A PARALLEL -SEQUENTIAL SEARCH ALGORITHM IN A HIGH DYNAMIC GPS RECEIVER

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ABSTRACT

It is need to design acquisition and tracking for code loop and carrier loop to detect the high dynamic Global Position System (GPS) signal. Acquiring signal quickly and shortening acquisition time in the cold case are key technology of a high dynamic GPS receiver. Moreover, fast acquisition of C/A code is the base of code tracking and carrier acquisition and tracking. This paper describes elements and implementation of a new parallel-sequential search Algorithm to acquire C/A code of the high dynamic GPS signal. And combined with a 12-channel correlator named GP2021 produced by GEC Co., the arithmetic implementation to acquire C/A code of the high dynamic GPS signal used sequential search based on DSP technology is also given.

KEY WORDS

Global Position System (GPS), pseudorandom codes; acquisition; false alarm

INTRODUCTION

In the high dynamic GPS receiver, the power of GPS signal is low through spread spectrum of direct sequential (DS) and carrier modulation and the range of Doppler frequency is large due to the high dynamic movement of vehicles. Therefore one of the most critical and time consuming function is the two-dimensional search and acquisition of the initial C/A code and Doppler frequency. The coarse estimation of Doppler frequency of carrier is included in the course of code synchronization, then four quadrant frequency discriminator is used to limit Doppler frequency into the linear range of carrier tracking. GPS receiver switches to code and carrier tracking mode when closing code and carrier loop.

This paper investigates a parallel-sequential search algorithm in a Digital Signal Processor (DSP)-based high dynamic GPS receiver for implementing a very fast signal search and acquisition.

ACQUISITION COURSE OF PN CODE

Pseudo-Random Noise Code(PN) is a binary sequence which have the random characteristic of white noise and can be confirmed and reproduced. GPS adopts the spread spectrum communication system, and C/A code is a PN code called Gold code. The PN code acquisition is as shown in Fig 1.

The received signal of a spread spectrum receiver is given by[1]

$$S(t)=\sqrt{2p}d(t)PN(t)Cos(\varpi_0 t+\theta_0) \quad (1)$$

where p is the power of signal, d(t) is the data code, PN(t) is a kind of spread spectrum code, ϖ_0 is round frequency and θ_0 is initial phase. The local device produces the spread spectrum code called PN(t-τ).The delay τ between PN(t) and PN(t-τ) is a random variable ranged from 1Tc to NTc when receiver has no prior knowledge about PN(t). Where N is the number of code to be searched and Tc is the period of code. Receiver produces local code PN(t-τ) to calculate the integral of PN(t-τ) and S(t) and judge whether achieve code is synchronization or not by comparing the integration result. If receiver does not acquire the code when local code delays a span of τ,it produces PN(t-2τ)…PN(t-nτ) separately to perform integration until reach to correlation peek and acquire PN code. But when either the frequency of received signal or intermediate frequency of receiver is differed from the central frequency of the BPF_2 very large, the integration result of two PN code is not larger than Ta even if their span is small enough. That searching the frequency of carrier is also in need and which is the two-dimensional search and acquisition of the initial C/A code and Doppler frequency.

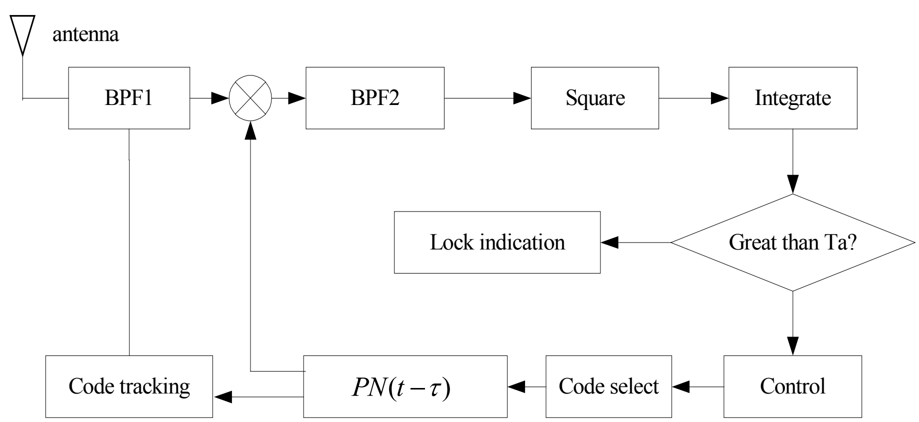

Figure 2:PN code acquisition

CURRENT STRATEGY OF ACQUIRING C/A CODE

In the spread spectrum communication system, there are two ways of the sequential search and the parallel search for signal acquisition. When acquire signal through the parallel search, the Doppler frequency is divided into several channels and each channel has N correlators. Every correlator is inputted with the received C/A code and the local code delayed a phase chip of the received C/A code sequentially. Then choose the best of the output of correlator as the acquired signal.

Another parallel search is based on FFT operation[2], the C/A code phase is divide into several searching cells. The carrier digitally controlled oscillator (DCO) is set to its nominal value and is kept constant during all acquisition process. A C/A code phase is set in C/A code generator and the outputs of correlators are processed by DSP. The power of signal at the FFT output is used to determine the presence or not of the signal using a statiscal test on FFT bin. If the signal is declared absent, the C/A code phase is changed and other cells are explored. If the signal is declared present, the FFT bin number provides an estimate of the Doppler frequency and achieves code acquisition.

These two ways of parallel search motioned above can acquire signal in a few seconds and are better adapted to the high dynamic circumstance. But they have complex equipments and need the special signal processing module. On the contrast, the sequential search Algorithm uses signal channel correlator and scans every discrete frequency span sequentially according to the effective prior information, which has the virtues of simple hardware and implementing easily, but consumes much more time especially in the circumstance with the high dynamic movement and low signal noise ratio signal.

PARALLEL -SEQUENTIAL SEARCH ALGORITHM

We design the parallel-sequential search scheme giving attention to both acquisition speed and equipment complexness. In the parallel-sequential search algorithm, the signal processing module consists of general correlator and DSP. Signal acquisition and tracking are worked in correlator controlled by DSP.

A. DIVIDE MUTICHANNEL

The Receiver makes 24-channel correlator of two GP2021 chips. Since the number of visible GPS satellite is at most eight, these channels are redundancies. The Doppler frequency range of the receiver is determined by the maximal velocity of receiver V_1 , the maximal Doppler frequency of GPS satellite("the radial velocity" relative to static consumer) and an additional frequency produced by receiver oscillator frequency uncertainty is F_c .The total Doppler frequency is shown as formula 2.

$$F_{\max} = \frac{f_{L1}}{C}(V_1 + V_2) + F_c \quad (2)$$
[3]

The maximal velocity of receiver is assumption to 10,000m/s, the maximal absolute value of Doppler frequency due to the satellite movement is 700m/s and the frequency produced by receiver oscillator frequency uncertainty is 40Hz. So the maximal Doppler frequency of the receiver reaches ±56KHz.

The Doppler range is divided into four parts and parallel search is carried out, however each channel adopts sequential search. The C/A code has 1023 chips and is also divided into two parts. Each channel scans 512 chips separately. Therefore, eight channels constitute a fasting acquisition channel of the receiver.

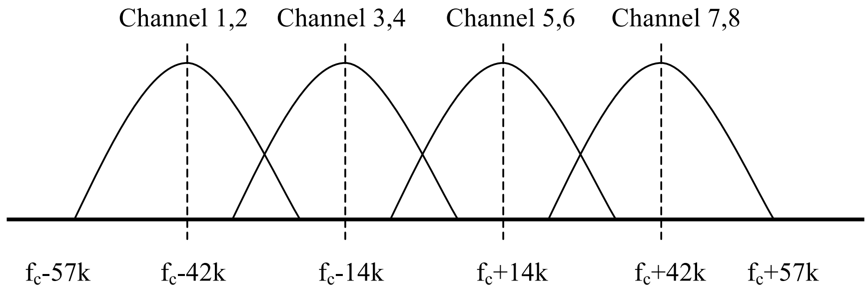

Figure 2:Channel Partition

For limiting initial carrier frequency into the range of main petal of the channel , and considering the acquisition range of Doppler frequency, the span of central frequency of these eight channels is set 30KHz and the central frequency of every two channels is same, which is shown as Fig. 2.

B. SEARCH STRATEGIES

In the parallel-sequential search algorithm each channel adopts sequential search. Sequential search is the two-dimensional search and acquisition of initial C/A code phase and Doppler frequency, which are used as starting values when closing the code and carrier loops and switching to tracking mode operation. We use the mode of approaching scan in turn in scanning Doppler frequency and dwell several times at one chip of code phase in the detection of signal to decreases the acquisition time of C/A code. The correlator adopts a kind of chip in GPS Integrated circuit group named GP2021 produced by GEC Co, which has twelve channels and each channel can produce prompt code and late code. The High dynamic receiver uses two chips of GP2021 composing 24-channel correlator. Just as mentioned above , the Doppler frequency range is divided into four equal portions and The C/A code phase is also divided into two equal portion. Searched in each portion used one channel and search algorithm in each channel is shown as Fig.3.

The increment of code phase is set half chip and the increment of Doppler frequency is one bin, which form a search cell. Set one Doppler frequency cell and move prompt code and late code in turn. The outputs of correlator have a statistical test by the DSP to determine whether the power is exceeded the threshold. When the correlation value is above the threshold, stop moving code phase and process signal at current code phase again. If the correlation value is continuous greater than the threshold three times, the signal declares present and switches to tracking loops. If the signal is not present when finishing moving 512 chips, search next Doppler frequency bin till achieve signal acquisition.

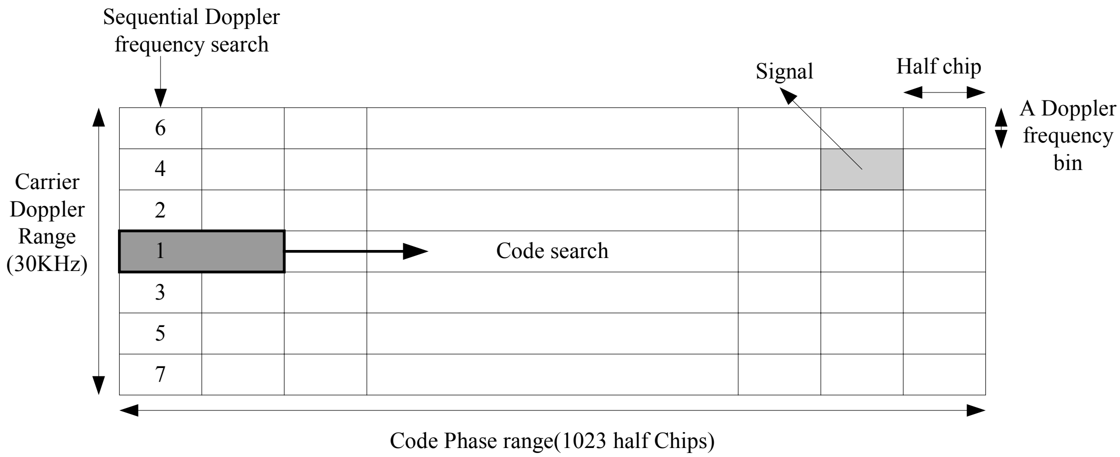

Figure 3: Sequential Code Searc

C. ACQUISITION THRESHOLD

The output of Accumulate and Dump blocks in GP2021 in the edge of the k-st correlation is as shown[3]:

$$I(k) \approx 0.5AD(k)R[\varepsilon(k)]\sin c\{[\Delta f_d(k)]\cdot \pi T\}\cos\phi_k + n_I(k) \quad (3)$$

$$Q(k) \approx 0.5AD(k)R[\varepsilon(k)]\sin c\{[\Delta f_d(k)]\cdot \pi T\}\sin\phi_k + n_Q(k) \quad (4)$$

where A is signal floor, $D(k)$ is modulated data, $\sin c(z) = \sin z/z$, $\Delta f_d(k)$ is estimate variance of the Doppler frequency, $\varepsilon(k)$ is estimate variance of the C/A code, $R(\cdot)$ is perfect binary auto correlation function of PN code, T is the integral time and $n_I(k)$ □ $n_Q(k)$ is the value of the in-phrase and quadrature produced by the input noise.

According to the electric characteristic of GP2021, the noise power of the In-phase(I) and Quadrature(Q) channel is equal to 48571 when no signal is present. With no signal present, the quantity $I^2 + Q^2$ is an exponentially distributed random variable. The distribution function is[4]

$$f_n(z) = \frac{1}{2\sigma_n^2} e^{-\left[\frac{z}{2\sigma_n^2}\right]} \quad (0 < z < \infty) \quad (5)$$

Where, σ_n^2 is the numerical variance of I and Q channel, σ^2=E(I^2)=E(Q^2)=48571□The signal acquisition threshold is assumed to V_t, the probability of false alarm is

$$P_f = \int_{V_t}^{+\infty} f_n(z)dz = e^{-V_t/2\sigma^2} \quad (6)$$

Known from formula 4, the correlation result is linear with the function of $\sin c\{[\Delta f_d(k)]\cdot \pi T\}$. Assumed SNR is equal to 6dB when acquiring signal; In sequential search, the maximal correlation loss is equal to 0.75 because of half code increment of the C/A code phase and the maximal variance of frequency is 250Hz when frequency increment is 500Hz. So The signal acquisition threshold V_t is

$$V_t = 97142 \times (1-0.25) \times 10^{\frac{6.0}{10.0}} \times \frac{\sin(250 \times 0.001 \times \pi)}{250 \times 0.001 \times \pi} = 261134 \quad (7)$$

and the probability of false alarm $P_f = 0.068$.

D. ACQUISITION TIME

Let us consider the code start case, the receiver has no knowledge of time and satellite position. In this case, the Doppler frequency range due to satellite velocity and an additional frequency produced by receiver oscillator frequency uncertainty are also taken into account. The acquisition time can therefore be expressed as[2]

$$T_q = \sum_{1}^{N_s} T_d \cdot N_d \quad (8)$$

Where T_q is acquisition time, T_d is the dwell time in every cell, N_d is the dwell times in every cell and N_s is the number of searches before finding the satellite signal.

In the parallel-sequential search algorithm, each channel has the search Doppler range of 30KHz, the dwell time in every cell is 1ms, a search Doppler bin is 500Hz. So there are 60 search Doppler bins. The code increment is half chip and the C/A code has 1023 chips. Because each channel searches 512 chips and GP2021 reads the correlation result of two half chips, the number of search code cell is 512 and the total search number is 30720(512*60). The dwell times is three times when the signal is present and the dwell times is once when the signal is not present . The dwell times is therefore at most three time when false alarm produces. Finally the maximal acquisition time in code start case amount to

$$T_q = \sum_{1}^{N_s} T_d \cdot N_d = [1 \times 30720 \times (1-0.068) + 3 \times 30720 \times 0.068] \times 1ms \approx 35s \quad (9)$$

APPLICATION

The high dynamic GPS receiver can be divided into three function modules of the receive front (RF) section, signal processing section and application processing section according to every portion different action in the system. The mainly assignments of signal processing section are acquiring and tracking GPS signal. We use correlator and DSP chip to implement these functions. Applying the parallel-sequential search algorithm to search C/A code in signal processing section, it takes few time to achieve signal acquisition and has less probability of false alarm.

REFERENCES

[1] Zhu Jingkang, Spread spectrum Communication and Its Application. HeFei, University of science and Technology China Press,1993

[2] Daffrara F, Vinson P. Improved search algorithm for fast acquisition in a DSP-based GPS receiver. IEEE Tran on Com,1998.310-314.