Abstract: Recent years Global Positioning System (GPS) has been widely used in industrial and trading activities such as navigation, mapping, power distribution, telecommunication, weather station, digital radio, industrial control systems and research centers, ... in these systems information have to transferred between different parts. One of the main exchanged information is time tag, which indicates the precise time of action. Synchronization between these tags is the main portion of these systems. This synchronization produced by one common reference which sends the time synchronizer signal in determined timing intervals to all sections. In this approach GPS satellite, timing signals, Golden Code, methods of coding and decoding of GPS satellite signals, way of correcting time with precise time calculation on GPS receivers and system simulation from GPS satellite transmitter to receiver in Matlab with implementing the receiver hardware will be discussed.

Key-Words: PRN Code, QPSK, Synchronization, Spread Spectrum, Almanac, Ephemeris, C/A & P(Y) code

1 Introduction

A Global Positioning System\(^1\) or Navigation Satellite System consists of more than 24 SVs\(^2\), rotate in middle earth circuit and transmit signals to GPS receivers for determining the position, speed and direction of movement.

For calculating the position and time synchronization, at least 4 satellites shall be used. PRN code is a code generated specially for each satellite. Minimal Cross Correlation to other PRN codes, noise and interferers, high autocorrelation allows all satellites signals to be transmitted at the same frequency. GPS satellite information, QPSK modulation, Simulation in Matlab and proposed algorithm for implementing will be discussed in section 3, 4, 5 and 6.

2 Calculating Position And Time

By calculating the distance between a receiver and one GPS satellite, we can suppose that receiver is located on the surface of sphere centered on the satellite with a radius equal to the distance between satellite and receiver. By calculating the distances of receiver from second and third satellites, location of receiver is estimated to be on one of the two points of intersection between surfaces of three spheres. By calculating the distance from forth satellite and intersect the forth sphere with two mentioned points, the precise time and position could be determined.

Distance between GPS receiver and satellite is calculated by multiplying the travel time and velocity of GPS radio signal with the speed of light or roughly 186,000 miles per second (Distance = Velocity * Time).

![Image of GPS satellites and a globe](image)

Fig. 1. The accurate location is calculated from distance measurements to at least three satellites

Each GPS satellite uses multiple atomic clocks for contributing very precise time data of GPS signals. GPS receivers decode these signals and effectively synchronized themselves to the GPS atomic clocks. With this opportunity, users in all around the world can determine the time to within 100 billions of a second, without the cost of owning and operating atomic clocks. Each satellite transmits its own navigation message with distinct spread spectrum codes: the Coarse / Acquisition (C/A) code, which is a 1,023 chip pseudo-random (PRN) code at 1,023 million chips/sec. Each satellite has its
own C/A code so it can be uniquely identified and received separately from the other satellites transmitting on the same frequency. By supposing a precise time for receiver, a receiver and transmitter send the PRN code simultaneously which are equal. To determining delay, receiver compares the bits sequence received from the satellite with an internally generated C/A code and then calculates delay and distance from GPS Satellite. But as the clock of receiver is not synchronized with GPS satellite, the offset (error in calculating delay and distance) has been occurred which in turn causes the offset in four radiuses of four GPS satellites.

![Diagram of signal delay](image_url)

**Fig. 2.** Receiver clock is not synchronized with GPS receiver, it causes offset error.

GPS receiver changes the offset error in positive and negative direction to lead the four spheres to intersect in one point which result to precise time, synchronic with GPS atomic clock. In this way precise time and position has been determined.

By comparing the rising and trailing edges of the bit transitions, modern electronics can measure signal offset to within approximately 10 nanoseconds for the C/A code. Since GPS signals propagate at the speed of light, this represents an error of about 3 meters. This is the minimum error possible using only the GPS C/A signal.

![Diagram of sphere intersection](image_url)

**Fig. 3.** Bolded spheres indicate the real position and colorless spheres indicate the position which receiver suppose it has. Precise time can be calculated when four spheres intersect in one point.

### 3 Method of Transmitting and Receiving Information

Two different carrier signals have been used in GPS satellites for transmitting information: \(L_1\) with 1575.42 MHZ frequency (2x77x10.23 MHz) for transmitting the Navigation Message, C/A and P Code, \(L_2\) with 1227.60 MHZ (2x60x10.23MHz) for transmitting P-Code and the new code named L2C for estimating the ionospheric delay using modeling parameters. These codes are broadcasted to the user in navigation message. In General, GPS satellites transmit three types of information.

- **Almanac:**
  Almanac data is course orbital parameters. Each SV broadcasts Almanac data for all SVs. This Almanac data is not very precise and is considered valid for up to several months. Almanac data consists of healthy or fault, current time and date. This information is essential for precise position calculation.
  From the almanac data GPS receiver identifies the satellites that are likely to be received from the actual position. Receiver limits its search to these previously defined satellites and hence this accelerates the position determination.

- **Ephemeris:**
  Ephemeris data is very precise orbital and clock correction for each SV and is necessary for precise positioning. Each SV broadcasts only its own Ephemeris data. This data is valid for about 30 minutes. The Ephemeris data is broadcasted by each SV every 30 seconds.

- **Timing Information:**

  - **C/A Code:**
    The Coarse / Acquisition code or C/A is a 1,023 bit long pseudorandom code broadcast at 1.023 MHz which modulates the L1 signal in phase and makes the widespread spectrum repeating every millisecond. Each satellite sends a distinct C/A code, which allows it to be uniquely identified.

  - **P-code:**
    Usually reserved for military applications.
    The P-code is a similar code broadcast at 10.23 MHz, but it repeats only once a week. In normal operation, the so-called "anti-spoofing mode", the P code is first encrypted into the Y-code, or P(Y), which can only be decrypted by units with a valid decryption key. P code modulates L1 and L2 carriers in phase. Navigation Message modulates L1 and C/A codes. 50 bytes/sec Navigation message Data is combined with both the C/A-code and P(Y)-code prior to modulation with the L1 carrier. This combination uses the XOR process.
    Since C/A-code XOR Data and P(Y)-code XOR Data is synchronous operation, the bit transition rate cannot exceed the chipping rate of the PRN codes.
The L2 frequency can be modulated by either P(Y)-code XOR Data or C/A-code XOR Data or with P(Y)-code alone as selected by the control segment. P(Y)-code and C/A-codes are never present simultaneously on L2, as is the case with L1.

In general, P(Y)-code XOR Data is the one selected by the control segment. Navigation message Data gives information about the satellite's orbits, their clock corrections and other system status. The P(Y)-code XOR Data is modulated in-phase quadrature with the C/A-code XOR Data. Therefore there 90 degrees phase shift between these two combined carrier frequencies. At each phase shift, the bit is flipped from 0 to 1 or vice versa.

![Fig. 4. QPSK modulation with four 90 degree phase region (A, B, C, D)](image)

The term "quadrature" implies that there are four possible phases (4-PSK) which the carrier can have at a given time, as shown in above figure the four phases are labelled {A,B,C,D} corresponding to one of {0,90,180,270} degrees.

![Fig. 5. C/A code and navigation message and combination of them with XOR (module 2 adding)](image)

4 PRN Code Generation (C/A & P(Y))

Pseudo Random Noise Codes have random noise characteristics but are precisely defined. A sequence of zeros and ones, each zero or one referred to as a "chip" because they carry no data. Selected from a set of Gold Codes. Gold codes use 2 generator polynomials. Uses two “10-bit generator polynomials” (G1 and G2).

G1 = 1 + x^3 + x^10
G2 = 1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^10

Fig 6 illustrates the two 10-bits for each of two polynomials G1 and G2 then shift the first step bits to the right and substitute the left bit with output of XOR of bits (in G1: bits 3 and 10 and in G2: bits 2, 3, 6, 8, 10) C/A cod generates by XOR the first bit of G1 with the XOR result from two bits of G2 that called phase tap. In the following figure tap 3 & 8 has been used for making PRN31.

Selecting two bits (Phase Taps) from G2 polynomial has individually done for each SV according to the following schedule. In this way different C/A codes with unique composition will be prepared for each of the GPS satellites.

![Fig. 6. C/A generate by two 10 bits generator polynomials](image)

Minimal Cross Correlation to other PRN codes, noise and interferers, high autocorrelation value only at a phase shift of zero, allows all satellites signals to be transmitted at the same frequency. Three types of Golden codes have been used by GPS: C/A, P and Y.
5 Computer Simulation

Figure 8 illustrates the algorithm of system from PRN generator in GPS satellite transmitter to the GPS PRN code Receiver, time delay calculation part and finding error offset for timing correction in receiver.

In PRN code generation part, the four codes have been generated. Then for each of four satellites, time delay between transmitted and received signals will be calculated. By these delay times, distances between receiver and GPS satellites (centered on GPS receiver) will be determined.

Fig. 8. Algorithm of system for determining the precise time from GPS satellite transmitter to receiver

Fig. 9. System implementation from GPS satellite transmitter to GPS receiver by MATLAB Simulink
Considering Error offset (adding and reducing the sizes of four sphere) caused by none synchronization between GPS satellites clock and receiver, until the four spheres intersected in one point, the precise time and position has been calculated.

Figure 9 demonstrates the implementation of the above algorithm from GPS satellite transmitter to GPS receiver by Matlab Simulink toolbox for calculating the delay time in one GPS satellite. Different parts of the system on figure 8 from the left are:  
- Sampled read with synchronized pulse2 which produces the random code with 1023 HZ frequency, - Unit delay1 and Unit delay 2 for producing delay causes by distance between GPS satellite to receiver, - Modulator QPSK band Base for QPSK phase modulation in satellite transmitter, -Channel AWGN for generating the Gaussian white noise for simulating the surrounding noise, -QPSK Demodulator Baseband2 for QPSK phase demodulation in receiver, - Error Rate Calculation for calculating the Error rate from the transmitter and receiver signal because of the delay between them, -Find Delay for calculating the delay between transmitter and receiver signal, -Display for demonstrating the calculated delay.

In this simulation two delay units has been considered for delay between GPS receiver and transmitter. The Find Delay part determines the delay equal to sum of two delay units. The above simulation has been repeated from transmitter to receiver for four satellites for determining four delays. The precise time will be determined by calculating the intersection point of four spheres centered at each satellite and apply the error offset (by changing radiuses of spheres till intersection the surfaces of them in one point).

6 Implementation

Based on the simulation, the following diagrams could be applied for implementing the GPS transmitter and receiver. QPSK demodulation has been done on the CPU.

Fig. 10. (a) PRN code in transmitter. (b) PRN code in receiver. (c) transmitted signal after QPSK demodulation. (d) Received signal after QPSK demodulation. (e) Constellation Diagram. (f) Intersection of four sphere in one point by AutoCAD for calculating the precise time and position with adding and reducing the error offset. (g) Correlation between PRN1 and PRN1. (h) Correlation between PRN1 and PRN22

Fig. 11. GPS receiver hardware implementation algorithm
7 Conclusion

In this paper, the time synchronization by GPS has been introduced and simulated from transmitter to receiver with QPSK modulation and PRN code generator has been done in Matlab. Implementing Algorithm for C/A code generation has been shown too. QPSK modulator with double information transition decreases the power consumption of the system. Using PRN code for data modulation with wide spread spectrum and noisy manner leads difficulties for unauthorized signal detection, so it makes the information very confidential. Based on simulation, the block diagrams of GPS receiver for hardware implementation has been proposed.

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