CODE TRACKING FOR GPS SIGNAL PROCESSING

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Abstract

This paper presents the code tracking method for software defined GPS receiver. A number of methods have been developed to enhance the robustness of Global Positioning System (GPS) receivers when there are a limited number of visible satellites. In this work, code tracking method is developed to improve the accuracy of positions of GPS receiver. The GPS signal consists of the navigation data, the carrier and code sequences for each of the satellite. The signal of each satellite is demodulated using Delay Lock Loop (DLL) for code tracking. The code tracking output errors feedback to Numerically Control Oscillator (NCO) frequency for exact signal lock between GPS signal and NCO signal. In position calculation, each channel of code is controlled by individual loop filter. The code tracking method for software defined GPS receiver is implemented by using MATLAB.

Keywords: *GPS software receiver, code tracking method, Delay Lock Loop, MATLAB,* Numerically Control Oscillator

Introduction

Satellite based navigation systems provide real time position, velocity and timing information of receiver. The most commonly used navigation system in today's world is Global Positioning System (GPS). The GPS system is a code division multiple access (CDMA) digital communication link. CDMA is a spread spectrum multiple access technique. Each satellite's signal consists of a sinusoidal carrier, a digital navigation message, and a unique wide bandwidth pseudo random noise (PRN) sequence. The navigation data from the satellites comprises of the orbital information of the satellite and precise timings.

Theoretical Background

2.1 Coarse Acquisition (C/A) Code Sequence

Each satellite has two unique codes spreading sequences. The first one is the coarse acquisition code (C/A), and the other one is the encrypted precision code (P(Y)). The C/A codes have a very wide bandwidth and are used to spread the spectrum of the data message over a wider bandwidth. The C/A codes are transmitted at a chipping rate of 1.023 Mbps. The code phase is the point in the current data block where the C/A code begins. If a data block of 1 ms is examined, the data include an entire C/A code and one beginning of a C/A code.

2.2 Coarse Acquisition (C/A) Code Tracking

To obtain a perfectly aligned replica of the code, code tracking loop is implemented. The goal of the code tracking loop is to keep track of the code phase of a specific code in the signal. The code tracking loop in the GPS receiver is a delay lock loop (DLL) called an early-late tracking loop. DLL block diagram with six correlators is shown in Figure (2). After multiplying the incoming signal with a perfectly aligned local replica of the carrier wave, the signal is multiplied with three code replicas, namely early, prompt and late, with a spacing of ½ chips. After the second multiplication, the three outputs are integrated and dumped. The output of these integrations is numerical value indicating how much the specific code replica correlates with the incoming signal. A perfectly tuned code loop with highest correlation at prompt output is shown in figure (1). The

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prompt replica of the code has a phase shift obtained from the acquisition. The early and late have additional shift of -½ and +½ chip from the prompt.

The common DLL discriminators are:

Coherent: $I_E - I_L$: Requires a good tracking loop for optimal functionality.

Noncoherent:

$(I_E^2 + Q_E^2) - (I_L^2 + Q_L^2)$: Early minus Late power, response is nearly the same as the coherent discriminator.

$\frac{(I_E^2 + Q_E^2) - (I_L^2 + Q_L^2)}{(I_E^2 + Q_E^2) + (I_L^2 + Q_L^2)}$: Normalized Early minus Late power, helps keep track in noisy signals when the chip error is larger than ½ chips.

$I_P(I_E - I_L) + Q_P(Q_E - Q_L)$: Dot product, it is the only DLL discriminator that uses all six correlators.

The implemented tracking loop discriminator is the Normalized Early Minus Late power discriminator. This discriminator is described as

$$D = \frac{(I_E^2 + Q_E^2) - (I_L^2 + Q_L^2)}{(I_E^2 + Q_E^2) + (I_L^2 + Q_L^2)}$$

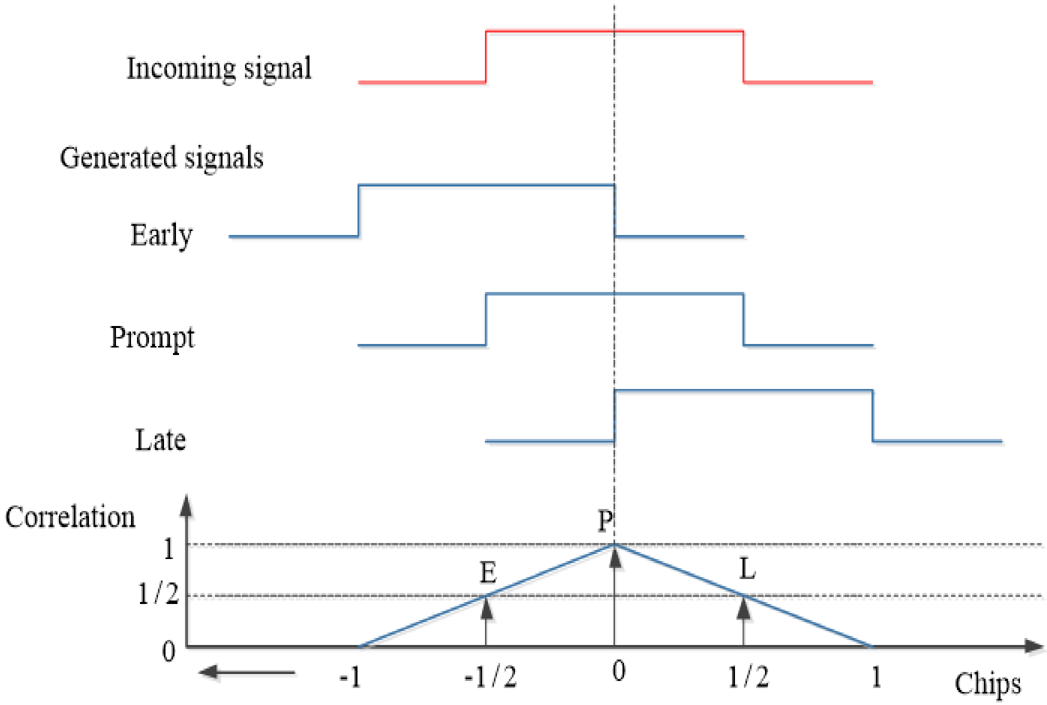

Figure 1 A perfectly tuned code loop with highest correlation at prompt output

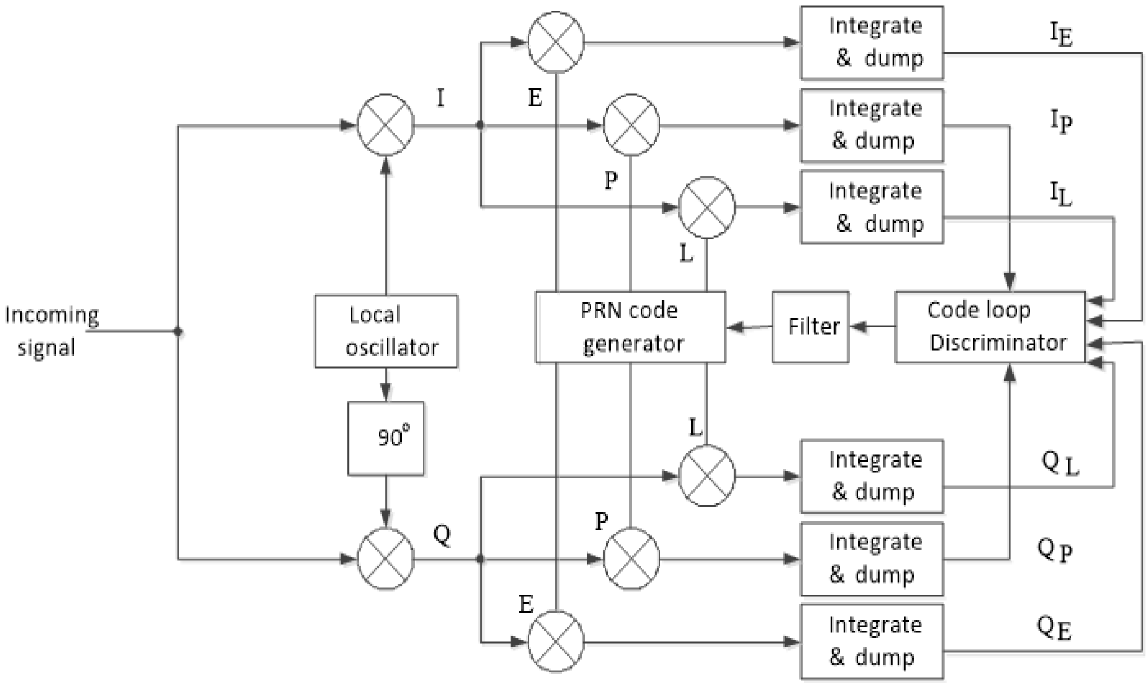

Figure 2 Delay Lock Loop (DLL) block diagram with six correlators

Experiment

3.1 Experiment apparatus

In this experiment, the GPS signal is captured by SiGe SE4110L front-end receiver and the sampling parameters are

- frequency of the received signal is about 1575.42 MHz
- intermediate frequency (IF) 1.364MHz and
- sampling frequency is 5.456MHz.

3.2 Received satellites positions skyplot

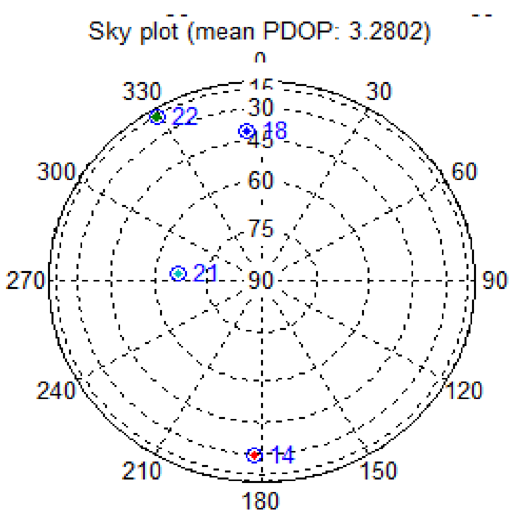

Figure 3 Mean position dilution of precision

The position dilution of precision plot shows satellites coverage on the receiver position with respective latitude and longitude coordinates. In Figure-3, the four satellites are scattered with the different elevation angles.

Result and Discussions

The I-prompt and Q-prompt arms of GPS signals are compared for each satellite (PRN) that all the power is in the in-phase of signal. Each of the scatter points has the phase angle from the discriminator output on the discrete time scatter plot. From discrimination data, the satellite number (PRNs) 14 and 18 have weak signal as shown in figures 4(a), (b) and figures 5(a), (b). The discrete time scatter points are scattered and continuous in both sides of Q prompt and I prompt for weak signal.

The satellite number (PRNs) 21 and 22 have strong signal as shown in figures 6(a), (b) and figures 7(a), (b). For the strength signal the power has in the I-prompt arm and Q-prompt arm has near zero in correlation. The discrete time scatter points are collected and separated in both sides of Q prompt and I prompt for strong signal. From the discrimination data of GPS signal, the satellite PRNs 21 and 22 have strong signals than PRNs 14 and 18.

The scattered positions variation from mean position is shown in figure (8). This discrimination data depends on the position of GPS receiver and the strong signal provide the exact position of the GPS receiver.

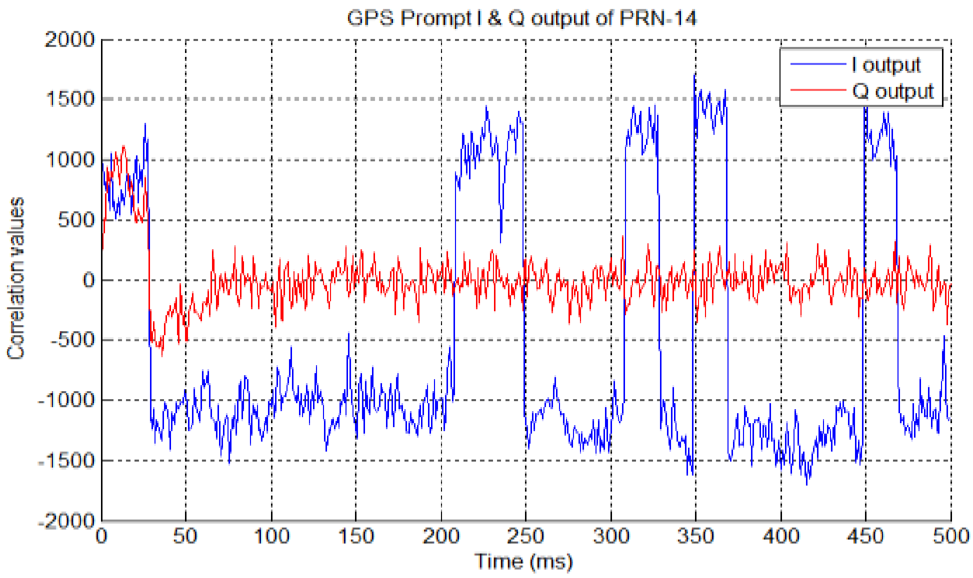

Figure 4(a) Output of prompt arms for C/A code-14

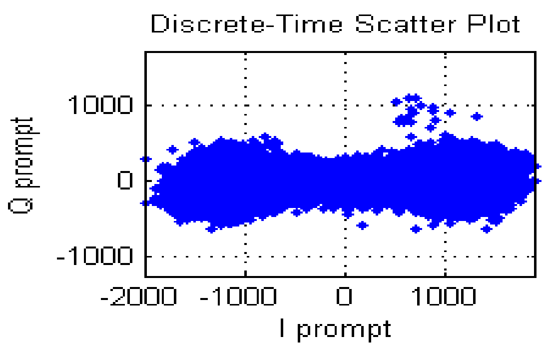

Figure 4 (b) Discrete time scatter plot for PRN -14

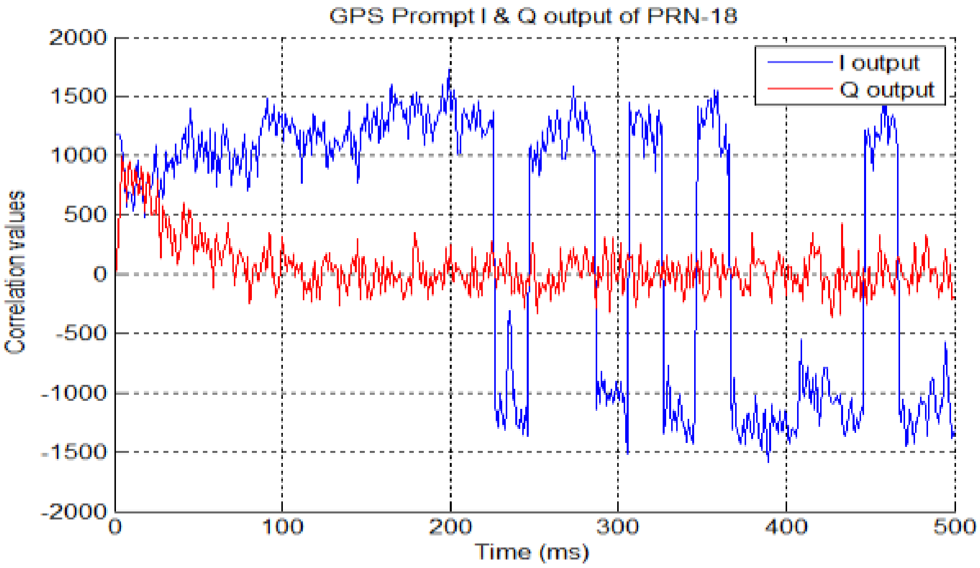

Figure 5 (a) Output of prompt arms for C/A code-18

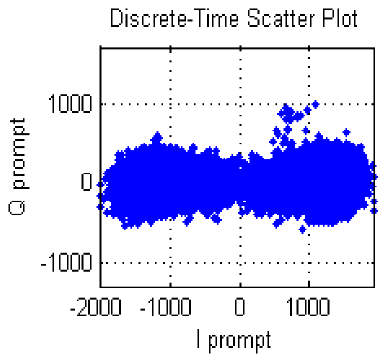

Figure 5 (b) Discrete time scatter plot for PRN -18

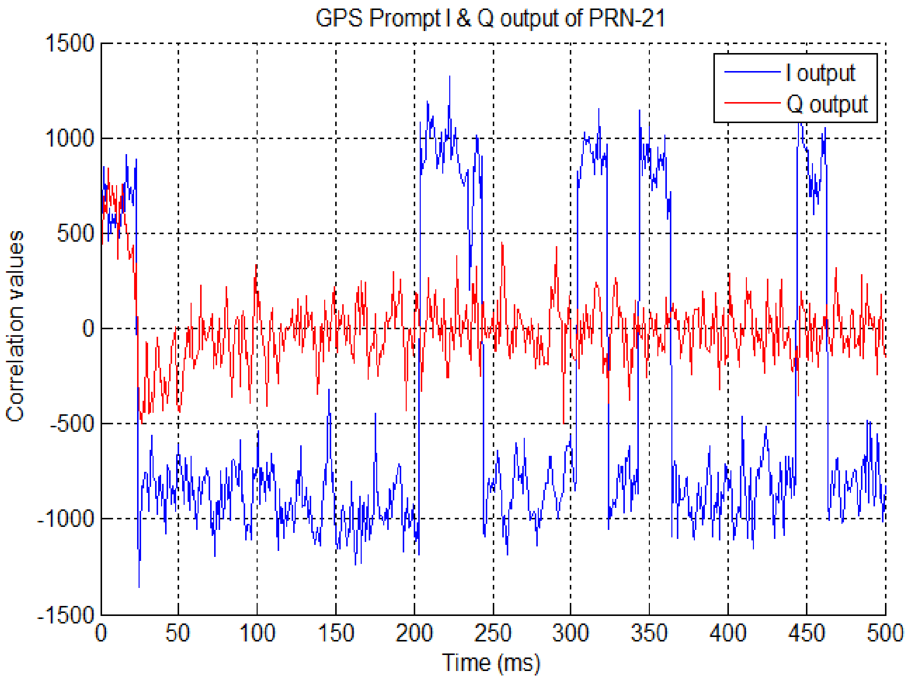

Figure 6 (a) Output of prompt arms for C/A code-21

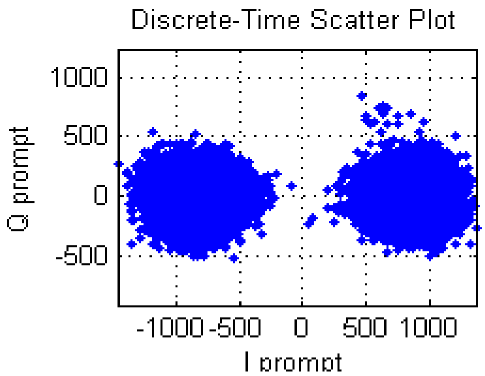

Figure 6 (b) Discrete time scatter plot for PRN -21

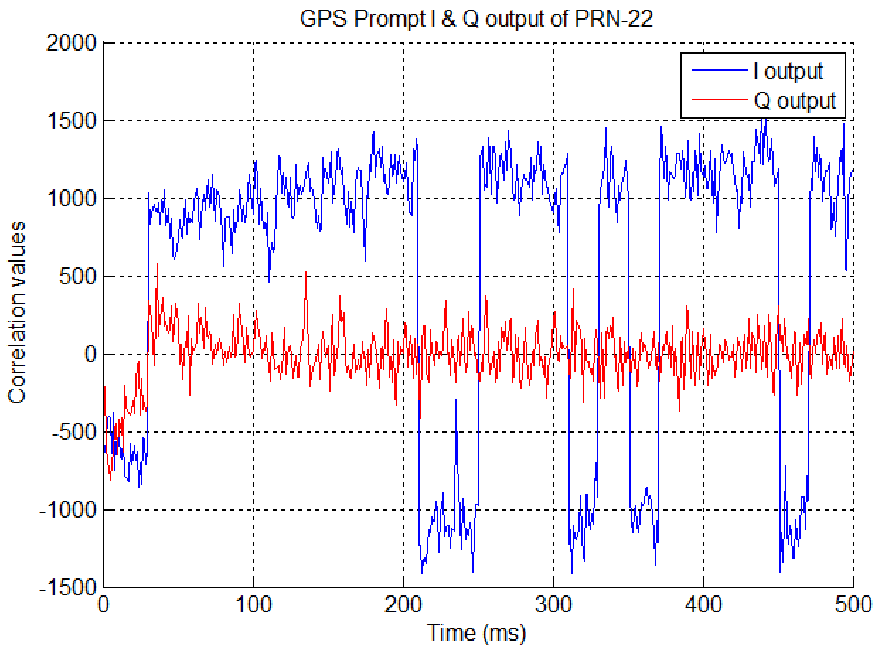

Figure 7 (a) Output of prompt arms for C/A code-22

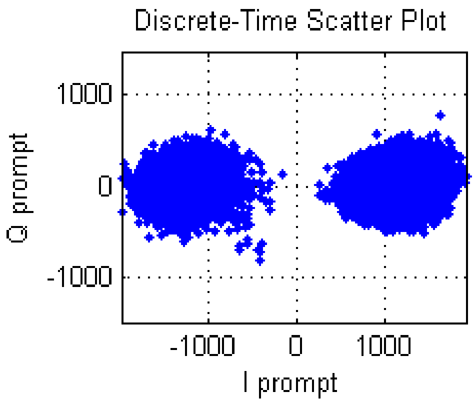

Figure 7 (b) Discrete time scatter plot for PRN -22

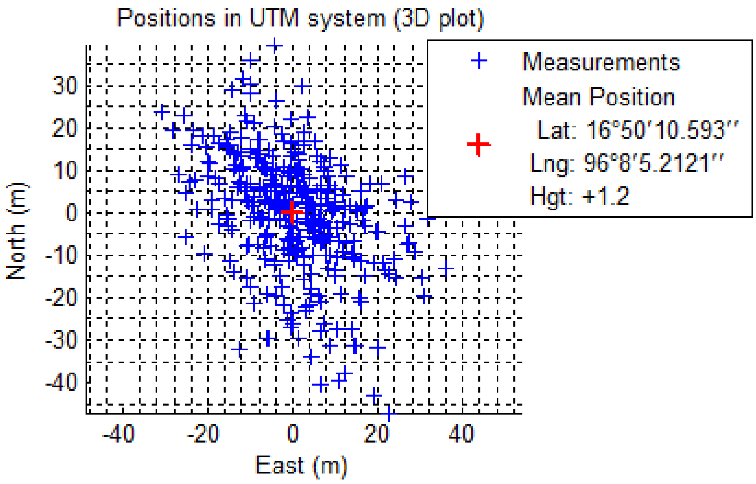

Figure 8 The scattered positions variation from mean position

The measurement points show the track of positions of the GPS receiver with latitude and longitude coordinates. The mean measurement position shows the positions of the GPS receiver with latitude, longitude and altitude coordinates.

Conclusion

The code tracking loop is based on delay lock loop filter design which relates between the GPS receiver navigation solutions and the code phase and carrier frequency of the received signal. The code tracking algorithm has been developed in MATLAB-based software for GPS satellite data demodulation. The GPS signals are down-convert to baseband signal and discriminated for error values. Then the errors are filtered and given the command NCO to add the generated frequency. Minimum four satellites are required for receiver position calculation and the code tracking are important for exact receiver position. The results demonstrate that if there are four or fewer satellites available, the proposed code tracking loop can maintain tracking on a satellite signal and generate reasonable navigation solutions.

Acknowledgements

The author is very grateful to Professor Dr Ye Chan within the Department of Physics, Universities' Research Centre, University of Yangon, for his valuable guidance throughout this work.

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