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Host organization: Department of Communication, Information, Systems & Sensors of the Faculty of Applied Sciences of the Royal Military Academy Brussels, Belgium

GSINTA - **G**NSS **S**ignal-in-Space **INT**egrity **A**ssurance project has addressed the underestimated and hazardous effects of external EM interference (jamming) signals on GNSS SiS integrity, in safety critical air navigation applications. The project timely supports safety assessment considerations during actual global transition to GNSS as a primary mean of airspace navigation. Moreover, the GSINTA is directly supporting latest ICAO 12th Air Navigation Conference recommendations related to GNSS vulnerability, particularly *"Recommendation 6/8 – Planning for Mitigation of Global Navigation Satellite System Vulnerabilities"* which urges States to *"Assess the likelihood and effects of GNSS vulnerabilities in their airspace and apply, as necessary, recognized and available mitigation methods"* and *"Support introduction on-board mitigation techniques"*.

Background

Underlining motivation of the project was to provide short term feasible and applicable solution, based on existing technical implementations of both, GNSS receivers and FRP (Fixed Reception Patter) antennas, as well as state-of the-art techniques developed purposely to protect GNSS signals for safety critical air navigation applications.

Scientific contribution was comprised of development of the new technical solution accompanied with signal filtering and navigation algorithms, and their fully operational validation in critical airspace navigation applications, with prospect to be used in other Safety-of-Life (SoL) applications.

Scientific and technological reasons for carrying out such research in the field of GNSS safety, is absence of well-established methodology for in flight SiS integrity calculation with regard to external interference signals and generic approach of interference mitigation for all GNSS in use over European area.

The research project was focused on active, aircraft on-board mitigation of jamming effects on GNSS SiS, presenting innovative approach in the field where similar researches did not exist at that time. Furthermore, continuous aircraft on-board monitoring of GNSS baseband SiS and detection of jamming signal, continuous calculation of SiS integrity with regard to external interference signals, and jamming mitigation at GNSS receiver level with use of standard GNSS aviation antennas, did not exist at that time.

Objectives

Main objective of the GSINTA was development of the IDLaM (Interference Detection, Localization and Mitigation) on-board aircraft solution, based on novel adaptive signal processing techniques using multiple FRP (Fixed Reception Pattern) antennas (EASA ETSO C-190 antennas, already in standard configuration on civil aircrafts). In particular, aircraft bottom mounted GNSS antenna was used to as a probe to pick-up mixed GNSS+Jamming signal, which was then transformed to match the jamming signal at top antennas and finally subtracted from the mixed GNSS+Jamming signal received at standard upward pointing top mounded antennas (Figure 1).

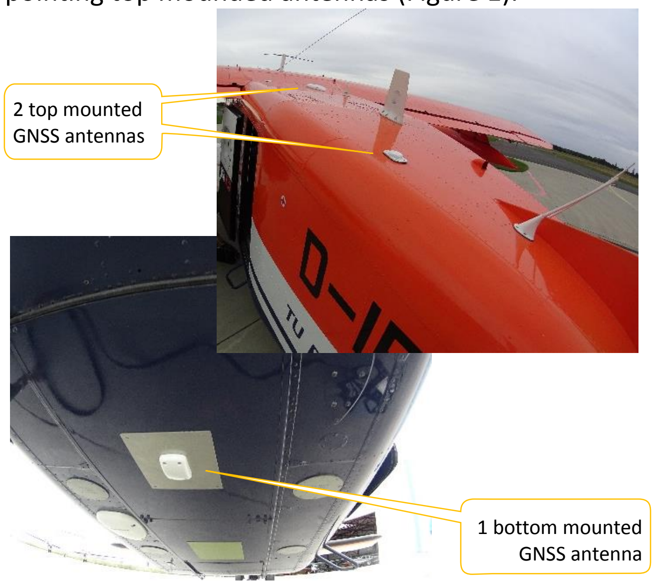

Figure 1 Multi-antenna set-up for novel aircraft on-board jamming mitigation solution

Other supporting objectives included: modelling of mechanism of various jamming signals and their impact on GNSS SiS, operational validation of navigation algorithms developed for continuous operation of GNSS based air navigation applications in interference environment (recovering and maintaining the SiS integrity levels), and capturing the far-field of multiple antennas on the full scale electric object (aircraft) (by means of EM simulation of the aircraft with multiple GNSS antennas attached to it).

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Activities & Work

Within the GSINTA project framework, the in-flight data acquisition of GNSS data with intentional jamming in the GLONASS L2 C/A code frequency band was conducted for the first time in the context of European civil GNSS jamming campaigns. GNSS band used for the data acquisition with on-ground real-world jamming was centred around GLONASS L2 only because the C/A-code signals on this frequency are not currently in use by the European civil aviation, and thus approvable for the R&D activities. However, solution under this project development is generically applicable to any of the GNSS part of spectrum and signals in use, thus GPS and Galileo as well.

Jamming signal was generated on-ground and radiated. Various jamming signals were used with pertaining characteristics: sweep-through, AWGN (Additive White Gaussian Noise), and noise only; emitted by directional antenna in order to deliver combined signal (GNSS + jamming) at receiving GNSS multi-frequency antenna port (Figure 2 and Figure 3).

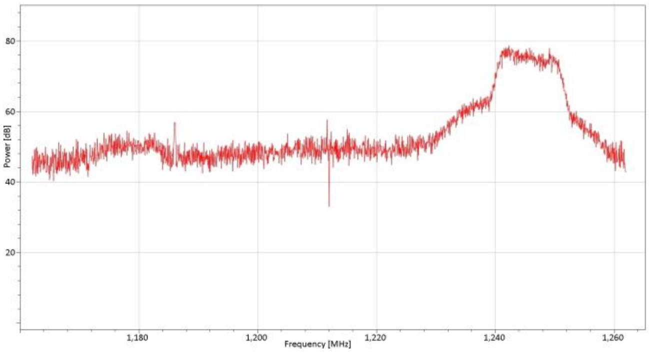

Figure 2 Noise only type of jamming signal acquired at GNSS antenna port during flight

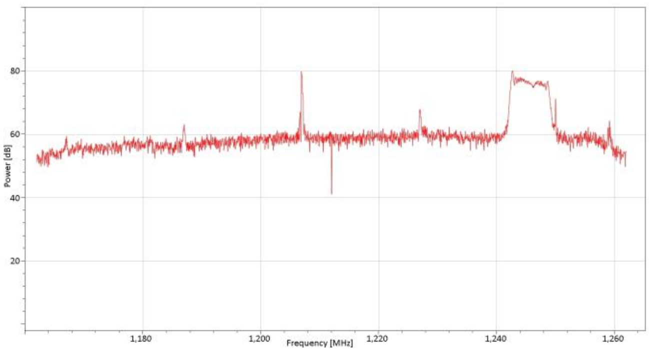

Figure 3 Chirp type of jamming signal acquired at GNSS antenna port during flight

Approval to use the GNSS part of the RF spectrum for this campaign together with certification of the research aircraft of has been issued by the *Bundesnetzagentur* and *Luftfahrt-Bundesamt*, respectively. Flight campaigns have been conducted at Braunschweig airport (Germany) with support of *Institute for Flight Guidance of Technical University of Braunschweig* and *Septentrio Sv*.

Results & Conclusions

Technical solution was implemented in the reconfigurable System-on-Chip FPGA based GNSS R&D receiver provided by the Septentrio company, the leader in development of GNSS receivers in Europe.

Preliminary results showed reduction in 15 dB of jamming signal when filtering applied (Figure 4), which in turn has satisfied critical requirement for GNSS based navigation of aircraft during approach for landing to complete the approach when distance to jammer is below 10 NM (corresponding to jammer source maximum EIRP of average PPD in use nowadays), and jammer source is located near runway. In other words, solution allowed to approach jammer approximately 5 times closer, which in case of aircraft jammed at Initial Approach Point is roughly corresponds to reaching runway threshold or Missed Approach Point.

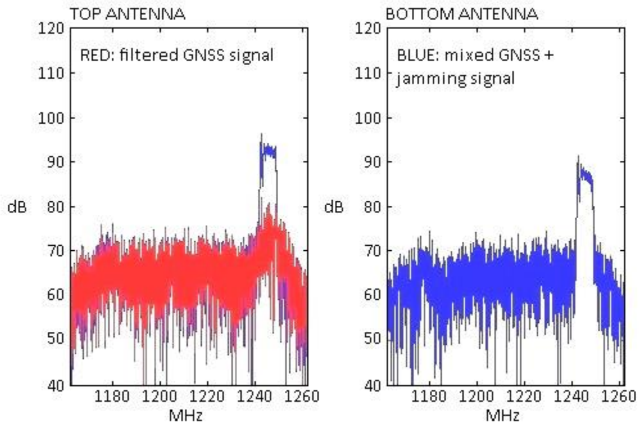

Figure 4 Real-time adaptive filtering applied to combined jamming+GNSS signal showing reduction of 15 dB

Research conducted has proved original hypothesis and has reached its objectives, namely GNSS SiS anti-jamming with use of existing aircraft on-board navigation technologies and novel state-of-the-art signal processing implemented at GNSS receiver level, to allow completion of the flight guidance based on GNSS in denied environment, during its most critical approach for landing phase, where any reversion modes implies discontinuity of the operation. Solution is applicable not only to air navigation application, but to most of the Safety-of-Life application where technical solutions for GNSS SiS anti-jamming requires robust and minimalistic approach.