I.J. Education and Management Engineering, **2013, 2, 40-45**
Published Online February 2013 in MECS (http://www.mecs-press.net)
DOI: 10.5815/ijeme.2013.02.07

Available online at http://www.mecs-press.net/ijeme

Principle of Satellite Navigation Orbit and Positioning

Guohai Yang

School of Physics & Electronic Engineering, Xiangfan University Xiangfan, China

Abstract

We first have studied the principle of satellite navigation orbit and positioning. Then we have taken GPS and Transit satellite navigation system for example, and have discussed them importantly. We also have introduced GLonass globe satellite navigation system of Russia and Navsat navigation satellite system which studied by ESA.

Index Terms: Satellite navigation; Satellite positioning; Glonass; Navsat

1. INTRODUCTION

With the development of society requirements and space technology and electronic technology, satellites are having been more and more used in communication services. Except telephone system, telegraph and broadcast television, satellites are also used in navigation, positioning, weather, scientific research, missile early alarm system, military reconnaissance and other applications widely.

Satellite navigation is the navigation by using satellite, which has been developed on the basis of traditional astronavigation and modern radio navigation. It has overcome the shortcoming that astronavigation depended on weather conditions greatly and there is a big error between the radio navigation operated in middle or long distance. It can provide accurate navigation data for all kinds of objects on the sufferance of earth. It also can be used to provide traffic control, space observation, navigation, positioning and commanding for ships, planes and automobiles at the same time. [1]

2. Transit navigation satellite system

Transit navigation satellite system is the type of Doppler. Observer determines the relative position by measuring satellite electric wave many times when one navigation satellite passes his overhead. The improved Transit navigation satellite is the mixed type of Doppler and distance. It is not only used in Doppler measuring, but also distance measuring. The earth synchronous orbit navigation satellite system is the type of distance. In

* Corresponding author.
E-mail address: hbxfqxyqxy_123@163.com

fact, it determines the observer's position by changing the measured a group of electric wave signals' time when from high-orbit satellite to observer into distance. [2]

The whole system consists of three parts, and Fig.1 shows the system.

The tracking station transmits Doppler radio-frequency shift when measuring satellite to central computer. The central computer then transmits the calculated coming satellite orbit parameters to injection station, and the injection station injects these data to satellite two times everyday. Usually, satellite produces two kinds of carriers (400MHz and 150MHz). According to ionospheric refraction, satellite will adjusts and phases carriers by using the injected data. The user calculates satellite position by acquiring the orbit parameters from receiving and demodulating satellite information. So the time of positioning devices will synchronize the tracking system by demodulating timing signal. According to the measured Doppler counting and inputted rough position (The error may be 10km.), the central computer can calculate the user's position.

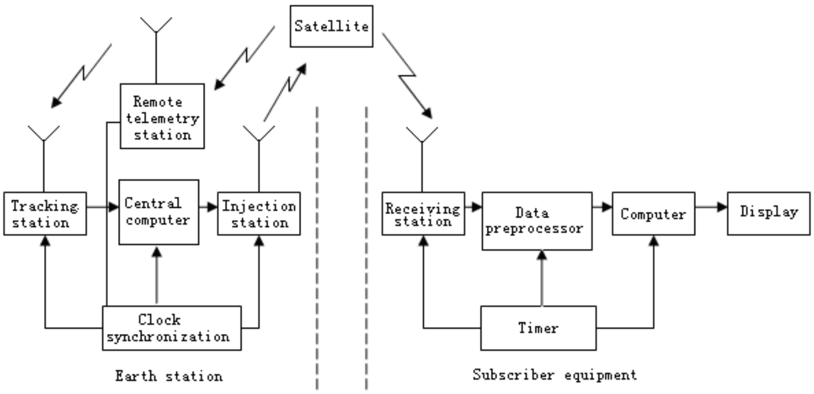

Figure 1. The whole satellite navigation system

Transit satellite navigation system consists of five or six pieces of Transit satellites and earth station which used to use, governor and control satellites. Earth stations include four tracking stations, one calculating center and two injection stations, which are all in America. Fig.2 shows the block diagram of Transit satellite communication repeater. Satellite usually transmits two kinds of very stable coherent carriers: 399.968MHz and 149.988MHz whose relationship is 8:3. The changing of two carriers doesn't exceed 2.5×10^{-11}. When the transmitted electric wave from satellite passes ionosphere, it will cause positioning error because of reflection effect. We can get rid of this error by using these two frequencies. The more stable these two frequencies, the higher positioning precision are. The realities have shown that the deviation error is only 30Hz after satellite has operated for several years. The transmitting power of 400MHz frequency range is 1.25W, and the transmitting power of 150MHz frequency range is 0.8W.

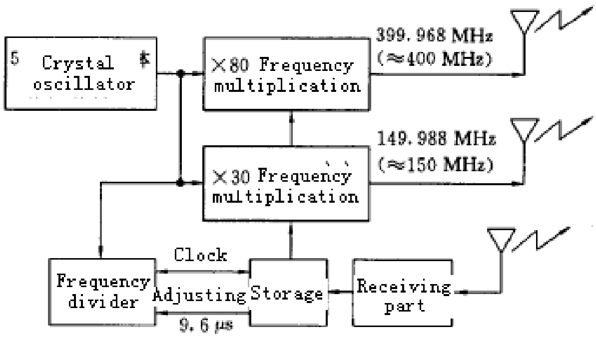

Figure 2. Transit navigation satellite communication repeater

To the observer who is near equator, five Transit navigation satellites pass his airspace at least 20 times. To the observer who is the area with latitude 60 degree, the satellites pass his airspace at least 40 times. These times are both needed to subtract when the satellite passes at the largest angle of elevation. Because when the largest angle of elevation is lower, the received Doppler counting data by navigation receiver will be reduced, this causes a bigger reflection error. If the largest angle of elevation is higher, although Doppler counting data will be increased, the precision of positioning will be worse. So we avoid using. Usually, when the largest angle of elevation is in the range from 10 degree to 70 degree, it is called effective passing. Only the effective passing satellite is useful for observer's positioning. Satellite navigation receiver has the function of predicting the time of satellite's effective passing.[3]

3. GPS

GPS is the second generation navigation satellite engineering which was decided to develop by United States Department of Defense (USDOD) in 1973. Its main principle is measuring distance depending on time.

Space satellite constellation in GPS system was firstly consisted on twenty-four pieces of satellites which lied in three orbital planes, and very orbital plane has eight satellites. The phase difference is 120 degree and inclination is 55 degree between every two orbital planes. The satellites in every orbital plane were distributed uniformly. The orbit was circular, the height was about 20000km, and the operation period was 12h. This can ensure that the user who lies in any location or near space on the earth can see more than six pieces of navigation satellites, which can realize all-weather continuous real-time navigation and get longitude, height, speed and time. Every positioning only needs several seconds or dozens of seconds. Fig.3 shows the orbit configurations about GPS system.

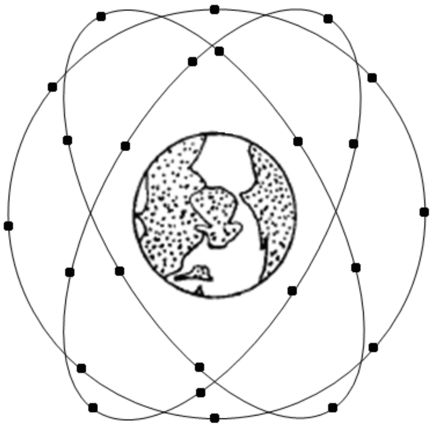

Figure 3. Orbit configurations about GPS system

Every satellite transmits two kinds of navigation signals L_1 and L_2 continuously. They both use Direct Sequence Spread Spectrum modulation which can increase the ability of anti-jamming. The carrier frequencies of L_1 and L_2 are 1575.42MHz and 1227.60MHz. The spread spectrum modulation of L_1 uses non-balanced QPSK, and the spread spectrum code of I-channel is Gold code whose length is 1023, rate is 1.023 Mbit/s and code-period is 1.0ms. Different satellites use different Gold code, which can make ground station distinguish them. This kind of short spread spectrum code is called C/A (Clear / Acquisition) code. C/A code is plain code, and any military user or ordinary user can use it, its positioning precision is limited in 25m. Q-channel spread spectrum code is long nonlinear code, and its clock rate is 10.230Mbit/s, which is called P code. Its period is the unit of day. Different satellites use different long code phase. P code is a kind of secret code. People only can use it on the assumption of United States Department of Defense's premonition. Its positioning precision is from one meter to ten meters. And we can see more satellites. C/A code is also used as searching code of P code. The power of P channel is less 3dB than C/A channel. The two kinds of signals of P channel and C/A channel are both modulated by 1500 bit data message, and transmitted at the rate of 50bit/s again and again. These 1500 bit data includes position information and adjusting transmitting time error and the data which used to adjust satellite time deviation. Fig.4 shows the generating method of L_1, which uses BPSK direct-sequence modulation. The two kinds of signals of C/A code and P code both includes such navigation information data as satellite state, system time, astronomical almanac of satellite which is being tracked by receiver.

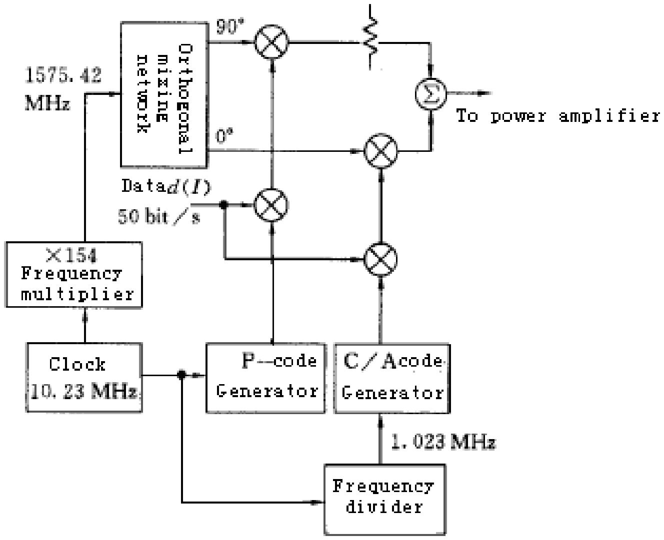

Figure 4. Generating of GPS L1 spread spectrum signal

The control part consists of one main-control station and many monitoring stations which are distributed many different places on earth. They are mainly used to position satellite and monitor and load data. Every monitoring station tracks all the satellites which are in their observing range and transmits the gathered data about satellite distance and clock to main station. Main station compares these data with the measured satellite astronomical almanac data, and then loads navigation dada into satellite by means of a earth station, which providing for users.[4]

The user equipment is a kind of receiver which used to determine position, time, direction, speed and destination by means of navigation satellite. It has four impendent channels, and every channel is used to track one piece of satellite signal. It can monitor and measure continually, and demodulate satellite signals which from four pieces of satellites in GPS at the same time. Another easy receiver only has one channel which used to choose satellite signal by switching, and recovers the four satellites' signals in turn. These two kinds of receivers both track C/A code firstly, and then the phase will be locked in accordance with the carrier. P code synchronization can be acquired by getting information from received data.

Receiver can determine the distance of satellite by means of C/A code or P code. Because the switching rate of P code is very high, so the precision of measuring distance is very high. The coordinate system which used to calculate user position is rectangular coordinate system whose base point lies in earth center. Fig.5 shows the coordinate system. The parameters X_u、 Y_u、 Z_u represent user position respectively, and X_i、 Y_i、 Z_i（$i = 1, 2, 3, 4$）represent the No.i satellite position in the rectangular coordinate system. So the user distance and distance error can be calculated by the following simultaneous equation.

$$
\begin{aligned}
(X_1 - X_n)^2 + (Y_1 - Y_n)^2 + (Z_1 - Z_n)^2 &= (R_1 - B)^2 \\
(X_2 - X_n)^2 + (Y_2 - Y_n)^2 + (Z_2 - Z_n)^2 &= (R_2 - B)^2 \\
(X_3 - X_n)^2 + (Y_3 - Y_n)^2 + (Z_3 - Z_n)^2 &= (R_3 - B)^2 \\
(X_4 - X_n)^2 + (Y_4 - Y_n)^2 + (Z_4 - Z_n)^2 &= (R_4 - B)^2
\end{aligned} \tag{1}
$$

In this equation, R_1 represents the pseudo-distance which is the satellite distance measured by receiver, and $R_1 = C \bullet \Delta t_i$. C is the velocity of light and Δt_i is the time from satellite to receiver. B is distance error and $B = C \bullet \Delta$. The parameter of Δ is the deviation error of receiver which relatives to satellite clock. Because all the satellites' clock is synchronized, so the clock deviation between receivers' clock and receiver clock are same. The input parameters in the simultaneous equation are demanded to pseudo-distance, clock deviation and satellite position coordinate. The satellite position coordinate can be measured in accordance with control part.[5]

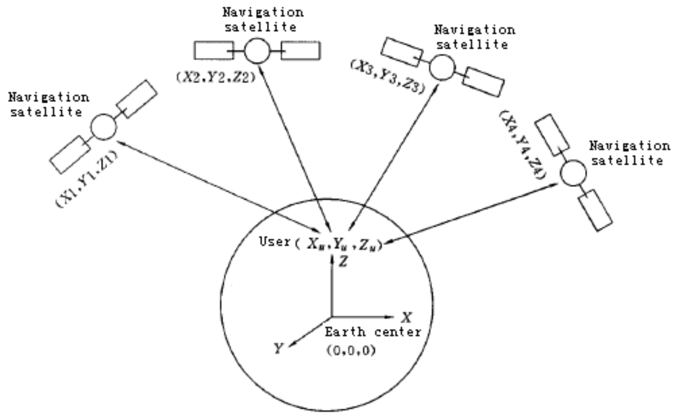

Figure 5. Principle of GPS positioning

The method which used to determine the distance from satellite to user is that producing a pseudorandom code sequence firstly which matches the same sequence which transmitted by satellite. Then the time which needed to transmit satellite code sequence to receiver can be acquired by means of the adjustment. At last, we can calculate the distance between satellite and user by means of the calculated time and known signal speed. [6]

4. Other global positioning systems

The current global positioning systems include GPS of America and GLONASS of Russia. Compass navigation satellite system of China is the active three-dimensional satellite positioning and communication system which developed by China alone. It is the third business satellite navigation system after GPS and GLONASS. Compass navigation satellite system has sent six pieces of satellites, and it will be developed the global satellite navigation system in 2015.

5. References

[1] WU Cheng-dong, ZHENG Jun-gang, Study on Smart Home Network Technology Based on Wireless Sensor Network[J], JOURNAL OF SHENYANG JIANZHU UNIVERSITY(NATURAL SCIENCE), 2005 21(6)

[2] LIU Xiao-qiu, XUE Lei, Application of blind source separation in radio surveillance[J], SYSTEMS ENGINEERING AND ELECTRONICS, 2006 28(11)

[3] TANG Zai-jiang, WANG Hao, Research on Modeling and Simulation for Radio Communication and Its Jamming[J], JOURNAL OF ACADEMY OF ARMORED FORCE ENGINEERING, 2009 23(1)
[4] LI Xiao-hong ZHANG Da-fang, An Energy Efficient Topology Control for Ad Hoc Networks with Steered Beam Antennas[J], ACTA ELECTRONICA SINICA, 2010 38(6)
[5] YUAN Xiao-gang, HUANG Guo-ce, Adaptive Frequency Hopping Co-Site Interference Cancellation with Community Antenna and Pilot[J], JOURNAL OF BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS, 2009 32(5)
[6] Xu Yiqun, Structure Analysis of MEO Satellite Mobile Communication System[J], WIRELESS COMMUNICATION TECHNOLOGY, 2010 19(2)

How to cite this paper: Guohai Yang,"Principle of Satellite Navigation Orbit and Positioning", IJEME, vol.3, no.2, pp.40-45, 2013.