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Pulsed Interference Mitigation for a NavIC Reference Receiver

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Abstract

Navigation with Indian Constellation (NavIC), also known as Indian Regional Navigation Satellite System (IRNSS), is the Indian regional satellite navigation system. NavIC relies on a vast network of one-way ranging reference stations for its precise orbit determination and time synchronisation (OD&TS) functions. These reference stations are equipped with reference receivers which act as measurement engines and provide the raw code and carrier phase measurements to the OD&TS process.

NavIC provides navigation services in two Radio Frequency (RF) bands, namely L5 and S. L5 band, centred at 1176.45 MHz is susceptible to pulsed interference from Distance Measuring Equipment used for civil aviation. ISTRAC is currently undertaking the development of an indigenous tri band reference receiver for the one way ranging stations of the NavIC ground segment. An asynchronous Pulse Blanker has been implemented for the in-house NavIC Tri-band Reference receiver for the detection and mitigation of the pulsed interference in L5. Furthermore, implementation of digital pulse blanking has been designed to be independent of the RF band and thus can provide benefits to NavIC receivers operating at frequencies other than L5, i.e. S with its known dense interference environment.

1 Introduction to NavIC

Navigation with Indian Constellation (NavIC) is a regional navigation satellite constellation consisting of seven satellites placed in geostationary and geosynchronous orbits (GSO) such that they provide navigation services over the Indian landmass and in the region extending to 1500 kilometer beyond the Indian geopolitical boundary. This system has been realized by the Indian Space Research Organization (ISRO) and has been operational since 2018 [1].

The NavIC satellites provide the navigation signals in two frequency bands namely the L5 (centered at 1176.45 MHz) and S band (centered at 2492.028 MHz). Figure 2 shows the frequency spectrums used in NavIC [2].

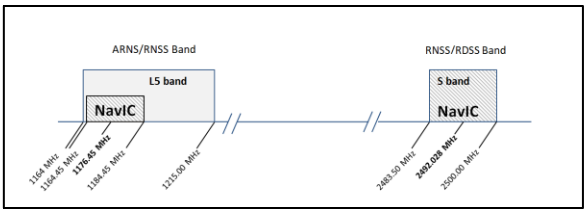

Figure 1: Spectrum of NavIC in L and S bands

2 NavIC Ground Segment

The NavIC ground segment consists of a network of IRNSS Range and Integrity Monitoring Stations (IRIMS) and a network of IRNSS CDMA Ranging stations (IRCDR). While the IRIMS perform one way ranging to the NavIC constellation, the IRCDR stations perform two-way CDMA ranging to the NavIC constellation. Laser ranging of the NavIC constellation is carried out on a best effort basis by the International Laser Ranging Service (ILRS). At the heart of the NavIC ground segment is the ISRO Navigation Centre (INC) which houses the IRNSS Network Timing facility (IRNWT) and also performs the Orbit Determination and Time synchronization (ODTS) of the NavIC constellation. Mode-1 IRIMS are the reference stations which are co-located with IRNWT(s) and receive direct frequency and timing inputs from the timing facility. All other reference stations work in Mode-2 and the reference receivers derive the system time using the broadcast parameters [1].

2.1 IRNSS Range and Integrity Monitoring Station

IRNSS Range and Integrity Monitoring Stations (IRIMS) consists of a wide network of stations (India and abroad) which have been established at accurately known locations for facilitating one-way ranging. These IRIMS continually track navigation signals of the NavIC constellation and transmit data containing pseudo-range and carrier phase information to the Navigation control centres where these measurements are used for performing Orbit Determination and Time synchronization (OD&TS) of NavIC constellation. The data from the one way ranging stations is also used for ionospheric modelling.

2.2 NavIC Reference Receiver

A reference receiver is the core component of the one way ranging station. It is a measurement engine dedicated for the continuous one-way ranging and monitoring of the NavIC-SPS signals. A reference receiver is different from a user receiver in the sense that a reference receiver is deployed at a surveyed and precise location and hence, does not solve for position, unlike a user receiver [3].
The following are the major outputs of a Reference receiver:

- Code phase measurement/Pseudorange measurement (m)
- Carrier phase measurements/Accumulated Doppler range (cycles)
- Receiver clock offset
- Receiver Autonomous Integrity Monitoring outputs
- Correlator outputs for Signal Quality Monitoring
- Raw Navigation data (as received by the receiver)

3 Pulsed Interference in L5 band of NavIC

L5 band of NavIC, centred at 1176. 45 MHz, coexists with systems operating in the same 960 – 1215 MHz Aeronautical Radionavigation Services (ARNS) frequency band. This band is shared by the Distance Measuring Equipment (DME) /Tactical Air Navigation (TACAN) systems used in civil and military aviation, respectively.
In November 1999, the Interagency GPS Executive Board (IGEB) endorsed the following set of recommendations for the coexistence of L5 receivers with that of ARNS systems [4]:

1. Incorporate amplifiers capable of handling higher power levels and recovering from saturation more quickly.
2. Provide greater selective filtering at the front end of the receiver to minimize the effects of any nearby pulsed interferers.
3. Implement blanking, i.e., zero the received signal prior to subsequent processing when its amplitude exceeds a threshold indicating the presence of pulsed interference.

Blanking of the received signal can be carried out either by analog or digital techniques. For the in-house developed tri band NavIC Reference Receiver, a digital technique namely the Asynchronous Pulse Blanker has been implemented.

4 Simulation of DME Pulses

DME baseband signal is a pulse pair which can be modelled as:

$$s(t) = e^{-\alpha/2(t-\Delta t/2)^2} + e^{-\alpha/2(t+\Delta t/2)^2} \qquad (1)$$

where, $\alpha = 4.5 \times 10^{11} s^{-2}$ determines the width of the pulse pair and $\Delta t = 12 \times 10^{-6}$s determines the interval. The half-amplitude width of each single pulse is 3.5 µs, and the interval between two single pulses is 12 µs.
Figure 2 shows the simulated DME pulse pair. Figure 3 shows the synthesised DME signal on an FPGA.

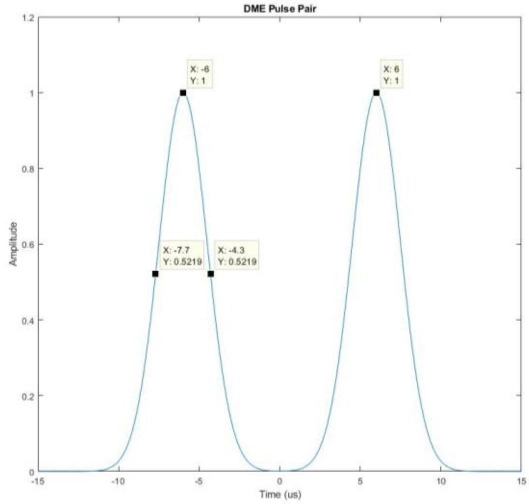

Figure 2: DME Pulse Pair simulated in MATLAB

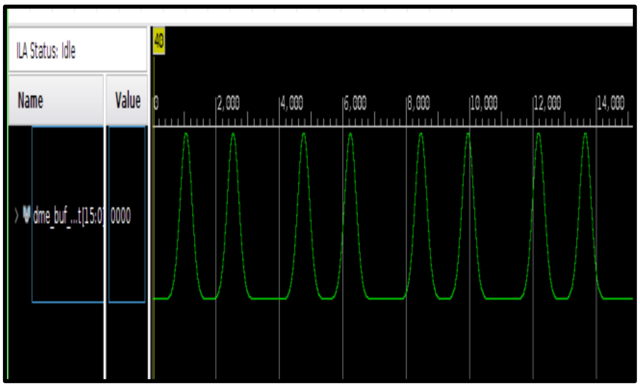

Figure 3: DME Pulse Pair synthesized on FPGA

5 Concept of Asynchronous Pulse Blanker

Digital pulse blanking (DPB) was implemented using the concept of Asynchronous Pulse Blanker (APB) concept first explained in [5]. This architecture of the blanker is termed as asynchronous as it does not assume any periodic properties of the interfering pulses. This blanker carries out zeroing on a sample-by-sample basis. Individual samples are compared against a user specified threshold and are zeroed or blanked if the threshold is exceeded. This approach has several advantages; it is much simpler to implement, it does not require a pulse detector circuit to identify the beginning and end of an individual pulse and it does not require memory to also track samples that are part of a pulse [3, 4]. Figure 4 shows the top level block diagram of the APB.

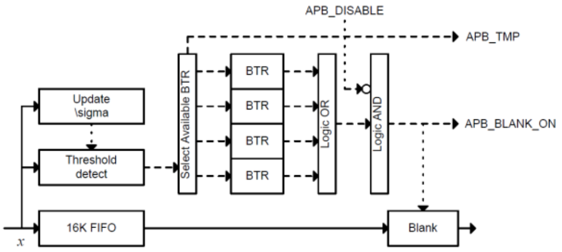

Figure 4: Top level block diagram of APB module

The APB consists of a fixed length buffer followed by a blanker. The squared magnitude of the sample x, currently entering the buffer is compared to a threshold δ. If threshold is exceeded, a configurable number of samples preceding and following the detected sample are set to zero. This is accomplished using a set of timing registers. Once triggered, timing register waits for a pre-determined number of samples and then blanking is requested [5].

5.1 Algorithm for Pulse detection

The following algorithm has been implemented for the detection of pulsed interference:

1. $m = (1 - \mu_{mean})\|x^2\| + \mu_{mean} m$
2. $TEMP = (1 - \mu_{var})(\|x^2\| - m^2) + \mu_{var}\sigma^2$
3. $If\ (\|x^2\| - m)^2 < \beta^2 TEMP$

   $\sigma^2 = TEMP$

   Else Pulse is detected.

Where,

$m = Mean\ of\ incoming\ signal$

$\sigma^2 = Variance\ of\ incoming\ signal$

$\mu_{mean} = Smoothing\ coefficient\ for\ mean$

$\mu_{var} = Smoothing\ coefficient\ for\ variance$

$x = Incoming\ signal$

$\beta = Blanking\ threshold\ coefficient$

6 Effect of smoothing coefficient on the convergence of mean and variance

A simulation was carried out to determine the effect of different values of smoothing coefficients on the convergence of mean and variance, respectively. Figure 5 and 6 shows the simulation results.

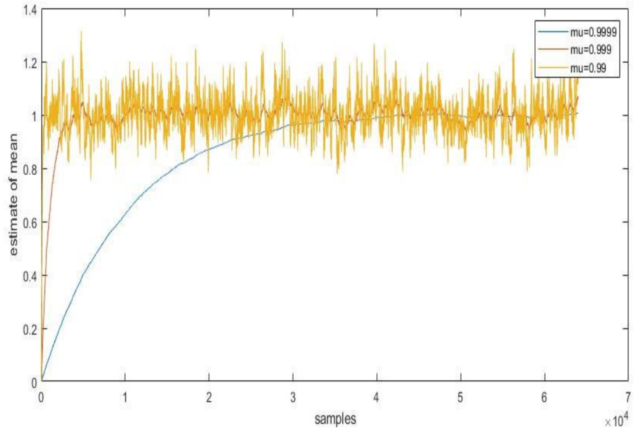

Figure 5: Convergence of mean of incoming signal with varying values of μ_{mean}

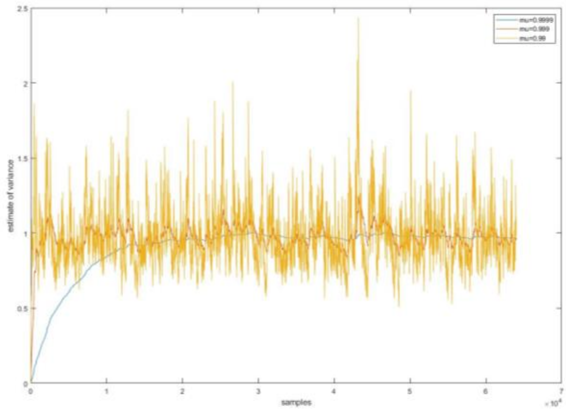

Figure 6: Convergence of Variance of incoming signal with varying values of μ_{var}

It can be observed that μ=0.99 provides faster convergence at the cost of higher settling time, whereas μ=0.9999 provides a slow convergence but with faster settling time. In our implementation, μ=0.9999 has been chosen for both mean and variance.

7 Results of APB module

To simulate the interference signal, random Gaussian noise was generated and mixed with DME pulses. This signal was then input to the APB module. The APB module generates a blanking control signal on the detection of a pulse and blanks the incoming signal for a configurable time period. Figure 6 and 7 show the output of the APB module with different threshold values, respectively. While a low threshold blanks in an aggressive manner, a high threshold (β>8) is likely to miss on some of the pulsed interference. Hence, the value of β=7 was found to be optimal during simulations.

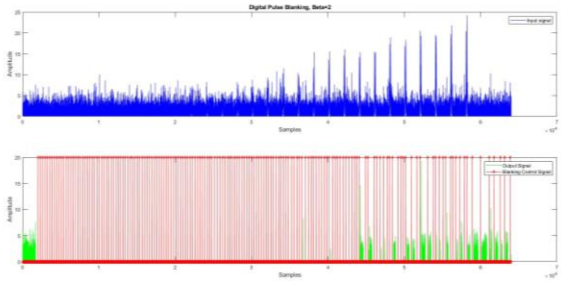

Figure 6: Output of APB with β=2

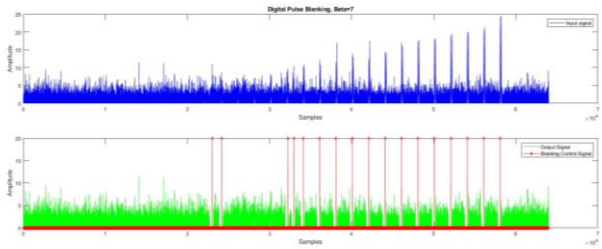

Figure 7: Output of APB with β=7

6 References

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