A Single Acquisition Channel Receiver for GPS L1CA and L2C Signals Based on Orthogonal Signal Processing

Maher Al-Aboodi[1], Ihsan A. Lami[1], Ali Albu-rghaif[1], Patrick Van Torre[2], Hendrik Rogier[2]

[1] Department of Applied Computing, The University of Buckingham, UK
[2] Department of Information Technology (INTEC), Ghent University, Belgium

UNIQUNESS OF THIS TECHNIQUE:

1. The complexity of our implementation is almost half of other methods. This is achieved by orthogonalising the received two GPS signals so to process them in a single channel, while the other methods combine the acquisition result of the two signals, by having side-by-side acquisition channels.
2. Enhance the acquisition sensitivity by 3dB, this achieved by estimating both L1CA and L2CM code delay and Doppler frequency at the same time, while keeping the frequency bins size as small as possible by using only 1 ms coherent acquisition.

ABSTRACT

In GPS modernization, the availability and the acquisition of GPS L1CA signal is improved by the L2C signal, which is transmitted from the same SVs. It is desirable, especially in commercial GNSS receivers, to have both of these signals acquired in a single receiver so as to assure better signal acquisition and improved reliability at wider operating areas as well as saving processing resources. To achieve this, we propose to integrate the GPS L1CA and L2CM signals orthogonally and acquire them in a single processing channel. After removing the Doppler frequency, our receiver adds the in-phase component of the L2CM signal together with the in-phase component of the L1CA signal, which is then shifted by 90^o before adding it to the remaining components of these two signals, resulting in an orthogonal form of the combined signals. The FFT of this orthogonal signal is then mixed with the complex conjugate of the FFT of a locally generated replica of the CA code combined with a 90^o shifted replica of the CM code. The output is then converted back to the time domain to acquire the signal's peak. The complexity of this implementation is half of that used in dual acquisition methods. Furthermore, MATLAB Simulation results show that our acquisition method compares favourably with other approaches in terms of detection of low sensitivity signals and false alarm probability; where we used an RF Signalion HaLo-430 to generate real-

world signals in order to show the effect of potential problems such as RF-impairments, channel estimation errors, fading, shadowing, scattering, etc.

IMPLEMENTATION

The L1CA and L2C signals are transmitted from the same Satellite Vehicle (SV) so that most of the received signal errors are related. Consequently, there are three important facts: (a) The transition bits occurs at the same time on both signals, (b) there is a correlation between the Doppler frequency on L1 and L2 by the ratio L2/L1 (0.7792), and (c) both codes, L1CA and L2CM, have the same code phase delay with respect to their code length. These facts give us an opportunity to combine the two signals in acquisition stage in a single channel.

The two L1CA and L2C signals are sampled at the same rate 4.092MHz (both signals have the same fold/IF frequency = 0Hz) based on using a bandpass sampling/direct conversion frontend. This will prevent re-sampling the signals again in order to make the length of the two signals the same, which can affect the combined signal. Since, each signal has a different power level, it is therefore necessary to scale their power level individually in the receiver to optimally acquire these signals as a combined signal. Note that the received power of the L2CM signal (the CL code is zeroed) is lower than L1CA signal by 4.5dB. The procedure for acquiring the combined signals in a single channel is achieved by the following steps:

1. To remove the Doppler frequency, the incoming L1CA/L2CM signals are multiplied by a local generated carrier wave at fixed Doppler frequency $F_d/0.779*F_d$ that will generate in-phase component $I_{L1}/I_{L2}$and quadrature component Q_{L1}/Q_{L2}.
2. Orthogonalise the signals components to the output combination is $(I_{L1} - I_{L2})+j*(Q_{L1} - Q_{L2})$.
3. FFT of the output combination is calculated.
4. The local replica of CA and CM codes are generated and then are gathered in orthogonal form CA +j*CM.
5. The complex conjugate of the FFT of the composite code is computed.
6. Multiply the output of step 4 and step 6 and then IFFT is applied to the output.
7. The real part and the imaginary part of the IFFT are squared separately and the results are gathered, the result is called a decision vector.
8. The process will then look for a maximum peak of the decision vector.
9. Exclude a number of samples of the main lobe width, which are around the maximum peak in the decision vector.

10. Now, look for the second maximum peak from the remaining part of the decision vector.

11. If the ratio of the first and the second maximum peaks is greater than a threshold, then the signal is acquired; else the whole procedure is repeated for all Doppler frequency range (from -10KHz to +10KHz).

EXPERIEMENTS AND CONCLUSIONS

The simulation parameters settings that are used to evaluate the proposed method in term of probability of detection and ROC curves are: Carrier to Noise ratio density (CNo) values are from 22 to 50dB-Hz and 17.5 to 45.5dB-Hz (for ROC 32dB-Hz and 72.5dB-Hz) for L1CA and L2CM respectively, the coherent integration time is 1ms, the probability of false alarm is 0.001 and the Monte Carlo simulation technique run 10,000 times.

The results of detection probability prove that there is a 3dB and around 1dB improvement in our implementation as compared to the best FFT-based combined method, in weak signal scenario, where the CNo is between 27 and 30 dB-Hz. This improvement is achieved because we combine the signals first and then processes the combined signal in the acquisition channel while the other methods combine the acquisition result of the two signals. This will increase the processing gain of the combined signals; however the noise will also increase slightly. Also, the detection probability of our implementation offers a constant improvement around 2.5 dB and 0.5 dB compared with others when the threshold is 2 and for CNo greater than 30 dB-Hz.

Finally our implementation analysis proves that we not only save the receiver resources but also improve the ratio of the detection probability in respect to the false alarm probability.