Impact and Detection of GNSS Jammers on Consumer Grade Satellite Navigation Receivers

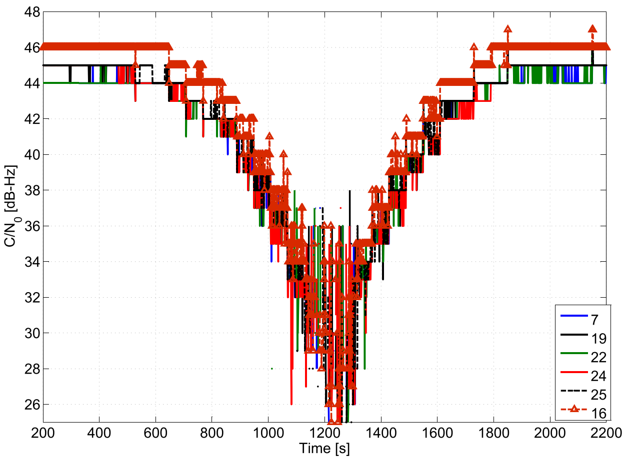

Fig. 11. ***C/N*₀ values of the individual GPS C/A signals tracked during the experiment considered in Fig. 3. The *C/N*₀ values are affected in a similar way by the jamming signal.**

detection. In particular, the following detection statistic was suggested:

$$\Lambda = \sum_{k=0}^{N-1}\left[\sum_{i=0}^{I-1}\left(\frac{C_i}{N_0}[n-k] - h_{\mathrm{LP}}[n] * \frac{C_i}{N_0}[n-k]\right)\right]^2 \quad (13)$$

where N is the number of time epochs considered and I is the number of satellites available. $h_{\mathrm{LP}}[n]$ is the impulse response of a low-pass filter with unit gain at direct current (dc) and symbol "$*$" denotes convolution. $(C_i/N_0)[n]$ is C/N_0 from the ith satellite at instant n expressed in logarithmic scale (dB-Hz). A decision is taken by comparing Λ with a decision threshold.

Although this method mitigates the C/N_0 ambiguity problem and can, for example, be used in dynamic scenarios [53], it can become unreliable when most of the signals are strongly attenuated such as indoors. In this case, additional information from other sources has to be adopted. A possible solution is considered in [32] which suggested a joint detection scheme combining C/N_0 values with AGC readings. Indeed the two time series provide complementary information. Additional detection approaches can be designed using the output of the digital tracking loops used to process each satellite signal. Bhuiyan *et al.* [25] considered the discriminator outputs of a noncoherent DLL and of a Costas PLL. Then an analysis window was used to select N consecutive samples and compute the sample variance of the discriminator outputs. If the sample variance passes a decision threshold, then the presence of jamming is declared.

In this case, a single decision is taken for each signal tracked. Then a combining rule, such as the Bernoulli scheme described in [56], has to be adopted for taking a final decision.

A similar approach can be adopted where the sample variance is computed using GNSS observables such as pseudoranges and Doppler measurements. In this case, the time-varying nature of such observables has to be accounted for. For example, N should be small enough to limit the time variations of these observables. Alternatively, measurements can be at first high-pass filtered.

V. CONCLUSION

In this paper, the characteristics of jamming signals and their impact on GNSS receivers have been reviewed. A survey on the state-of-the-art methods for jamming detection was also provided. It was shown that jamming can practically impact all receiver stages, from the front-end to the navigation solution. Specific emphasis was given to intermediate power jamming attacks when jamming signals are sufficiently powerful to significantly degrade receiver performance without interrupting receiver operations. This case is considered the most dangerous since jamming may be undetected and GNSS users may continue their operations without realizing the degradation of performance experienced by their receivers. In this respect, detection is the first line of defense against a jamming attack. Several detection approaches were discussed and it is shown that detection can be implemented at almost any receiver stage. Interference detection units are becoming common accessories in new GNSS receivers and the constantly growing computational capabilities of GNSS chipsets are enabling new and more sensitive detection strategies. ■

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ABOUT THE AUTHORS

Daniele Borio received the M.S. and Ph.D. degrees in communications engineering from Politecnico di Torino, Torino, Italy, in 2004 and 2008, respectively.

From January 2008 to September 2010, he was a Senior Research Associate in the PLAN group, University of Calgary, Calgary, AB, Canada. He is currently a Scientific and Policy Officer at the Joint Research Centre (JRC), European Commission, Ispra, Italy, in the fields of digital and wireless communications, location, and navigation.

Fabio Dovis received the M.Sc. degree in electronics engineering and the Ph.D. degree in electronics and telecommunication engineering from Politecnico di Torino, Torino, Italy, in 1996 and 2000, respectively.

He is an Associate Professor at the Department of Electronics and Telecommunications, Politecnico di Torino. He contributed to the creation of the Navigation, Signal Analysis and Simulation (NavSAS) group. His research interests are focused on the design of architectures for GNSS receivers and on advanced signal processing algorithms for interference detection and multipath mitigation, considering for both current and modernized GNSS signals.

Heidi Kuusniemi received the M.Sc. and D.Sc. (Tech.) degrees in digital and computer engineering from Tampere University of Technology, Tampere, Finland, in 2002 and 2005, respectively.

She is the Director of the Department of Navigation and Positioning, Finnish Geospatial Research Institute (FGI), National Land Survey, Masala, Finland. She is also an Adjunct Professor at the Department of Real Estate, Planning and Geoinformatics, Aalto University, Helsinki, Finland and at the Department of Electronics and Communications Engineering, Tampere University of Technology. She is the President of the Nordic Institute of Navigation. Her research interests cover various aspects of GNSS and sensor fusion for seamless outdoor/indoor positioning, especially reliability monitoring.

Letizia Lo Presti received the M.Sc. degree in electronics engineering from Politecnico di Torino, Torino, Italy, in 1971.

She is a full Professor with the Information Engineering Faculty, Politecnico di Torino, Torino, Italy, working in the Electronics and Communication Department. Her research activities cover the field of digital signal processing, simulation of telecommunication systems, and the technology of navigation and positioning systems. Her teaching activity is mainly focused on signal processing (from the fundamentals to advanced concepts, such as statistical signal analysis, time-frequency distribution, and estimation theory), and algorithms for GPS and Galileo receivers. She is the scientific coordinator of the Master on Navigation and Related Applications held by Politecnico di Torino (since 2003).