

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

*Original*

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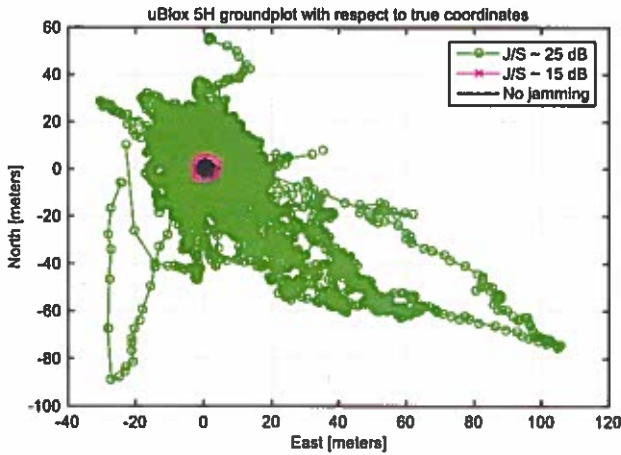
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**Fig. 8.** Positioning results around the true coordinates of a u-blox 5H receiver in a single-frequency jamming test.

of the impact of jamming on the navigation message decoding process is out of the scope of this paper.

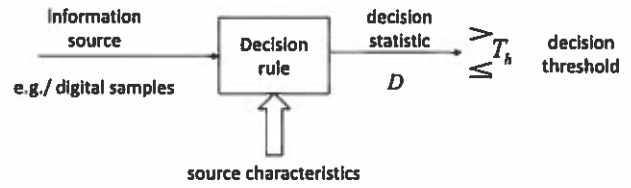
#### D. Impact on the Position

Provided that the interfered signal can still be processed by both acquisition and tracking stages, the GNSS receiver would be able to output an estimate of the position, which will be degraded by the fact that it will be based on interference-affected pseudoranges. The actual error in the position domain is strongly dependent on the positioning algorithm employed, and a general rule to quantify the performance degradation in terms of positioning error is hard to be found. Typically, the jamming signal deteriorates the position solution or induces total loss of lock of the GNSS signals depending on the perceived  $J/S$  at the receiver. For sake of example, Fig. 8 presents in more detail the positioning accuracy of a u-blox 5H receiver where two test cases are considered. In the first case,  $J/S = 25$  dB while for the second case  $J/S = 15$  dB. Interference-free conditions are also considered. When  $J/S = 25$  dB, a maximum horizontal error of 129.3 m was observed and the position solution was available only 16% of the time. The duration of the experiment was 24 h.

### IV. JAMMING DETECTION

Jamming detection is the process of revealing the presence of a jamming source. It is generally formulated as a binary hypothesis testing [29] problem where it is necessary to decide between

$$\begin{aligned} H_0 &: \text{absence of interference} \\ H_1 &: \text{presence of interference} \end{aligned} \quad (7)$$



**Fig. 9.** Classical detection process: A decision variable is formed using the data from an information source. The decision statistic  $D$  is formed according to a decision rule based on the source characteristics. The final decision is taken by comparing  $D$  with the decision threshold  $T_h$ .

where  $H_0$  and  $H_1$  are the null and alternative hypotheses, respectively. Problem definition (7) is general and needs to be specified with respect to

- the source of information adopted to formulate the problem;
- the characteristics of the source used to decide between  $H_0$  and  $H_1$ .

In order to illustrate this principle, consider the digital samples in (4). The detection problem in (7) can be formulated as

$$\begin{aligned} H_0 &: y[n] = s_{IF}[n] + w[n], & \text{for } n = 0, 1, \dots, N-1 \\ H_1 &: y[n] = s_{IF}[n] + vq[n] + w[n], & \text{for } n = 0, 1, \dots, N-1 \end{aligned} \quad (8)$$

where additional hypotheses on  $vq[n]$  could be made. In (8), a decision is taken using  $N$  digital samples. A general approach is to use such samples and construct a decision statistic  $D$ . A decision between  $H_0$  and  $H_1$  is then taken by comparing  $D$  with a decision threshold  $T_h$ , which can be set according to several criteria. This process is depicted in Fig. 9 where the decision variable is formed using the data from an information source. The decision statistic  $D$  is formed according to a decision rule based on the source characteristics. Such characteristics can be, for example, a statistical model describing the behavior of the digital samples in the absence and in the presence of jamming. Well-known approaches are available for the design of decision rules. In classical (or frequentist) statistics, the most popular approaches are the likelihood ratio test (LRT) and the generalized likelihood ratio test (GLRT) [29] which need a (partial) statistical characterization of the information source under both  $H_0$  and  $H_1$ .

Detection techniques are usually characterized in terms of receiver operating characteristic (ROCs) [29] that are the plot of the detection probability as a function of the false alarm rate. The detection probability is the probability that the detector correctly reveals the presence of jamming. Conversely, the false alarm rate