WHITEPAPER

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Anti-Jamming techniques in u-blox GPS receivers

GPS receivers differ considerably in their anti-jamming effectiveness

white paper by:

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Executive Summary

A critical factor when selecting components for a GPS system is the receiver's immunity to external noise, or "jamming". The ability to lock onto typically faint GPS signals in the presence of noise generated from other electronic devices has a large influence on the system's ability to provide correct location data.

The use of an advanced, proprietary adaptive digital filtering technology allows the u-blox 5 and u-blox 6 GPS positioning engines to overcome jamming signals up to 25 dB stronger than conventional GPS receivers can withstand. The result is the most sensitive and reliable GPS receiver technology available.

Anti-Jamming

While underway, whether walking or driving a car, you'll notice how the signal strengths from satellites as read by a GPS receiver vary quite a bit, and in some areas for some unexplained reason you can completely lose satellite lock. While such reductions in signal strength can be due to attenuation and signal blockage while in urban canyons, inside building or even underneath heavy tree cover, it can also be due to unintentional jamming – signals from everyday electrical and electronic devices that create so much noise that they mask the satellite signals. These jamming signals can even come from ordinary battery-operated consumer devices such as portable music players or mobile phones as well as automobile electronics.

To ensure that their GPS systems provide the optimal functionality, engineers of any consumer appliances incorporating GPS capabilities should not only follow good engineering practices, they should also select components designed to mitigate these jamming effects. The proper antenna is certainly one aspect to keep in mind, but engineers should also be aware that the abilities of individual GPS receiver chipsets vary widely in their ability to counteract jamming signals. To help engineers during their component evaluations, this white paper first reviews some aspects of jamming, and then shows how u-blox 5 and u-blox 6 uses proprietary technology to provide anti-jamming capabilities significantly better than conventional GPS receivers.

Capturing extremely weak signals

GPS Satellites transmit with a power output of roughly 30 W and are 20,000 km above us.

One reason that jamming is an issue with any GPS receiver is that the signals coming from the satellites are so weak. Satellites transmit with a power output of roughly 30 W and are 20,000 km above us. Just imagine: how much strength would the signal with the strength of a weak light bulb have after traveling that distance? In fact, a typical signal, when acquired outdoors with open sky, is in the range of –120 dBm (1×10^{-15} W), and moving inside a normal residential building can add 20 or 30 dBm of attenuation. With such a weak signal, other signals in the same GPS frequency band don't need to be very strong at all in order to override the satellite signals.

As noted, such unintentional jamming can come from ordinary commercial electronic appliances. You might expect for consumer electronics that the FCC, CE and other agencies would regulate against interference of GPS systems. Unfortunately, that is not the case. First, the regulations don't address signals at frequencies higher than 1 GHz whereas GPS carriers are at 1.575 GHz. Second, the regulations allow emissions with levels of –60 to –80 dBm, which are many orders of magnitude stronger than GPS signals.

Thus, GPS receivers must deal with unintentional jamming due to the inadequate design in the electrical world around them. Common sources of such jamming signals are the clock circuits or switching power supplies in virtually any electronic device you purchase today and even their displays due to their driver circuitry and scan rates. For instance, a PDA can generate noise on its display, through its WLAN port or Bluetooth interface. A mobile TV can also create heavy interference. There is also considerable potential for interference in a car – not only from the electronic engine controls but also from dashboard electronics and entertainment systems.

Anti-Jamming

If you would like to give yourself a very quick demonstration of such interference, simply take any GPS receiver and place it next to the display of a desktop or a laptop PC – you will immediately see how the signal strength of the various satellites drops, and sometimes you can even lose the lock on the satellites.

Further, it's often difficult to isolate the cause of such unintentional interference. In one famous case (Reference 1), the whole of Moss Landing Harbor south of San Francisco was being jammed so that GPS reception was impossible even 1 km out to sea. With the help of directional antennas and by turning off shore power to individual boats, it was possible to determine the actual emitter: a pleasure boat had a preamplifier built into a commercial VHF/UHF television antenna that was powered even when the TV was not on. Even though the TV antenna was stored in a paint locker, its emissions were strong enough to cause severe problems for both commercial fisherman and pleasure boaters.

Mitigation measures

We're not going to eliminate all such unintentional jamming signals, so we have to learn to live with them. Manufacturers of GPS equipment and chipsets take a variety of approaches in combating jamming signals. For instance, as a first mitigation measure, virtually every GPS receiver places one or two SAW (surface-acoustic wave) filters into the signal path to attenuate out-of-band signals (Figure 1).

Next, some manufacturers such as u-blox place a lowpass antialiasing filter in the RF chip to remove signals that would create aliases during the digitization process in the A/D converter. In addition, a highpass filter just after the A/D removes DC components that might come from the data conversion and also removes the flicker noise inherent in CMOS circuitry.

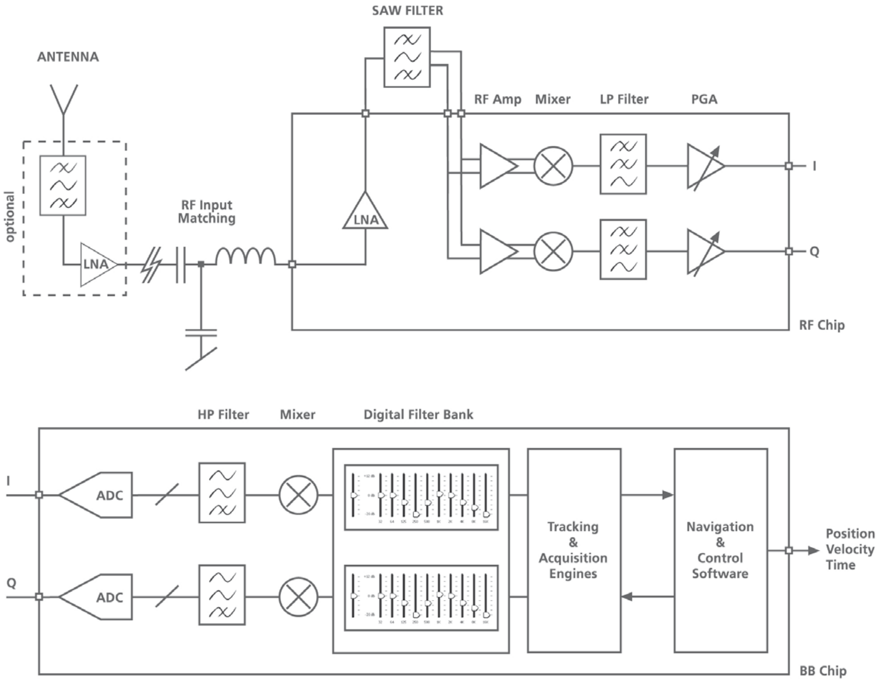

Figure 1: This simplified block diagram of a GPS receiver based on the u-blox 5 / 6 technology shows the SAW filter at the signal input to block out-of-band interference plus the software-controlled digital filter bank that blanks out specific interference sources.

Anti-Jamming

However, the issue remains of dealing with in-band interference signals. Each GPS receiver uses its own special methods, but here u-blox 5 / 6 employs some particularly effective techniques. First is the fact that the analog signals from the LNA are digitized to 5 bits of resolution (thus giving 30 dB of dynamic range) in contrast to other receivers, which typically digitize to only 1, 1.5 or perhaps 2 bits (and thus up to 12 dB of dynamic range). With this extra dynamic range, u-blox 5 / 6 is then able to apply a proprietary filtering method based on a bank of on-chip digital filters whose configuration can be changed under software control. Specifically, this technique sweeps across the GPS receiver band looking for strongest signal peaks, and for each it performs statistical analysis to determine if it is actually a satellite signal. Upon finding a jamming signal, the scheme puts it into a list so that this signal is subsequently blanked out. Finally, if a signal for some reason can't be removed in this way, the technique builds up a table of thresholds, and if a real GPS signal drops below this threshold, the detection algorithm is very cautious about using it so the receiver doesn't track false signals.

This special jamming-mitigation method requires considerable processing power, which u-blox 5 / 6 supplies with an ARM® processor. Under control of this processor, this proprietary combination of hardware and software can reduce jamming signals by 30 dB compared to conventional products. To see the results more clearly, examine Figure 2, which shows two curves comparing the performance of u-blox 5 / 6 with conventional receivers. The curves show the amount of interference power needed to result in a 3 dB degradation in the signal at the receiver output (the 3-dB de-sensitization point), and the curves show results for the +/– 40 MHz around the GPS carrier signal. For example, directly at the carrier, an interference signal of only roughly –110 dBm is sufficient to degrade the received signal by 3 dB using conventional methods, whereas u-blox 5 / 6 can handle interference that is 25 dBm stronger before it reaches its 3-dB de-sensitization point.

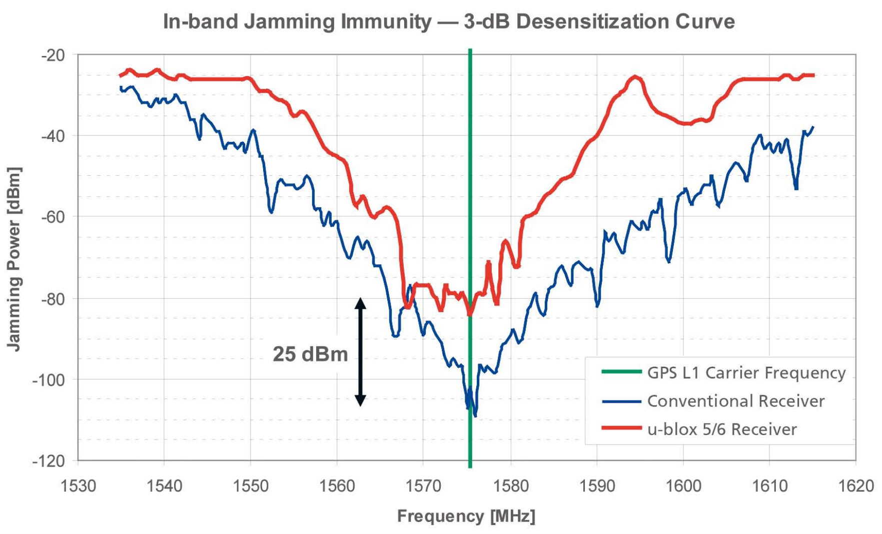

Figure 2: Measured directly at the GPS carrier frequency, an interference signal of only about –110 dBm is sufficient to degrade the signal by 3 dB for receivers using conventional approaches (blue trace), whereas u-blox 5 / 6 can handle interference that is 25 dBm stronger before it reaches its 3-dB de-sensitization point (red trace).

Anti-Jamming

Field comparisons

Let’s now translate this talk of dBm into the impact of a jamming signal on a GPS receiver’s performance in the field. Figure 3 shows results from an experiment using conventional technology (left) and u-blox 5 / 6 technology (right) for various signal levels of a continuous wave (CW) jamming signal. With a CW signal level of 10 dB above thermal noise floor, the u-blox 5 / 6 can receive signals from more satellites. In addition, the large dot on the floor plan shows that for both systems, each time they read their location, the results are virtually the same. This gives you confidence in the readings being accurate. Already with the CW jamming signal level increasing to 20 dB above thermal noise floor the strengths of satellite signals received using conventional technology are starting to drop so that the GPS receiver calculates a slightly different position almost every time; as shown with the spread of position points. In contrast, u-blox 5 / 6 continues to read most of the satellites with strong signal strength and provides a constant position. While an even higher CW jamming signal level leads to the failure of the conventional-technology GPS receiver to read any satellites, u-blox 5 / 6 continues to do so such that its position accuracy remains constant. Only with a CW jamming signal level of more than 40 dB above thermal noise floor do signal strengths and number of satellites decrease to where there is some positional variation – but the system continues to function.

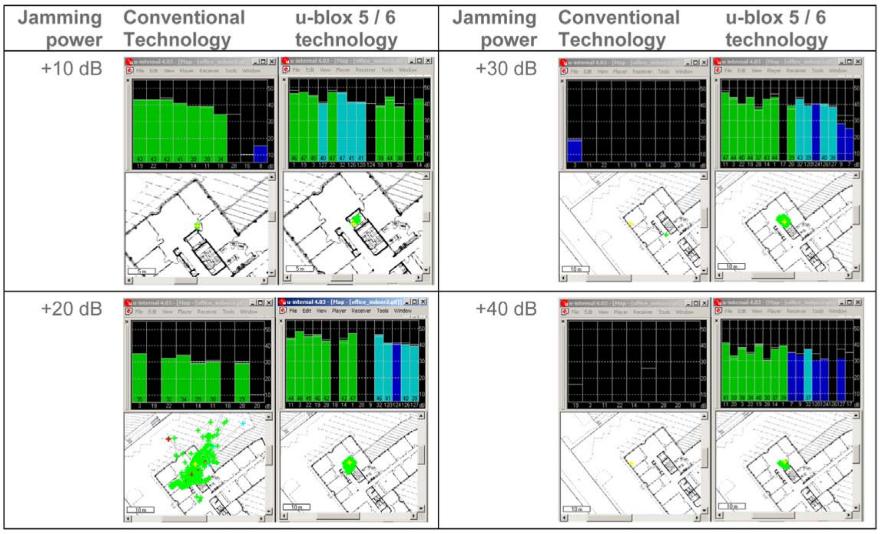

Figure 3: Field tests using conventional technology (left) and u-blox 5 / 6 technology (right) at various levels of a single-frequency, in-band interference signal. The upper part of each screen shot shows the signal strength of the GPS satellites, and dots in the lower part track several calculated positions. As the jamming signal increases, the number of satellites each technology can track and their signal strengths decreases.

Conclusion

GPS system designers should consider where their systems will be used, the type of noise they are likely to encounter, the effects of unintentional jamming, and the benefits to the end user of selecting the technology with the most effective jamming mitigation. In any case, a system incorporating a GPS receiver should always be designed with utmost care avoiding generation of any interference signals in the GPS frequency band. As the data in this white paper clearly illustrates, innovative jamming-mitigation techniques as implemented in u-blox 5 and u-blox 6 GPS receivers considerably improve GPS sensitivity and accuracy in noisy environments.

Reference 1: “Unjamming a Coast Harbor,” GPS World, January 1, 2003.

For more information about Anti-Jamming, visit
http://www.u-blox.com/en/gps-modules.html
or contact: info@u-blox.com

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About u-blox

u-blox is a leading fabless semiconductor provider of embedded positioning and wireless communication solutions for the consumer, industrial and automotive markets. Our solutions enable people, devices, vehicles and machines to locate their exact position and wirelessly communicate via voice, text or video.

With a broad portfolio of GPS modules, cards, chips, and software solutions together with wireless modules and solutions, u-blox is uniquely positioned to enable OEMs to develop innovative solutions quickly and cost-effectively. Headquartered in Switzerland and with global presence in Europe, Asia and the Americas, u-blox employs 180 people. Founded in 1997, u-blox is listed on the SIX Swiss Exchange.

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