The design of GPS IF signal Software simulator

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***Abstract*-This article designed a GPS IF signal simulator [1]which is based on the software; it can simulate the GPS IF signal after the user assigned the moving condition of its carrier. It is very facility for the GPS software receiver to research or validate its arithmetic. The papers start with GPS IF signal architecture; illustrate the theory and arithmetic of simulator, then give the detail flow chart for generating the signal. At last use the software receiver to acquire and track the signal generated by the simulator and confirms it.**

I. INTRODUCTION

The GPS satellite signal simulator is able to simulate the navigation signal accurately according to carrier's moving condition. Thereby, it could provide a good test simulation platform for the receiver and new technologies development. The Research of GPS signal simulator started very early in other countries, and has developed various models of GPS simulator which has put into use. Among them, some products with excellent performance can directly simulate the differential navigation signal or stance measured signal, and this technology develops so well [1]. However, the domestic research of GPS simulator hangs behind in some sort. After a few years development, some hardware products have appeared in market and put in use. The traditional hardware GPS satellite signal simulator direct simulate the RF signal to test the performance of GPS receiver, but the software receiver is likely to demand the IF digital signal source for algorithms authentication and performance testing[2]. So we design a GPS IF signal simulator to meet the demand.

The papers introduce physical simulation processes of GPS navigation signal at first, and then concludes the mathematical model and the key parameters calculation of the GPS IF signal, using the matlab software programming to implement the IF signal simulation; and through the GPS software receiver to verify the IF signal by acquiring and tracking it. The results show that the model calculation and the software designed is correct; accordingly, the simulator can be used as signal source for software receiver.

II. THE THEORY OF GPS IF SIGNAL SIMULATOR

It is the theory of positioning and navigating to calculate carrier's position and movement state with the GPS signal character received. When global positioning system receiver move with its carrier at different moving state, the signal's information character which has received will follow [3]. So the GPS satellite signal simulator simulate the navigation signal after known the carrier's moving state in the corresponding observation time through mathematic modeling and calculating. As shown by figure1. The signal disposed by software receiver always sampled by A/D chip after the former RF module dispose. So the papers will put away antenna receive and RF module dispose, simulate the IF digital navigation signal after sampling directly [4].

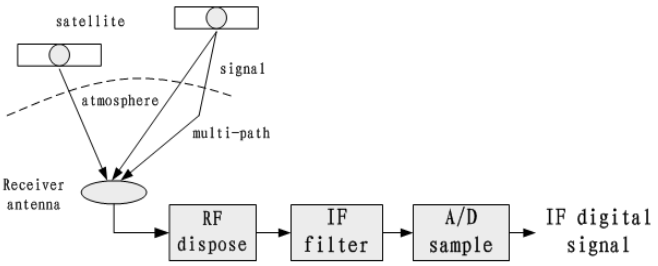

Figure1. IF signal receive process

A. The mathematic model of IF signal

The GPS navigation sends signal contains two channels, one is the L1 frequency segment signal which cross-modulated by the C/A-code and the P-code. The other is the L2 frequency segment signal only modulated by the C/A code. The simple GPS simulator only gives the L1-signal because the P-code is kept as a secret strictly. As shown in the formula1.

$$S_{L1}(t) = A_c(t)C(t)D(t)\sin(\omega_{L1}t + \varphi_1) \quad (1)$$

Where $A_c(t)$ is the range of signal at t time; $C(t)$ is the C/A-spread-code at t time; $D(t)$ is the navigation code at t time; ω_{L1} is the angle-frequency; φ_1 is the initial phase of carrier;

The GPS navigation signal transmitted by satellite at t time pass through the atmosphere to the GPS receiver. there are multi transmission errors interfuse in the pure signal such as the satellite's clock-error, multi-path radiate, ionosphere and troposphere influence; At the same time, there are some frequency excursion in the navigation signal which contains the Doppler frequency offset caused by relative movement between satellite and GPS receiver[5]. So after the RF module dispose, the IF-signal acquired actually by GPS receiver can express by the formula2.

$$\begin{aligned} R_{L1}(t) &= A_c(r)C(t-\Delta t_{iono}-\Delta T_d)D(t-\Delta t_{iono}-\Delta T_d) \\ &*\sin\left(\left(\omega_I+\omega_{e\_SV}\right)\left(t-\Delta t_{iono}-\Delta T_d\right)+\varphi_1\right)+n(t) \end{aligned} \quad (2)$$

Where $A_c(r)$ is the range of receive signal; Δt_{iono} is ionosphere delay; ΔT_d is total delay caused by the rest errors; ω_I is the angle-frequency; ω_{e_SV} is the signal frequency excursion; $n(t)$ is the receive noise;

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We can assume the IF sample time interval as Ts. After the A/D chip module, the IF signal sampled at K times is superposed by multi satellites signal transmitted at different time. So the GSP IF digital signal generated by the software simulator can express by the formula3.

$$R_{IF}(kT_s)=\sum_{i=1}^{M}A_{rc}(r)C_i\left(kT_s-\Delta t^i_{iono}-\Delta T^i_d\right)*D \qquad (3)$$
$$\left(kT_s-\Delta t^i_{iono}-\Delta T^i_d\right)\sin\left(\omega^i_{IF}(kT_s)kT_s+\varphi_1\right)+n(kT_s)$$

B. The realize theory of software simulator

The GPS software simulator generate navigation signal must keep consentaneous with the actual navigation signal under the moving condition assigned by its user as possible. This request us to modeling the influences caused by each error source and simulate the radiate signal accurately in the real time. Calculate out the key control parameter. Then follow the formula 3 to generate corresponding navigation signal. It is usually take the ability of acquiring and tracking the navigation signal for the key indexes of the GPS receiver. So we should focus on some important issues such as the frequency of carrier, signal phase and transmit time calculate [1] [6].

All the navigation satellite which elevation is larger than 5° in the receive reference frame at observational time should be seen as eye able satellite. So we should estimate whether the object is eye able via calculating the relative position between carrier and satellite's position firstly; calculate each satellite's signal transmit time corresponding its observation time afterward which should take many delay modifications into account; Then recalculate the satellites' position and speed according to each transmit time, calculate the frequency of signal's code and its carrier wave according to the relative radial speed between the satellite and the receiver, calculate the offset of C/A code and the phase of its carrier according to pseudo range confirmed by transmit time; at last, make all the parameter in line with the change of observation time, and take them into the formula 3 to generate the GPS IF signal follow the sample time.

The method to calculate satellite's position and speed could refer to the thesis 7; the GPS signal transmission errors contains satellite clock error, ionosphere delay and troposphere delay. The relative theory effect syncretize with satellite clock error, it can be calculate according clock modified parameters in the ephemeris. There are many models to modify the delay time caused by ionosphere and troposphere. Because the delay is related with the factors that are different from one place to another, we choose the Klobuchar typical model and the Hopfield model to modify each delay in order to have common characters [8].

The errors of GPS IF signal simulator are mainly come from model errors and calculation errors. The calculate errors is very little than model errors. Signal simulator could take the same error model with the software receiver, and it is only have the calculate errors. So the GPS software simulator could meet the need of receiver completely.

III. THE SOFTWARE REALIZATION OF SIGNAL SIMULATE

The simulation method in this article is match the ideal signal with rectangle window: that is to divide the observation time into about 1ms discrete intervals, we can match the ideal signal with the simulation signal in the discrete time through calculating the signal's parameters, and keep all the parameters unchanged in the interval time. Then complete the generation of satellite signal in the interval. Because the distances between satellite and the receiver are different, the range of each satellite's signal should have different attenuate; and in order to keep the simulation signal in line with actual condition. We can take the Gauss white noise into the signal, the detail value assigned by its user, and the noise power always tower above the signal power 10 to 40dB. Finally the synthesis satellite signal is quantified with two bits and stored as. BIN file on an assigned way of the computer.

This paper use matlab software to realize signal simulation. The sample times of the IF signal is 5MHz, and the center frequency of the carrier wave is 1.25MHz. We designed a man-machine conversation interface for the software simulator as shown by figure2; users can assign the carrier's observation time and moving condition. The tables1 give a set of parameters to introduce it. The initial position assigned in Xi'An University of technology. Its latitude is 34.225051 degree, the longitude is 108.9905 degree and its altitude is 435.689 meters. The simulation time start at 12:37:40 on 18th March, 2009, and the observation time last for 40 seconds. The ephemeris is the intraday broadcast ephemeris that received by the GPS receiver which designed by the Oriental Union Star company. It takes about 20 seconds to simulate the IF signal which observation time is only 1 second.

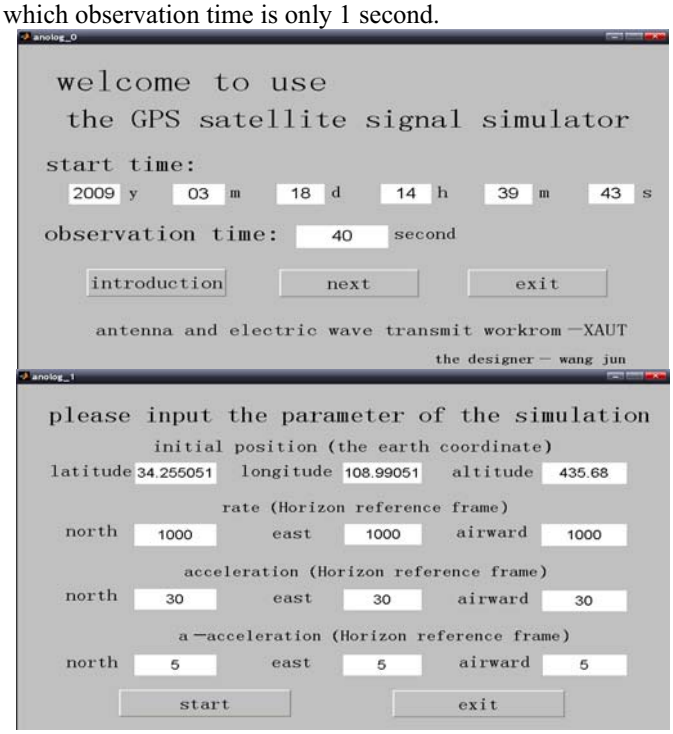

Figure2. Conversation interface

TABLE 1. The carrier's moving condition

The direction	north	east	upward
speed .m/s	1000	1000	1000
acceleration.m/s^2	30	30	30
A-acceleration. m/s^3	5	5	5

IV. THE ANALYSIS OF GPS IF SIGNAL

The spectrum of satellite signal generated according to the parameters lies in table1 shown by figure 3, and figure 4 is the spectrum with the white noise. Obviously, the central frequency of carrier wave is 1.25MHz and its bandwidth is about 2MHz which is match with the fact and parameters we have assigned; the useful signal is submerged completely by white noise. In order to verify the software GPS simulator, we need a GPS receiver to analyze the IF simulation navigation signal. In this article we choose a GPS software receiver which could receive the actual satellite signal correctly to verify it.

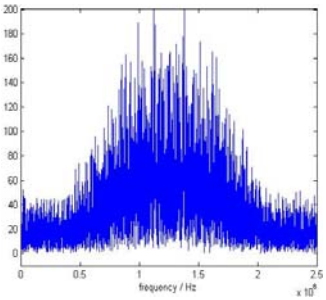

Figure3. Signal spectrum

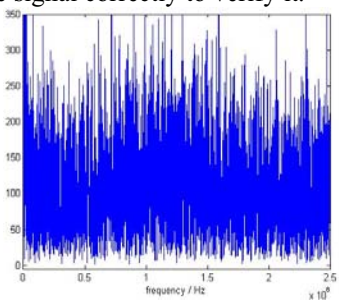

Figure4. Signal with noise

All the eye able satellites that calculated in the simulator are searched by the GPS receiver in the IF navigation signal. They are shown by figure5. Figure6 tell us the result of signal acquire, the parameters such as Doppler frequency and code

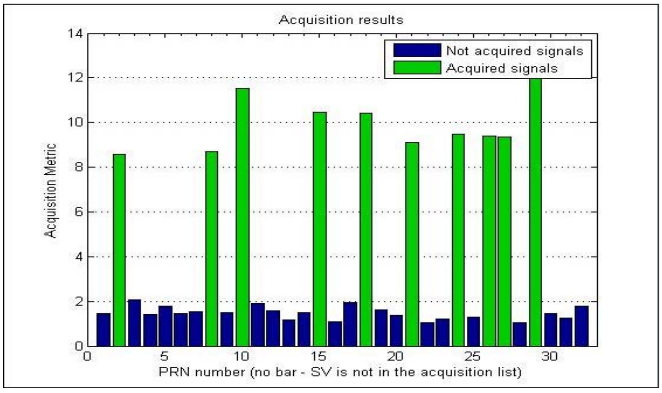

Figure-5 eye able satellites

Excursion of each satellite is equal to the result that calculated by simulator. The navigation code tracking result is shown by figure7. We have contrasted it with each satellite's navigation codes modulated in the signal for 40 seconds, to our surprise, they are consistent. In other words, the acquire and track results are all right. So the GPS satellite IF signal simulator we designed in this paper can simulate the actual IF navigation signal under the carrier's moving condition correctly.

Channel	PRN	Frequency	Doppler	Code Offset	Status
1	29	1.25096e+006	963	4041	T
2	10	1.25096e+006	963	1888	T
3	15	1.24796e+006	-2041	2799	T
4	18	1.24596e+006	-4044	1049	T
5	24	1.25096e+006	963	2552	T
6	26	1.24796e+006	-2041	3935	T
7	27	1.24896e+006	-1040	4182	T
8	21	1.24897e+006	-1030	4945	T
9	8	1.25096e+006	963	4098	T
10	2	1.25196e+006	1965	577	T

Figure-6 signal acquire result

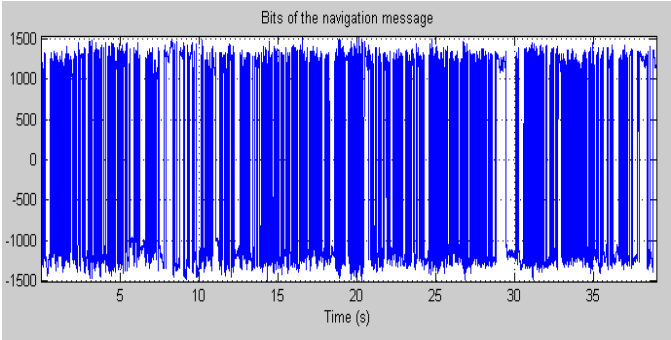

Figure-7 the navigation code track result

V. CONCLUSION

The GPS IF signal simulator designed in this article take the advantage of software's calculated. Implement the simulation of actual navigation signal and use the software receiver to verify it, the results shows that the signal can be acquired and tracked by the GPS software receiver and used for the signal source of software receiver. Compare with the typical hardware simulator. On the side, the GPS IF signal software simulator is more convenient to add the new signals such as the L2C, L5 or Galileo signal only by change its arithmetic.

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