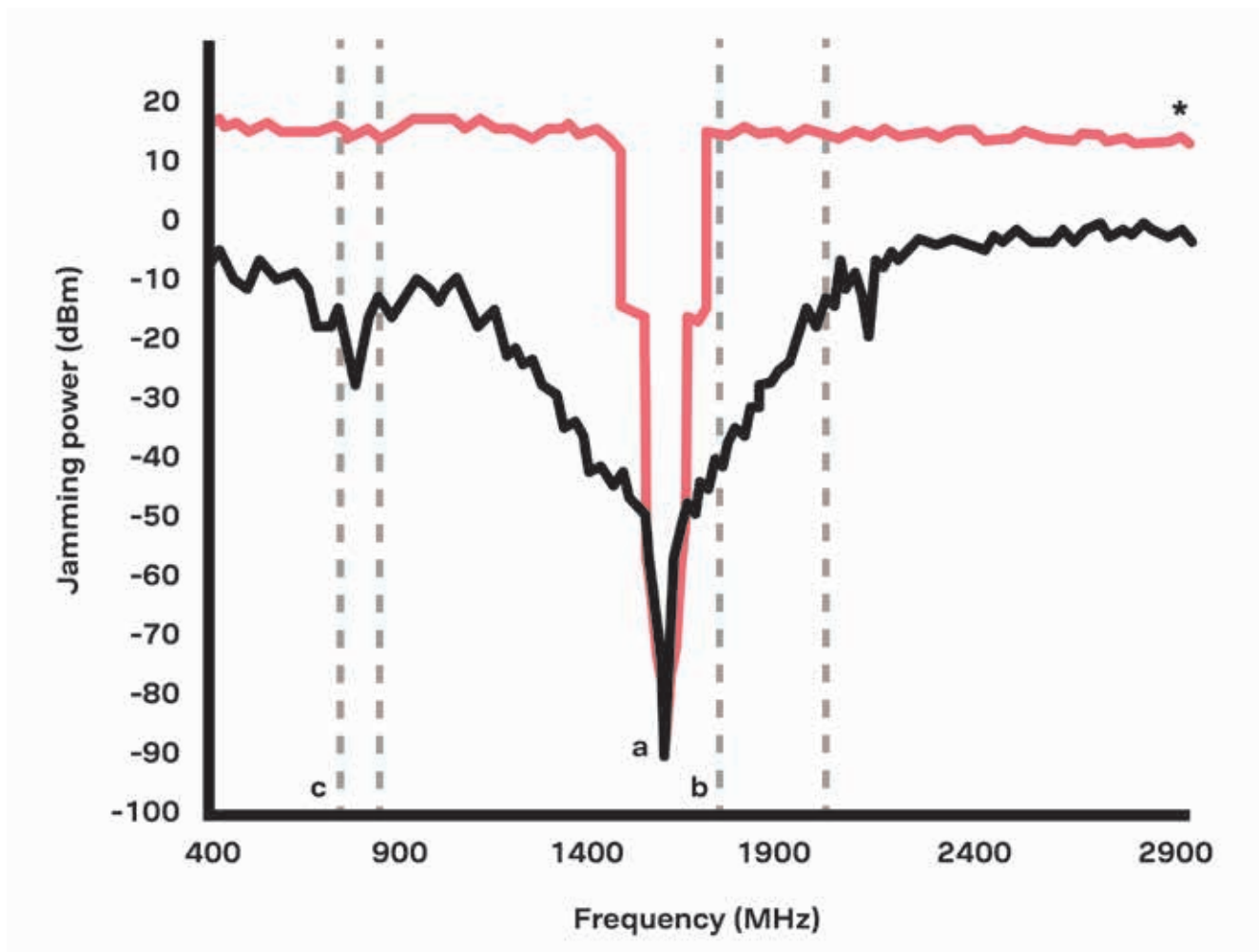


Image 5: Maximum power level that can be applied at each frequency without impacting the performance of the GNSS receiver. (red: with SAW filter, LNA, black: no SAW filter, LNA; a: 1574 MHz, b: 1800-1900 MHz LTE band, c: 700 MHz LTE band; * max. jamming power measurement limited by the test bench).

The performance of outband interference attenuation depends on the performance of the SAW filter used. Image 5 below compares the capability of two GNSS receivers to attenuate outband interference. The steep slope of the red jamming power curve is achieved using a high-quality SAW filter.

Best practices for reducing the impact of RF interference on GNSS receiver performance

In conclusion, the impact of RF interference on GNSS receiver performance can be significantly reduced by following best practices.



Maximize the distance between the antennas of the GNSS receiver and the wireless transmitter to reduce the strength of the transmitted signal received by the GNSS antenna.



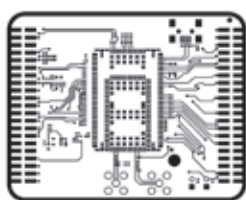
Select a highly selective narrowband GNSS antenna to keep outband RF interference from entering the RF path.



Design your board with a GNSS chip using a SAW filter to attenuate outband RF interference in the expected frequency band. As an alternative, use a GNSS module with a built-in SAW filter.



Calculate the expected power arriving at the GNSS receiver's RF input and compare with the datasheet to ensure that the signal strength does not exceed this limit.



Review RF interference sources on your board using a spectrum analyzer and re-design to remove them.

Selecting GNSS receiver modules designed specifically to reduce GNSS interference is vital to reaching performance and robustness targets.

With a totally delivered volume of more than half a billion GNSS receivers u-blox is a major player in the market.

The u-blox NEO-M9N module provides meter-level accuracy with excellent RF interference mitigation capabilities. It resists against cellular transmitter RF interference up to a level of 15 dBm.



To learn more about our full portfolio of GNSS receivers and cellular modems, please visit our website at:

<https://www.u-blox.com/en/guided-product-selector>

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About u-blox

u-blox (SIX:UBXN) is a global provider of leading positioning and wireless communication technologies for the automotive, industrial and consumer markets. Its solutions let people, vehicles and machines determine their precise position and communicate wirelessly over cellular and short-range networks.

With a broad portfolio of chips and modules, and a growing ecosystem of product supporting data

services, u-blox is uniquely positioned to empower its customers to develop innovative solutions for the Internet of Things, quickly and cost-effectively.

With headquarters in Thalwil, Switzerland, the company is globally present with offices in Europe, Asia and the USA.

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