Advanced Technologies | Whitepaper

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Securing pure and clean signals

Making the case for XF technology to enhance GNSS reliability

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Compared to the early days of GPS, the quantity of signals within the radio frequency (RF) spectrum have drastically exploded with the rapid introduction of Bluetooth, Wi-Fi, cellular signals, and other communication broadcasts. RF congestion at frequencies above, below, and in between the protected Global Navigation Satellite System (GNSS) frequency bands (1164 MHz to 1300 MHz and 1559 MHz to 1606 MHz) threatens the clear reception of GNSS signals, and the problem continues to get worse! Figure 1 shows GNSS constellations and frequency bands.

The primary sources of interference are LTE and 5G mobile networks, plus Iridium, Globalstar, and to some extent, the Inmarsat uplink frequencies (1626.5 MHz to 1660.5 MHz). New LTE signals in Europe [Band 32 (1452 MHz to 1496 MHz)] and Japan [Bands 11 and 21 (1476 to 1511 MHz)] are also potentially significant interferers. It is clear these signals are closely located to the GNSS signals in the frequency spectrum.

The amplitude of potential received interferers is a function of the frequency and distance between a transmitter and the GNSS antenna. For example, in North America, a 5G network is planned in a lower segment of the Inmarsat downlink (1525 MHz to 1536 MHz), and it is quite conceivable that a GNSS antenna could be physically close to an operating smartphone or handset. This new 5G network especially threatens L-band corrections services broadcast (1539 MHz to 1559 MHz).

Do we really need to worry about RF congestion?

The short answer is yes! Traditional GNSS antennas are not as capable of filtering out near-band and out-of-band interference, leading to degraded signal quality and potentially impacting critical applications that are reliant on precision GNSS. This poses a significant challenge for industries such as autonomous vehicles, precision agriculture, and telecommunications, where uninterrupted and accurate positioning, timing, and navigation, is paramount for success and safe operation. Most commonly, in-band interference results from distortion of high-amplitude signals due to non-linearity in the antenna low noise amplifier (LNA), or occasionally, from a jamming device used to disable tracking. In either case, once present, there is no filter, digital or analog, that can filter it out; prevention is the only cure.

Strong out-of-band signals can generate in-band interference by saturating the antenna LNA or by cross multiplication with other strong signals. For example, a single strong signal at 800 MHz could cause a plethora of harmonics, each offset by the signal carrier frequency, including a harmonic signal at 1600 MHz, which falls close to the center of the GLONASS-G1 band.

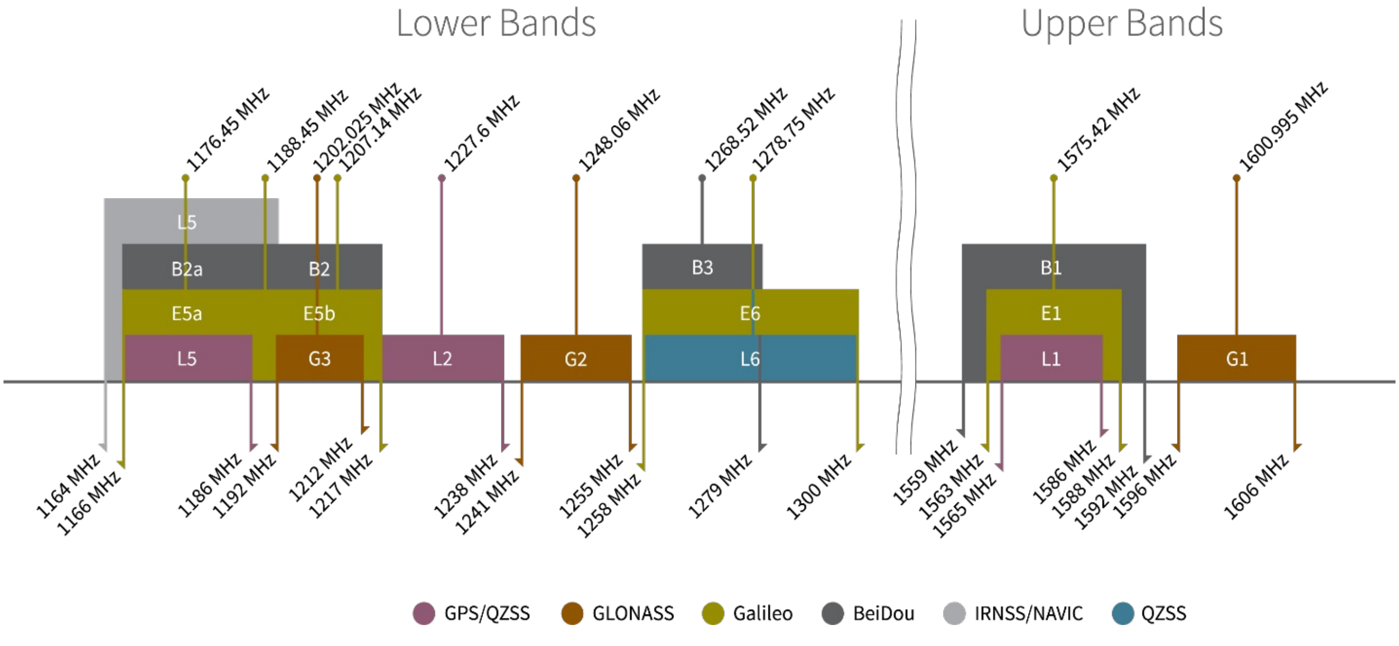

Figure 1: Frequency spectrum showing the GNSS bands

Although modern GNSS receivers concurrently track many satellites from several GNSS constellations concurrently, temporarily losing some of the tracked signals can lead to a reduction in position accuracy. In the worst case, the result can be a full loss of the position fix.

Here are key market drivers further signalling the imminent threat of RF congestion and the need for new solutions:

1. **Mobile networks are rapidly expanding:** The proliferation of LTE and 5G mobile networks around the globe is causing additional congestion around and within the GNSS spectrum.
2. **Satellite communications services are growing:** the deployment of satellite communication services, such as Iridium and Globalstar, introduces additional sources of interference near GNSS frequencies.
3. **Sensitivity to interference is more pronounced:** As the world increasingly turns to vehicles and equipment reliant on modern GNSS, any degradation in GNSS phase quality due to interference can have significant implications for safety, efficiency, and operational performance.

Basically, any nearby RF transceivers transmitting in the frequency bands close to those used by GNSS satellites can wreck the positioning performance of a GNSS receiver. This creates a pressing need for robust GNSS solutions capable of mitigating interference from these adjacent frequency bands.

Why is XF technology a solution?

Historically, antenna LNAs have included one or more passband RF filters, usually placed after the first or second of the two or three amplifier stages. This provided the best achievable signal to noise ratio because the filter loss did not contribute addition noise. However, it left the LNA susceptible to interference. This was not a problem until the launch of high-amplitude near-band interferers.

Traditional filtering approaches have struggled to effectively mitigate this interference. That's why innovative pro-active solutions like XF are needed to ensure uninterrupted GNSS reception that can ensure operational integrity across critical applications. Here is further evidence pointing to XF technology as a viable solution to enhance GNSS reliability.

1. **The escalating congestion in the RF spectrum** surrounding GNSS frequencies underscores the critical need for advanced filtering solutions.
2. **Rising demand for high-precision positioning in industries** such as timing, autonomous vehicles, precision agriculture and surveying, are driving the demand for XF technology.
3. **Regulatory bodies and industry standards** increasingly mandate stringent requirements for GNSS signal integrity and reliability. XF technology helps meet these requirements.
4. **Advances in RF filtering**, such as surface acoustic wave (SAW) and dielectric filters, enable the development of XF solutions with superior performance characteristics.

RF filtering is the standard method of mitigating out-of-band interference. A different approach, however, must be taken for in-band interference. In this case, prevention is the only cure for the in-band interference that results from very high out-of-band signals that push the antenna LNA into non-linearity, i.e.: the antenna malfunctions. Clearly, an antenna capable of handling higher interference power levels is helpful but that comes at the cost of higher power consumption, and even then, that is ultimately limited. So, the only way to prevent distortion is to strongly attenuate those high amplitude signals with RF filters and make the LNAs as capable as possible. Figure 2 shows the LNA response for our standard TW3972E versus that of the TW3972EXF, showing rejection down to the noise floor of the measurement.

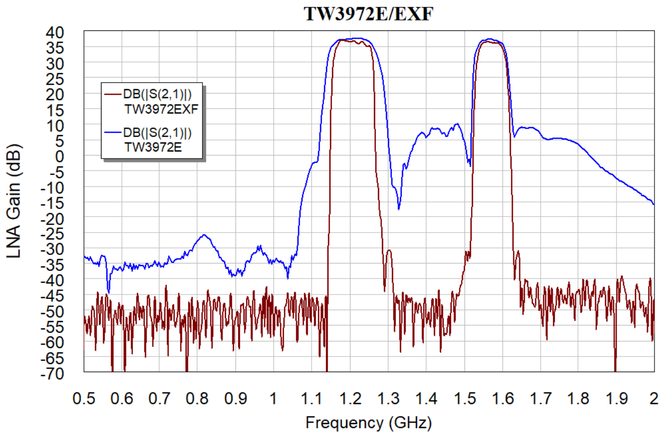

Figure 2: LNA frequency response showing the benefit of XF filtering on the TW3972EXF.

It sounds easy but is not! Ideal bandpass RF filters have 0 dB insertion loss (i.e. lossless), sharply defined corners at band edges, plus extremely steep skirts to provide deep rejection just a few MHz offset from the passband edges. In practice, depending upon the technology, filters are lossy, which add noise to the system, have rounded corners at band edges, and have finite roll-offs.

What is the advantage of Calian XF antennas?

Calian XF antennas will continue to provide pure GNSS reception in both low and high GNSS bands in the presence of strong interfering signals that often dwarf the power levels of the wanted GNSS signals. Calian's XF products have double-hump filtering done right at the very input of the antenna's LNA, prior to the signal being amplified by subsequent stages.

This has the advantage that the first and subsequent amplifier stages are protected, but at the cost of a somewhat higher noise figure because of the pre-filter insertion loss. There is no free lunch! Single-band antennas also feature a pre-filter, but the diplexer is not required. Both surface acoustic wave (SAW) and dielectric filters are suitable for this purpose, with convenient form factors. SAWs have small footprints, are low cost, but have very good temperature variation characteristics, and insertion losses from 1.5 dB to 3.0 dB, depending on the bandwidth and steepness of the skirts. On the other hand, dielectric filters have relatively large footprints, insertion losses around 1 dB, or better, and almost no performance variability with temperature.

Both filter types introduce a group delay variation (GDV) as a function of frequency over the passband, which impairs how the signal is received by the receiver. Typically, for a full-band GNSS antenna, the GDV is smallest in the center of the bands, increasing toward the band edges. GDV can be temperature sensitive because SAW filters have finite temperature coefficients. 0

The necessity to use different filters to cover the various GNSS bands results in unequal group delays between the bands, introducing an effect known to the reference antenna community as Differential Code Bias (DCB). GDV and DCB can generally be compensated for at the receiver.

Calian uses SAW filters in the Accutenna® and Helical antenna lines and a combination of dielectric and SAWs RF filters in our high-end antennas (VeroStar™, VeraPhase®, and VeraChoke®).

Time to be proactive to ensure pure and clean GNSS signals

The escalating congestion of RF spectrum bands surrounding GNSS frequencies is an ongoing problem that is only expected to worsen. Traditional filtering approaches continually struggle to mitigate this interference, which underscores the need for innovative and pro-active solutions such as XF technology.

High power out of band signals can, also, push the antenna's LNA into non-linearity, meaning the antenna will no longer be providing a usable signal to the GNSS receiver.

Calian has developed XF technology to address these challenges by effectively filtering out-of-band signals below the lower GNSS band, in between the two bands, and above the upper GNSS bands. In addition, Calian's XF technology incorporates LNAs designed with excellent linearity characteristics to mitigate in-band interference. Calian's XF technology has been demonstrated around the world to enable clean and pure GNSS signal reception in challenging RF environments.

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