

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

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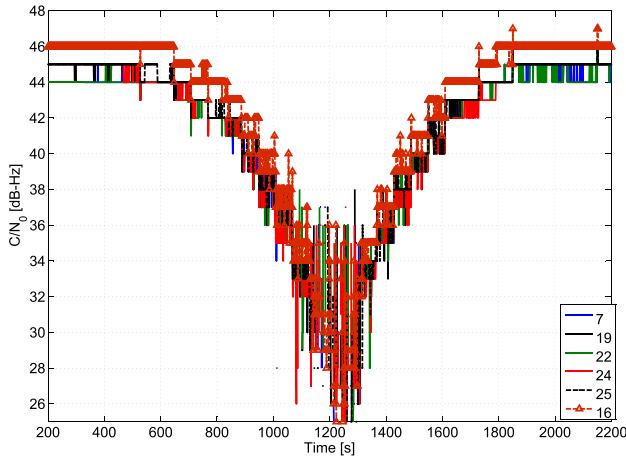


Fig. 11. C/N_0 values of the individual GPS C/A signals tracked during the experiment considered in Fig. 3. The C/N_0 values are affected in a similar way by the jamming signal.

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

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

where N is the number of time epochs considered and I is the number of satellites available. $h_{LP}[n]$ 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 i th 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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