Development of Satellite Navigation in China

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Abstract — **China completed the first satellite navigation system at 2003. The system named Beidou is an active-mode regional navigation system. The service area of the system covers the east and south Asia. The functions of the system include positioning, short-data communications and time service. During the present time, China is constructing the second-generation satellite navigation system, which named Compass; it will be passive-mode global navigation system including 35 satellites. In addition, China joined Galileo Project some years ago.**

Ⅰ. CHINA'S FIRST SATELLITE NAVIGATION SYSTEM

On May, 2003，with the launch of the third navigation satellite, China has completed the first satellite navigation system. It is the third satellite navigation system established following GPS and GLONASS in the world. The system named Beidou, being an active-mode regional navigation system, is composed of three satellites, control center and several tens calibration stations.

A. Main parameters of the system

The system includes three geo-stationary satellites, which locate at 80ºE, 140ºE and 110.5ºE (backup), respectively. This service area of the system covers the east and south Asia (Longitude: 70ºE-140ºE, Latitude: 5ºN-55ºN). The uplink Frequency is 1610-1626.5 MHz and the downlink Frequency is 2483.5-2500 MHz. This system can provide the navigation service for limited users, and the number of the service is 150 per second [1].

B. The functions of the system

Positioning: The system can determine the user' position. The accuracy of positioning is less than 100m; the accuracy of differential positioning is less than 20m. The respond time from the user-sending signal to receiving positioning information is from 1s to 5s for different type users. The success rate at one positioning is greater than 95%. Fig. 1 simply shows the positioning.

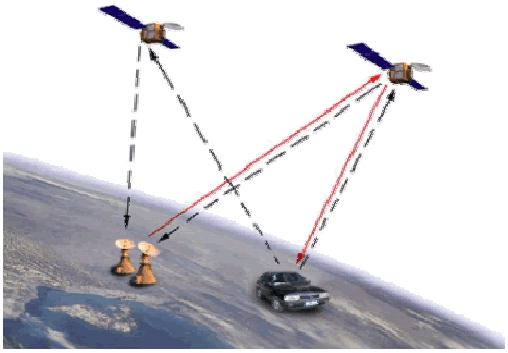

Figure 1 The positioning of Beidou system

Communication: The system has the ability of short-data communications between user and the control center. At most 120 Chinese characters can be

transmitted per time.

Time service: The standard time signal at the control center is firstly transmitted to the user, after that, the center can receive the respond signal from the timing terminal of the user, and figure out the path delay. At the end, the path delay together with the correct value of UTC and UT1 are again transmitted to the user. The accuracy of one-way method is less than 100ns. Besides, two-way time transfer between user and control center can also be achieved, and the accuracy is less than 20ns.

C. The positioning principle

The control center sends the inquire signal to the two satellites, and then relay it to the users via the transponder on the satellite. After user receives the signal from a satellite, the user sends the response signal to the two satellites, and the signal is relayed to control center. The center processes the user' requires and sends the positioning results to the user. The specific steps are as follows.

- Control center sends the inquire signal to the two satellites.
- The satellites receive the signal, and send the inquire signal to the service region.
- The user receives the inquire signal from one satellite, and sends the response signal to the two satellites.
- Two satellites receive the response signal, and relay it to control center.
- Control center receives the response signal, and demodulates the contents.
- Control center calculates the user' three-dimensional position, and sends the information to the satellite, or makes other processing.
- The satellites receive the information, and relay it to the user or other receiving sector.

The control center can measure two delays between the moment that user sends the respond signal and the moment that the satellite receives the signal. Since the positions of control center and two satellites are known, the two distances from user to satellites can be obtained. Thus, the user must be on the intersect curve of the two spherical of which the satellite is the center and the distances measured is radius. In addition, the control center can offer a digital map that is an uneven spherical, whose center is the center of the Earth, and the radius is the distance from the center to the Earth surface. By solving the intersect point between the curve and the uneven spherical, the three-dimensional position of user can be obtained.

D. The characteristics of the system

Since Beidou is independent navigation system, some important departments including military sector, may be free themselves from GPS.

Based on Beidou system, the regional augmentation of global navigation systems can be established, which will improve the positioning accuracy, increase the availability and integrity and continuation of services for aircraft navigation.

The system is very suite to the situation of the positioning together with mobile communication. Based on the communication function, the control departments can timely track, supervise and dispatch some users. Especially, it can promote services for sectors of transportation, meteorology, petroleum production, forest fire prevention, disaster forecast and public security [2].

Because the user must be active, namely it must have the ability of transmitting the signals, and because the calculation of the positioning must be at the control center, the system has some disadvantages, such as, the cost of use is high, and the condition of use is limited. When the user emits the signals to the satellite, it is easy to expose its position, so the safety

is particularly endangered to military users. In addition, the system is no inter-operability with other navigation systems.

Ⅱ. CHINA'S SECOND GENERATION SATELLITE NAVIGATION SYSTEM

A. The current status

China has started to expand its current Beidou system, already operational and providing coverage of the China. The enhanced system will cover China and parts of neighboring countries by 2008 before developing into a global system. The latest iteration of the Beidou, to be known as Compass, will include 27 medium earth orbit (MEO) satellites, 3 inclined geosynchronous orbits (IGSO) and 5 geostationary earth satellites (GEO). Fig. 2 simply shows a simulative configuration of Compass satellites.

Figure 2 Simulative Compass satellites

The table 1 gives the constellation parameters in Compass system. Each satellite transmits the same four carrier frequencies for navigational signals, which are modulated with a predetermined bit stream, containing coded ephemeris data and time, and having a sufficient bandwidth to produce the necessary navigation precision without recourse to two-way transmission or Doppler integration [3].

TABLE CONSTELLATION PARAMETERS IN COMPASS SYSTEM

Constellation	GEO (5), IGSO (3), MEO (27)
GEO longitudes	*58.75°, 80°, 110.5°, 140° and 160°*
IGSO equatorial crossing	*118°*
Eccentricity	*0*
IGSO inclination	*55°*
MEO inclination	*55°*
MEO altitude	*21500 km*

The Compass system will provide two navigation services. The "open service" is designed to provide users with positioning accuracy with 10 meters, velocity accuracy with 0.2 meter per second and timing accuracy within 50 nanoseconds. An authorized service will offer "safer" positioning, velocity, and timing communications for authorized users. These subscribers will obtain the services on a more secure network, along with additional information about system integrity.

Besides three GEO satellites launched, April 14, 2007, A MEO inclination navigation satellite (Compass-M1) was launched.

The will of China to develop its own global navigation system is clearly reflected in the policy document released by the State Council Information Office on October 12, 2006, which stated that China will independently develop application technologies and production in applying satellite navigation, positioning and timing services. Compass could begin operation in 2012 if the political statements are brought into reality.

B. On several types of satellites

Geo-stationary satellite (GEO): For the regional service, the utilization ratio of GEO is the most high. But, since GEOs are in the equatorial plane, according to the geometry among GEOs and user, it is impossible only to use GEOs for establishing a passive-mode navigation system due to the GDOP (or PDOP) being infinite. It is necessary that the constellation include the satellites with high inclination.

Inclined geosynchronous satellite (IGSO): The satellite is with high inclination and 24hours period. Using several GEOs and IGSOs can construct a regional passive-mode navigation system. However, the performance in marginal region of the service will decrease, and it is not easy to enlarge the regional system to the global system.

Medium earth orbit satellites (MEO): The period of the satellite is about 12 hours. A global navigation system at least needs 24 MEOs. However, for China's regional navigation system, "12 MEOs + 4 GEOs" is enough. By adding the MEO to 24, the regional system can become a global system with regional augmentation. And due to

1) The principle between regional system and global system is the same.

2) Regional constellation can easily be enlarged to global constellation.

3) That "regional" becomes "global" will be steady, no effect to users, and at the lowest price.

So, the scheme for "regional" to become "global" is more practical way than others.

III. CHINA JOINING GALILEO PROJECT

Compared with GPS, the positioning accuracy and security of Galileo navigation system may have greater superiority. Such as, the positioning accuracy will reach 1m, which is higher than an order of that of GPS. China shows high enthusiasm for Galileo project. The "China-Europe Global Navigation Satellite System Technical Training and Cooperation Center" set up marks the beginning of the cooperation in the project. Although it is the biggest science and technology cooperation program between China and EU, China's participation is only equivalent to one EU member. China will invest 230 millions (Euro), and it will attend the cooperation in the fields of satellite launching and manufacturing, experiment on the environment of radio transmission, ground systems, the standards for receivers etc.

China's huge market provides promising prospects for the project. China's hundred million mobile phones users and its rapidly growing number of autos can expand Galileo's market. On the other hand, Beidou system is only an active-mode regional navigation system, moreover, the global navigation system is a space infrastructure facility, and China is now making great efforts to become a space power country in the 21st century, so, to possess own global navigation system is eventual aim. The cooperation will thus significantly help China to attain the goal.

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