CASE STUDY

Delivering the Next Generation of GNSS Anti-Jam and Anti-Spoof Technology with DLR

KEYSIGHT

Challenge

As the use of global navigation satellite system (GNSS) spreads across more and more industries, the threats of jamming and spoofing are growing exponentially. Eurocontrol received an all-time high number of reports of GPS disruption during 2019 (see Figure 1), and as recently as November 2020 it has been reported that GPS outages are now standard occurrences on commercial flight routes between the US, Europe, and the Middle East.

In addition, military impact on commercial activities has been noted in the central and eastern Mediterranean areas, as a likely result of electronic warfare in Syria and Libya, and on commercial aircraft in the vicinity of tests in the US.

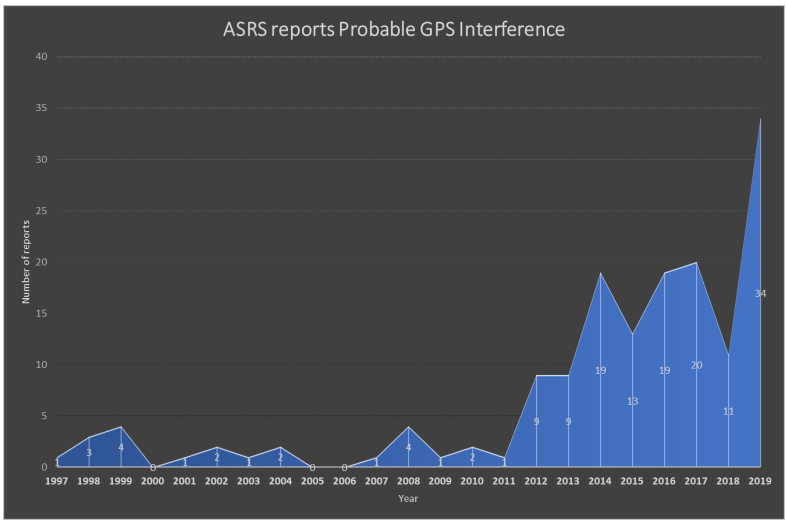

Figure 1. Reports of suspected GPS interference collated by Guy Buesnel (Keysight)

The Customer

Deutsches Zentrum für Luft- und Raumfahrt (DLR) is Germany's research center for aeronautics and space. DLR conducts research and development activities in a wide range of application areas, including aeronautics, space, energy, transport, security, and digitalization. This includes a pre-eminent role in the Galileo system and its downstream applications, with one of the two Galileo control centers located at the DLR site in Oberpfaffenhofen. Research in the field of resilient GNSS receivers is a focus of the Institute of Communications and Navigation of DLR.

Spoofing has been a concern in the military and defense domains for decades, but the proliferation of expertise and affordable offensive equipment has increased its threat to safety- and mission-critical civilian applications — including commercial aviation, shipping, and autonomous vehicles. In the maritime industry there have been reports of suspected spoofing in areas ranging from the Mediterranean to the Black Sea, and to ports in China.

Figure 2. GALANT array receiver system

To protect a broad range of applications from these critical threats, DLR has been developing its GALANT anti-jam, anti-spoof array receiver system over the last decade. GALANT is a space time adaptive system that directs nulls towards detected interference sources while beamforming by steering the antenna main beam in the direction of uncompromised GNSS satellites (see Figure 3). It is an advanced form of controlled radiation pattern antenna (CRPA) electronics designed for the use of registered and approved users of Galileo's public and restricted signals in safety-of-life (SoL) applications.

To develop and test the nulling (pre-whitening) and beamforming capabilities, DLR needed powerful simulation capabilities with high degrees of both flexibility and control. Testing needed to encompass a full range of scenarios, including multiple constellations and directional jamming/spoofing inputs, as well as precision modelling of up to eight antenna elements for conducted testing. Because of the nature of the system under test, precision phase alignment was a critical aspect, as was the generation of a calibration signal to be used by the array receiver for its internal phase calibration.

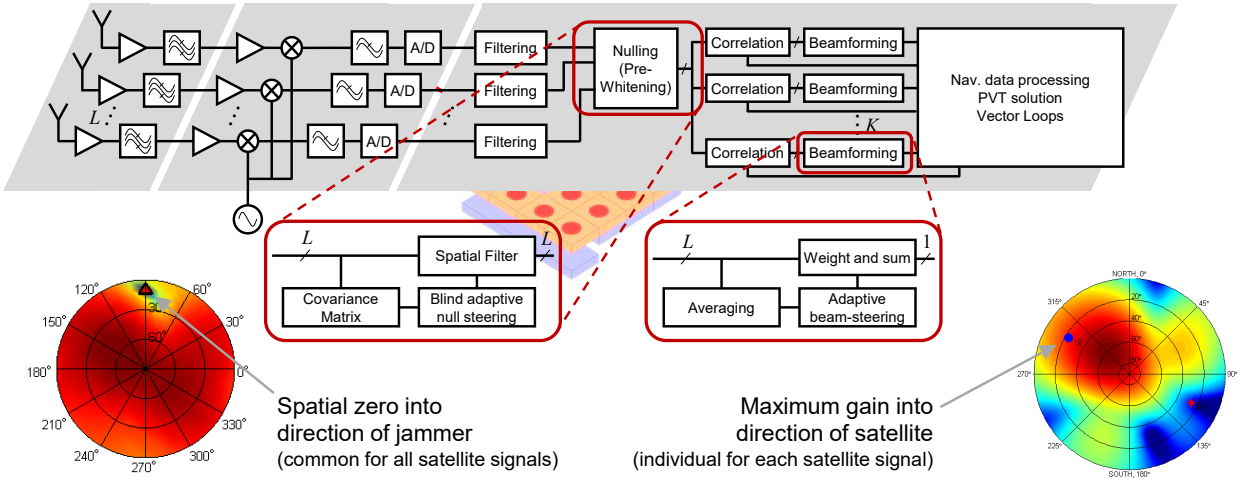

Figure 3. Schematic of the components of GALANT

Solution

Keysight was able to supply a customized, comprehensive GSS9000 advanced multi-element GNSS simulation system to DLR with a lead time of under six months.

The system comprised:

- Multiple GSS9000 Series chassis with a total of eight composite radio frequency (RF) outputs
- SimGEN simulation control software

This configuration was capable of generating:

- Combinations of up to 64 channels per antenna, from:
  - GPS L1 + L2 + L5
  - GLO L1 + L2
  - GAL E1 + E5 + E6
  - BD2 B1 + B2
  - QZSS L1
  - Interference L1 + L2 + L5 + E6
- Prepared for PRS — Galileo's restricted signal
- Maximum jammer-to-signal (J/S) of 110 dB relative to -133 dBm nominal
- Eight individual antenna elements
- Altered navigation data, chipping rates etc. for custom waveforms
- Multiple concurrent constellations for advanced spoofing testing

Every aspect of the system was designed and built to rigorously test the performance of CRPAs and other advanced GNSS applications.

Figure 4. Keysight CRPA simulation system

Results

Using this high-precision GNSS simulation equipment DLR was able to prove the performance of GALANT in a number of areas (see Figures 5–7). Scenarios were performed in a highly controlled and repeatable fashion, demonstrating the impact of GALANT countermeasures with truly scientific results.

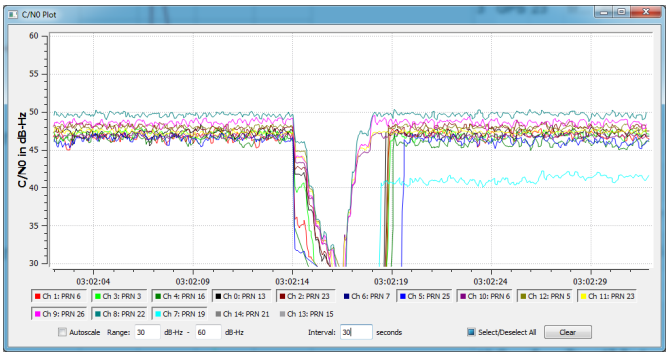

Figure 5. Continuous wave (CW) signal centered at L1

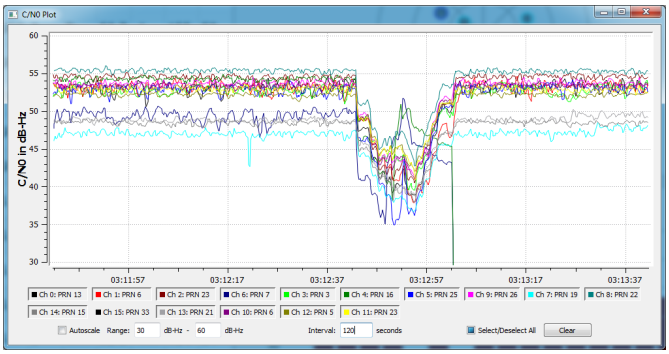

Figure 6. Single-antenna reception — no beamforming

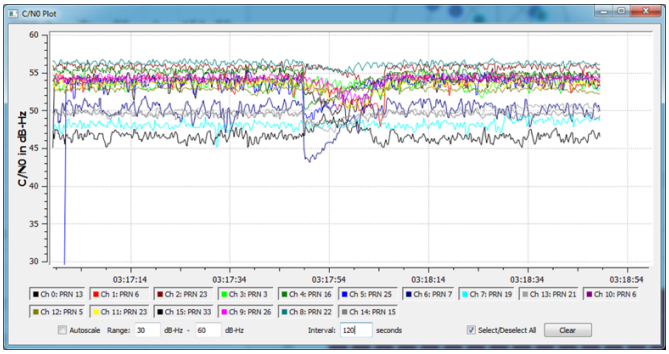

Figure 7. Array reception — post-correlation beamforming

Through these tests DLR was able to demonstrate that its post-correlation beamforming significantly reduced the impact of a jamming attack on receiver carrier-to-noise. Subsequently, the introduction of the intelligent null steer meant there was no significant or long-lasting impact of the interference on receiver performance.

In addition, the number of available satellites was measured through the same series of tests, demonstrating that beamforming and null steering not only prevented a drop in the number of available satellites, but actually increased it. This was likely due to increased gain enabling the use of low elevation satellites that would usually be below the noise floor.

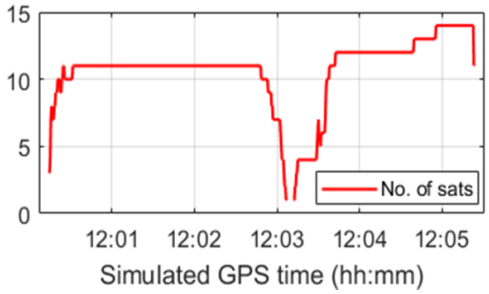

Figure 8. Number of available satellites, continuous wave (CW) signal

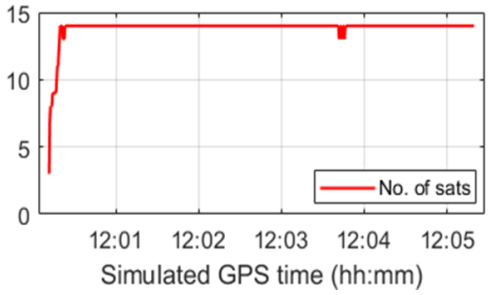

Figure 9. Number of available satellites, single-antenna reception — no beamforming

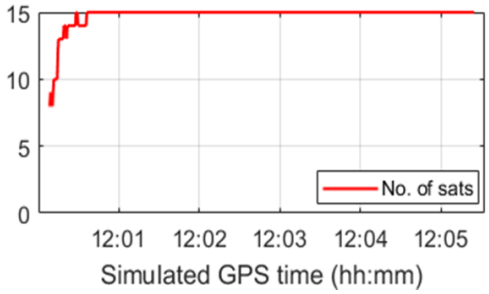

Figure 10. Number of available satellites, array reception — post-correlation beamforming

The highly flexible and modular nature of the GSS9000 product line configured for use in the advanced multi-element simulation system means that all future developments and requirements on the GALANT and other projects will be met with the required confidence and performance.

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.

KEYSIGHT

This information is subject to change without notice. © Keysight Technologies, 2026, Published in USA, June 1, 2026, 3126-1138