REVIEW ON DIFFERENT GNSS JAMMER MITIGATION TECHNIQUES

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Abstract: **Global Navigation Satellite System (GNSS) based navigation used to provide Position, Velocity and Timing (PVT) for real time applications. Sometimes, GNSS receivers receive a weak satellite radio signal cause by Jamming. Jammer is one type of radio frequency transmitters which is intentionally block, jam or disrupt the received signal.**

This paper summaries the techniques of jamming mitigation such as spatial domain, time domain, frequency domain and time-frequency domain. Spatial domain can filter both wideband and narrowband jamming but it constraints additional hardware. Time domain, frequency domain and time-frequency domain techniques are employed for CW interference. Time domain and frequency domain has several drawbacks. However, time-frequency domain techniques suitable for jamming mitigation and improve receiver performance.

Keywords: **GNSS, interferences, jammer, jamming mitigation,**

I. INTRODUCTION

GNSS based navigation system used for Safety-of-Life (SoL) applications, critical sectors like law enforcement, transportation, communication and finance and for the reliable estimation of user position, velocity, and time (PVT) [1]. Several GNSS applications such as tracking of goods and of animals, train and ship localization, sport applications need privacy issues. [2].

Received Global Navigation Satellite System (GNSS) signals are very weak and vulnerable to both intentional and non-intentional radio-frequency interference (RFI). Jamming signal is one type of intentional RFI generated by devices, called jammers. Jammers can disrupt GNSS-based services in wide geographical areas with radii of several kilometres so; their usage is illegal in most countries.[3].

GNSS receiver employs RF front end block and acquisition, tracking, navigation stage in Digital signal processor block. Jammer gives a serious impact on both blocks. In the presence of strong jamming signals several elements of the front-end (filters, amplifiers) may be led to work outside their regions and generating nonlinear effects. Dummy harmonics are generated and mixed to the useful signal in the front-end itself. [2]. Main goal of the Acquisition stage is to determine the signal presence and to provide a rough estimate of the signal code delay and Doppler frequency. Due to jamming signal acquisition stage cannot acquired the efficient no. of satellites. [4]. Tracking stage is used to provide good estimates of the signal parameters. A tracking stage is made of several components such as signal correlators, loop discriminators, and loop filters. Jamming gives an error between the estimated and actual signal parameter values. [4]. Navigation stage is able to give position, which will be degraded by the fact that it will be based on interference-affected pseudo ranges. [2].

It is important that the GNSS receiver fulfill a minimum level of reliability and robustness even at the cost of increased price and complexity. For improving receiver performance, have been developing GNSS receivers equipped with anti-jamming capabilities. [1]

There are several mitigation techniques such as spatial domain, time domain, frequency domain, and time-frequency domain techniques. Spatial domain techniques use N antenna element arrays which gives extra hardware load on receiver so it is computationally complex. [1] ,[5], [6]. In time domain techniques, Pulse blanking is one which is used. [1], [7], [8]. In frequency domain techniques, adaptive notch filter is used to cope with CW interference. [1].

Both time-domain and frequency-domain mitigation algorithms have some major limitations. Time-domain methods do not consider that only few frequency bins may be affected by the jammer at a given time. Same as for frequency-domain methods ignore the fact that only few time samples may be affected by the jammer for a given frequency. None of above techniques is used to removing jamming signal such as PPD jammer.[1].

The remainder of this paper is organized as follows. Section I is introduction and GNSS and system model in II.. Review of different interference Mitigation technique analysed in Section III. Finally, conclusions are provided in Section IV.

II. GNSS AND SYSTEM MODEL

GPS receiver described in two parts: First part is RF front end and second is Digital Signal Processing. RF front end consist LNA (low noise amplifier), AGC (Automatic Gain Control) and A/D converter and DSP processor is consists Acquisition, tracking and navigation block as shown in fig 1.

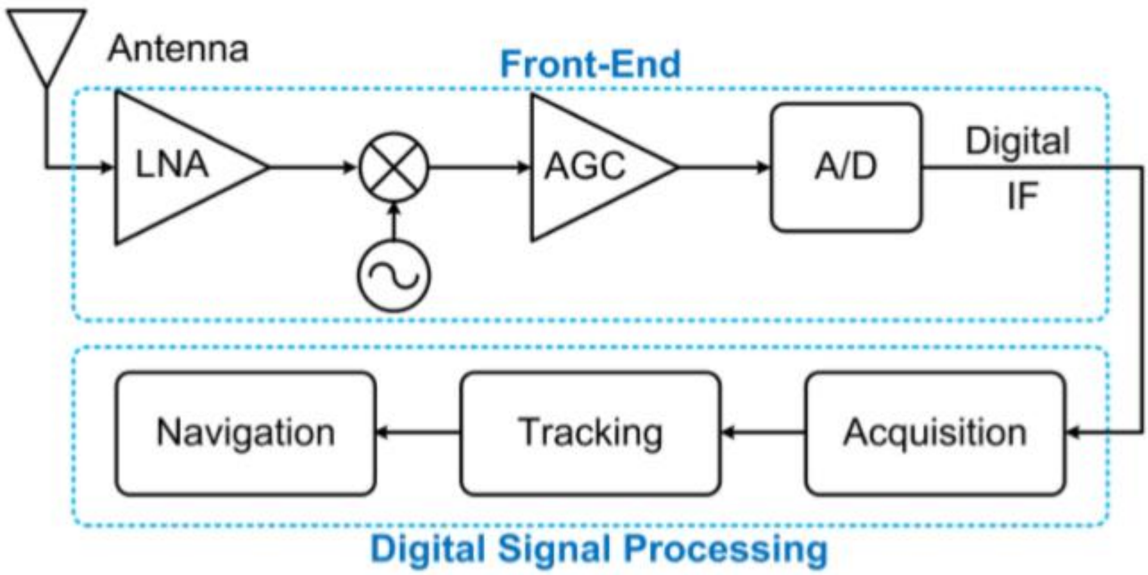

Fig 1: Block diagram of GPS receiver [5]

A simplified block diagram of the GPS receiver is shown in Fig. 1. It is illustrated in the figure that the received signal r(t) is composed of three parts: GPS signal s(t), noise n(t), and interference i(t) and Down-converted to the intermediate frequency (IF). Then, it is fed to an ADC and the output of the ADC (digital IF) is processed by acquisition, tracking, and navigation units, respectively. Digital version of the received signal can be modelled as: [5], [6], [10].

$$r(k) = s(k) + i(k) + n(k) \quad (1)$$

Where, the s (k) is the digital version of the GPS L1 signal introduced as:

$$S(k) = \sqrt{2P_S} D(k)\, CA(k) \cos(2\pi f_{IF} k + \theta) \quad (2)$$

Where P_S is power of the GPS IF signal, CA(k) is the coarse-acquisition (C/A) code with the chip rate of 1.023 MHz, D(k) is the binary data from GPS satellites with the rate of 50 Hz, f_{IF} is the IF center frequency, and θ is phase delay. In (1), n(k) is additive white Gaussian noise with variance σ^2 and i(k) is the digitized interference signal.

$$J^{\sim}(t)=\sqrt{2PJ}\cos(2\pi\ (f_J t+0.5\Delta\ ft^2)+\theta_J \quad (3)$$

Where P_J, f_J, Δf, and θ_J are the power, starting frequency (at time t =0), the sweep rate of the chirp signal, and the initial phase of the jamming, respectively. . [5], [6], [10].

III. DIFFERENT MITIGATION TECHNIQUES

Spatial domain techniques: Spatial filtering uses N element antenna arrays to point the receiver antenna beam towards the GNSS satellites and away from jammers. There are several algorithms such as SAP (Spatial Adaptive Processing), STAP (Spatial Time Adaptive Processing) and SFAP (Spatial Frequency Adaptive Processing) for jamming mitigation. These algorithms have some shortcomings. The no. of interfering signals narrowband or wideband source should be less than the number of antenna element; otherwise jamming signal not removed. It needs extra hardware so it is computationally complex [1], [5], [6].

Time domain techniques: Pulse blanking is one of the techniques which used in time domain for targeting the excision of pulsed interference. The basic principle of time domain method is to zeros out the signal whenever its amplitude exceeds a certain threshold. This technique is efficient when no. of interfering signal is limited, low duty cycle and sparse in time. [1], [7], [8]. Main drawback of this technique is due to removal of time windows of the useful signal in the presence of strong jammer interference. [9].

Frequency domain techniques: Mitigation algorithms used in the frequency domain is to very effective in countering the threat of narrowband interference, so called continuous wave (CW) interference. There are lots of publications on frequency domain mitigation algorithms. Most commonly used frequency domain technique is adaptive notch filter to cope with CW interference. The use of a notch filter based on Least Mean Square (LMS) algorithm guaranteed with CW interferer. [11]. An IIR filter is used against FIR because of IIR filter has low computation cost and has better statistical performance than the FIR filter. [12]. A multipole IIR filter has been designed by cascading a no. of two-pole notch filters, based on LMS algorithm. [12].The no. of two-pole notch filters required by the system can vary with time and matches the number of CW signals affecting the receiver. [1].

Jamming mitigation techniques			
Antenna based	Signal processing		
Spatial domain	Time domain	Frequency domain	Time-frequency domain
A. Array processing[1] B. Null steering[9] C. Beam forming[9] D. Direction of arrival(DoA)[9] E. Direction of Interference(DoI) [9]	Pulse blanking [1],[7],[8]	A. Adaptive filtering [11],[12] B. Frequency domain adaptive filtering[1]	A. STFT(Short time fourier transform) [1],[16] B. WD(Wigner distribution) [14] C. WT(Wavelet theory)[17]

Table 1: Different jamming mitigation techniques

Time-frequency domain techniques: Time- Frequency domain technique is very effective to improving the receiver performance when a broadband interference with narrowband instantaneous interference affects the system. Instantaneous frequency of interference is estimated by using TFD (Time Frequency distribution) and represents the single and multitone component signals in time and frequency [1].[15]. Some of the technique is better for single component frequency needs to be estimated, but they are failing in multiple component interference scenarios. Wigner distribution (WD) allows high resolution in TF plane and WD introduces unwanted cross-terms when multiple signal sources are present [14]. A short-time Fourier transform (STFT) was used, Since STFT suffers from the trade-off between time and frequency resolution. Interference excision was performed by either clipping or masking for the optimum STFT.[1][16] The masked STFT is synthesized using the orthogonal-like Gabor expansion and the resulting signal, namely the estimation of the interference, was subtracted from the original signal to obtain the interference-free signal.

For broadband jamming, wavelet transforms (WT) method is very effective in time frequency domain methods for system robustness and improve the receiver performance. Interference excision is performed in the wavelet transform domain. [17]. The idea is to choose a mother waveform, for which the interference representation in the wavelet transform domain is confined in a small region. Wavelet-based mitigation algorithm was used to mitigate both high-power and lowpower pulsed interference, in particular DME. [1]

IV. CONCLUSION

This paper provides an overview of various techniques used to protect GNSS receivers from jamming and interference. The techniques are categorized as: 1) spatial domain 2) time domain 3) frequency domain 4) time-frequency domain. Spatial domain techniques mitigate both narrowband and wideband jamming signals but it is computationally complex. Time-frequency domain techniques are beneficial and effective for GNSS antijamming system. These algorithms can also be integrated and applied together for greater robustness and protection against jamming.

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