Interference detection and mitigation for fail safe GNSS positioning system

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Introduction

The availability of jammers poses a severe threat to the GNSS (Global Navigation Satellite System) user. These devices can disrupt the satellite signals that can lead to a complete denial of the positioning and timing services. It requires robust countermeasures for the detection, characterization, mitigation and in some cases localization the jamming signal to effectively counter the influence of the jammers that broadcast disruptive signals within the GNSS band.

The role of interference management solutions for satellite navigation system has becomes very important in safety-related road and railway applications to withstand the potential threat posed by easily accessible personal privacy devices.

Objective of study

- In the framework of the LOCSP project, to develop a reliant system that can effectively detect and mitigate the influence of jamming signals while maintaining an adequate performance level. This system will comprise a battery of algorithms that will be examined against a wide range of jamming signals at different power levels.
- As a first step, an Adaptive Notch Filter (ANF) is implemented to attenuate the non-stationary jamming signal and the influence of this interference mitigation technique is investigated on the subsequent stages of GNSS receiver chain.

Mathematical Model of Notch Filter

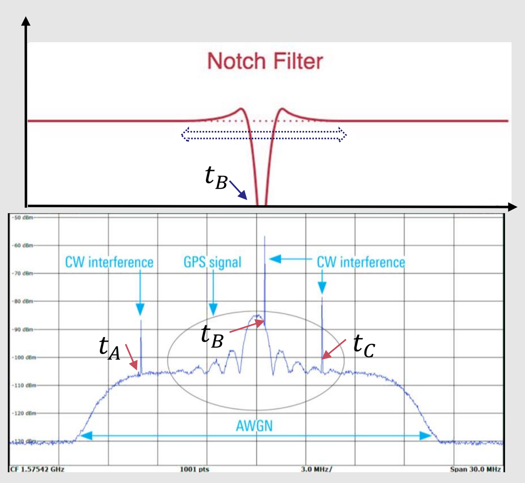
Filter transfer function $$H(z) = \frac{1 - z_0 z^{-1}}{1 - k_\alpha z_0 z^{-1}}$$

Notch filter blocks the frequency of the narrow band interference while leaving other frequencies nearly undisturbed

Notch Frequency $$z_0 = A_0 e^{j\,2\pi \frac{f_0}{f_S}}$$

Pole contraction factor $$0 < k_\alpha < 1$$

$k_\alpha \to 1$ **narrow** frequency notch but closer to **instability**



Adaptive control parameter: pole contraction factor k_α and adaptation step δ

Adaptive Notch Filter working

output of Auto Regressive (AR) part

$$y_{AR}[n] = x_i[n] - k_\alpha z_0[n] y_{AR}[n-1]$$

output of Moving Average (MA) part

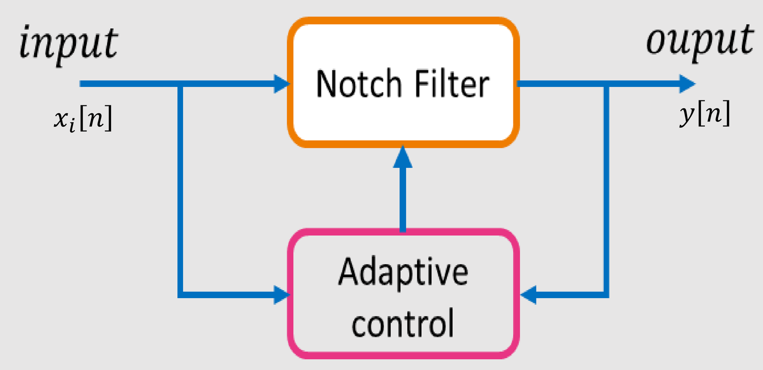
$$\tilde{y}[n] = y_{AR}[n] - z_0[n] y_{AR}[n-1]$$

$$z_0[n+1] = z_0[n] + \frac{\delta}{E_y} \tilde{y}[n] y^*_{AR}[n]$$

adaptation step

input signal energy

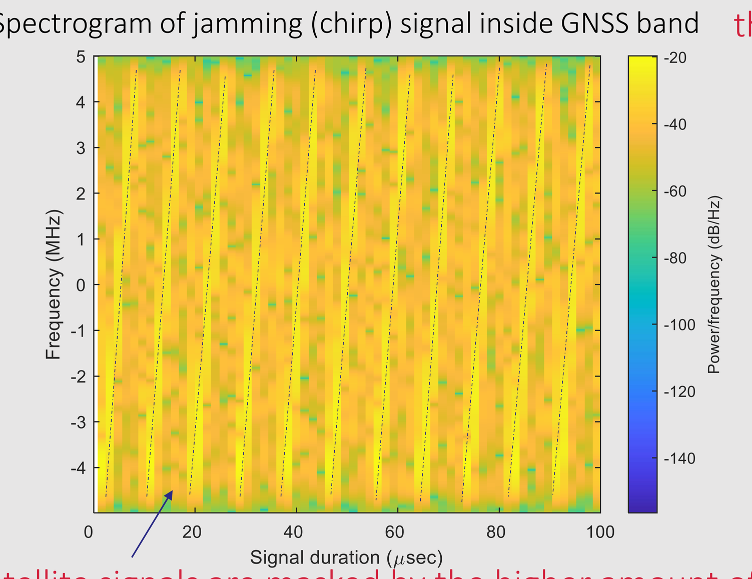
z_o is estimated for input sample by minimization of the energy of the output sample



Results and Analysis

Frequency estimation by Adaptive Notch Filter for chirp removal

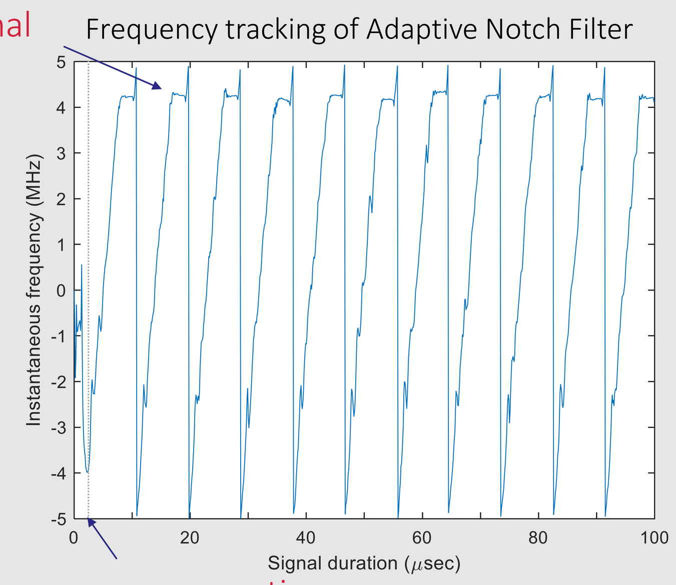
Spectrogram of jamming (chirp) signal inside GNSS band



satellite signals are masked by the higher amount of power of a non-stationary jamming signal.

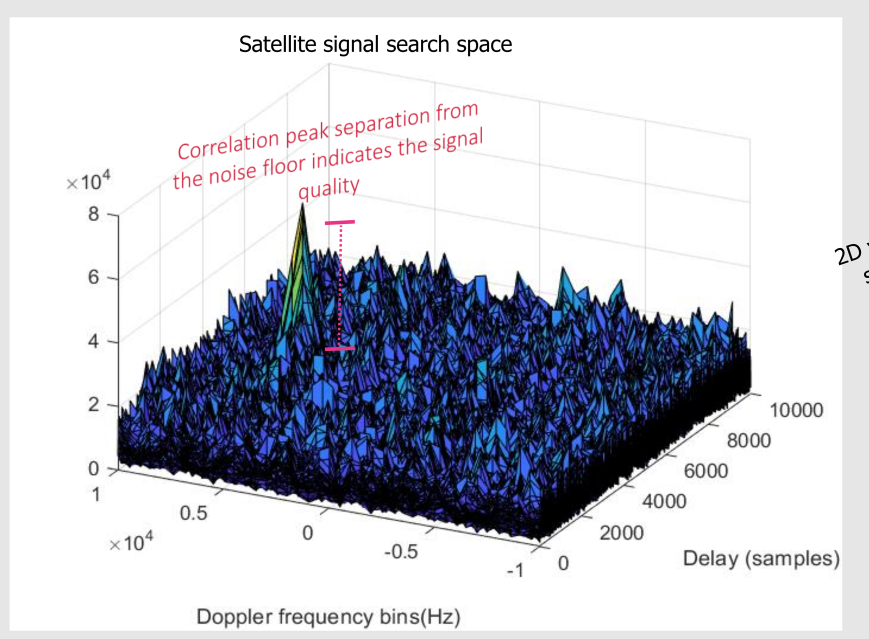
ANF tracking the frequency of the jamming signal

Frequency tracking of Adaptive Notch Filter

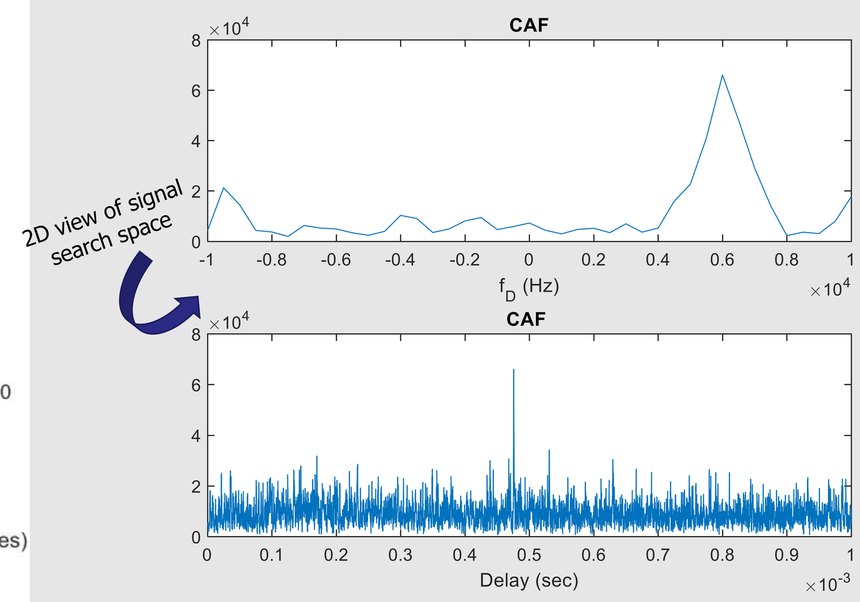


convergence time

Cross Ambiguity Function (CAF) after chirp removal for satellite 07



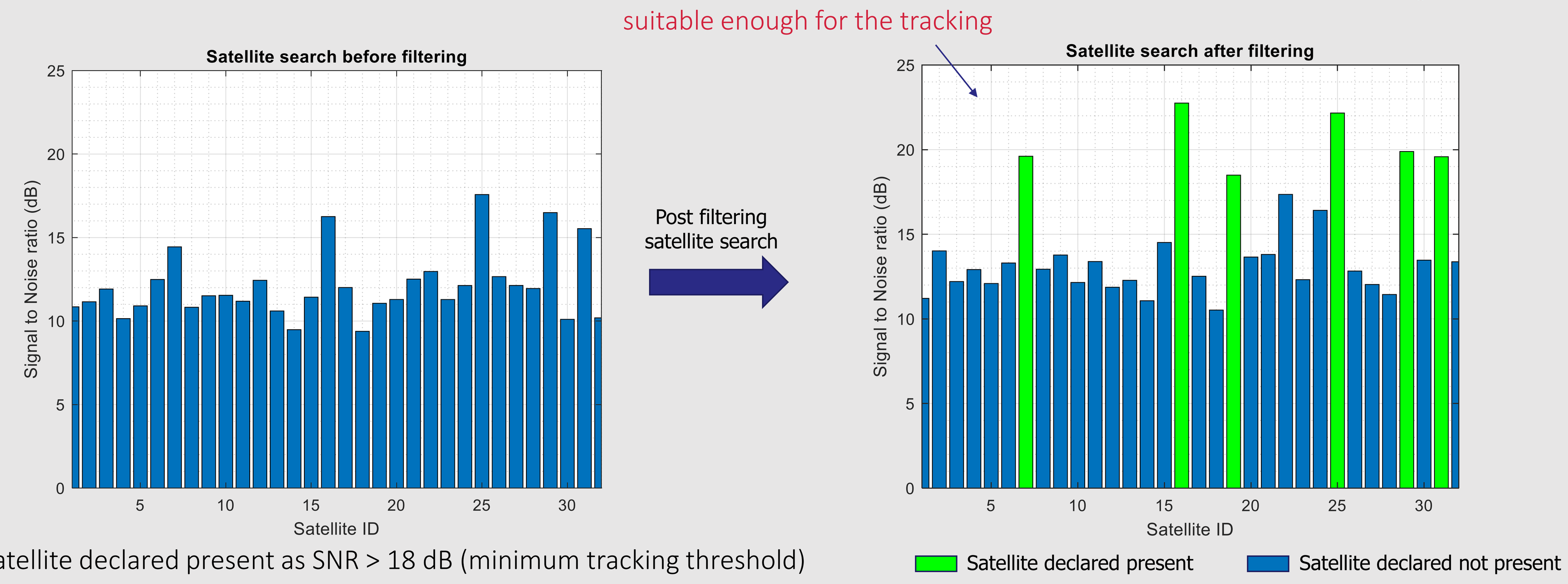
2D view of signal search space



Estimation parameter: **Doppler frequency** $f_D = 6$ **kHz** and **time delay** $t_D = 0,4$ ms

Satellite Acquisition

With the use of notch filter, 6 satellites (represented by green bars) crosses the minimum threshold that is set to consider satellite signal suitable enough for the tracking



Satellite declared present as SNR > 18 dB (minimum tracking threshold)

Conclusions

- Jamming detection and countermeasure techniques are much more effective as they are implemented in the initial stages of the receiver chain.
- Adaptive notch filtering is considerably the simplest technique to counter time varying jamming signal.
- The filter must be tuned properly to effectively track the interfering jamming signal otherwise an inappropriate parameter settings could induce distortions in the correlation process.
- A single mitigation solution can not be considered as sufficient to counter all kind of interfering signals.

Future Work

Short-term plan

- Investigation of other approaches at the pre-correlation level and in the precedent level of the receiver chain.
- Impact of the mitigation techniques (if any) at the next stages particularly at the position level.

Long-term plan

- Smart combination of different techniques will be proposed.
- Inclusion of information from different sensors to enhance the robustness of the system will also be assessed.

- Simulations and tests with real data

Bibliography

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