The Design and Implementation of GPS CA Code Simulation Experiment

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Abstract. The research on GPS C/A code has certain practical significance. This paper chiefly explain the principles of C/A code generation. On the basis of studying the principle of GPS pseudo-random sequence C/A code generation, the 1.023MHz C/A code is simulated to modulate and transmit 50Hz navigation message information at the frequency of L1 carrier signal. Based on the GUI interface of MATLAB, an executable program is designed. By clicking the button, the time domain diagram and spectrum diagram of navigation message signal, C/A code, L1 carrier signal, spread spectrum, modulation and noise added signal are generated, and the spectrum analysis of GPS L1 satellite signal is completed on MATLAB.

1. Introduction

The GPS system mainly adopts direct sequence spread spectrum modulation technology, and modulates and transmits 50Hz navigation message information on the frequencies of L1 and L2 carrier signals by pseudo-random codes of 1.023MHz (C/A code) and 10.23MHz (P code). Therefore, this subject carries out research on GPS C/A code. Based on the simulation and spectrum analysis of GPS C/A code based on MATLAB, the GPS L1 satellite signal is simulated[1,2]. This design realizes the simulation and spectrum analysis of the GPS L1 satellite signal. The operation is simple, the function is correct, and it has a certain human-computer interaction ability. The simulation software can also change the simulation parameters as needed, and can be used in demonstration links such as scientific research and teaching. It can not only deepen students' understanding of spread spectrum communication, but also combine their knowledge with practical applications.

Researchers in the research of GPS C/A code generation principle, based on various platforms to achieve the simulation of C/A code, such as MATLAB [3], Modelsim [4], FPGA [5], mainly for GPS. The satellite signal structure and C/A code generation method are studied. The functional modules of this design software are shown in Figure 1.
2. C / A code generation principle and parameter setting

The GPS system mainly adopts direct sequence spread spectrum modulation technology, and modulates and transmits 50Hz navigation message information on the L1 and L2 carrier signal frequencies by using a pseudo-random code of 1.023MHz (C / A code) and 10.23MHz (P code) rate.

2.1. C / A code generation principle

GPS contains three signal components: carrier, two pseudo-random noise codes (C / A code, P code), and data code. Among them, the C / A code is a kind of coarse synchronization code in GPS, which can meet general positioning accuracy requirements. The C / A code uses a Gold code structure with a length of 1023 \( (2^{10}-1) \) and a pseudo code rate of 1.023 MHz. Then, a C / A code has a period of 1 ms. The GPS C / A code is a Gold code formed by combining two m-sequences with the same code length and the same code clock rate generated by two 10-stage shift registers.

\[
g_{2s} = [5, 6, 7, 8, 17, 18, 139, 140, 141, 251, 252, 254, 255, 256, 257, 258, 469, 470, 471, 472, 473, 474, 509, 512, 513, 514, 515, 516, 859, 860, 861, 862]
\]

This allows the satellite number to correspond to the G2 chip delay. Then define two \( 1 \times 1023 \) arrays \( g_1, g_2 \) to store the generated Gold code, define a 10-bit array \( \text{reg} \) of all 1, as a shift register, according to the characteristic polynomial:

\[
G_1(t) = 1 + t^3 + t^{10} \quad (1)
\]

\[
G_2(t) = 1 + t^2 + t^3 + t^6 + t^8 + t^9 + t^{10} \quad (2)
\]

Generate two Gold code sequences, and then generate all \( G_1 \) signal feedback values based on the \( G_1 \) feedback polynomial. The feedback polynomial: MATLAB program, define an array \( g_{2s} \) in the program:

\[
\text{saveBit} = \text{reg}(3) * \text{reg}(10) \quad (3)
\]
\[
\text{saveBit} = \text{reg}(2) \times \text{reg}(3) \times \text{reg}(6) \times \text{reg}(8) \times \text{reg}(9) \times \text{reg}(10) \quad (4)
\]

According to the original polynomial, the shift register array `reg` is repeatedly operated 1023 times to generate g1 code. Based on this, the corresponding chip delay g2s is introduced, and the chip delay time is used as the dividing point. The next half of the data is shifted forward, and the first half of the data is shifted back to obtain the g2 code. Multiply the g1 and g2 codes point by point and then reverse to obtain the C / A code.

2.2. L1 carrier signal

There are two carrier signals for GPS, L1 and L2, of which CA code and P code are orthogonally modulated on L1 and P code is modulated on L2. GPS uses this dual-frequency structure, which can eliminate ranging errors caused by ionospheric RF signal delays. For civil GPS systems, only the L1 band is needed, and its center frequency is 1575.42 MHz [6,7]. In order to ensure the normal sampling of the carrier signal, according to the Nyquist sampling theorem, the sampling frequency is selected here as 10GHz [8].

3. MATLAB simulation verification of GPS C / A code

3.1. C / A code generation principle

The interface after design and operation is shown in Figure 2 below:

![Figure 2. GPS C / A code simulation implementation interface operation diagram.](image)

The GPS C/A code simulation implementation project of this subject is implemented using MATLAB, and adopts the GUI interface design concept. The navigation message, C / A code, C / A code characteristic judgment, L1 carrier, spread spectrum, Each process of modulation and noise signal generation, the output results are displayed graphically, which is simple and convenient, and it is easy to demonstrate the operation.

3.2. C / A code correlation

It can be seen from Figure 3 that the self-correlation characteristic of the CA code has the largest correlation peak 1023 when the phase value is 0; the correlation peak at the remaining phases is about 60; the maximum correlation peak of the cross-correlation characteristic is also about 60. That is to say, the ratio of the largest correlation peak to the second largest correlation peak in the auto-correlation and cross-correlation characteristics is 1023/60 ≈ 17 times. This good correlation characteristic makes the GPS system have good anti-interference performance and can be used in
complex channels. Reliable transmission of signals in the environment can also distinguish individual users using code division.

**Figure 3. C/A code related characteristics**

### 3.3. Noisy signal

**Figure 4.** the SNR is 0dB, 20dB, 50dB, the simulation waveform diagram
When the input signal-to-noise ratio is 0dB, 20dB, and 50dB, the resulting simulated waveforms are shown in Figure 4 above. It can be seen from Figure 4 that when the signal-to-noise ratio is relatively large, the time-domain waveform and spectrum of the signal are almost unchanged; when the signal-to-noise ratio is reduced, the time-domain waveform is still smooth, but there is a slight change in amplitude. At this time, it can be seen in the spectrogram that the noise floor has been raised to a certain extent, but the envelope spectrum of the spread spectrum signal is still visible; when the signal-to-noise ratio is reduced again, the time domain waveform is obviously distorted at this time, It is the envelope of the initial sine wave, but it is already difficult to distinguish the envelope spectrum of the spread spectrum signal in the spectrogram.

4. Conclusion

Through the design of the composition parameters of the GPS C/A code and the explanation of the basic principles of spread-spectrum communication, we know the methods based on the GPS C/A code's various processes, including navigation messages, C/A code generation and related characteristics, The generation of L1 carrier, and the corresponding processes and steps of spread spectrum, modulation, and noise. The simulation experiment project of this subject is realized through the GUI interface. The above process steps can be simulated and run, and the results are displayed in a graphical manner. Through the simulation test, all the processes can run and the results are correct.

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