Analysis of Galileo and GPS systems

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ABSTRACT

This paper describes key points in the field of Galileo application abroad spacecraft and normal vehicles. On the basis of ephemeris of Galileo constellation, the mathematic model and procession are given in high dynamic signal environment, the digital simulation is also completed, the results are statistics and analyzed and presented. On the topic of navigation satellite constellation orbit and visibility, the paper presents the Galileo frame system, time system, navigation satellite orbit elements, constellation structure, and GDOP calculation. The users include low dynamic as well as high dynamic spacecraft. The analysis for relevant GPS is also showed. About the navigation signal structure, main points are Galileo system working frequency, including E5, E6 and L1 frequency spans, the modulation and navigation data, ets. At the same time, this paper compares Galileo with GPS. On the aspect of signal communication link, Dopplar frequency shift and power level calculation are present as well as compare with GPS system.

KEYWORDS

High-Dynamic, GDOP, Budget Link, Galileo, GPS

INTRODUCTION

With the normal start of Galileo navigation system, there will be two radio global positioning navigation system in the world-GPS and Galileo systems. How to apply these systems, especially under the high dynamic environment, is a key and difficult project to complete. This paper analyzes and compares in detail these global satellite navigation systems and their applications for high dynamic users such as a launching spacecraft. Together with defined space mission, simulation and analysis are finished. The background of the project is the pre-research of China satellite navigation system.

According to the design of Galileo constellation, two scenarios were selected for investigated: the user is under high dynamic environment such as spacecraft, including launching period and another one is in-orbital period.

The compatibility and Interoperability of Galileo and GPS are also well analysized. Afterwards detailed considerations of the constellation and signal in space are presented. Results from the different users analyses are discussed and showed. The result shows that Galileo in the design phase has its more advantages than GPS.

The figures and results are very important to design the Galileo receiver and simulator, especially for the bigger Dopplar frequency shift, which means the user is under high-dynamic environment, the circuit and tracking acquireed and positioning algorithms must be considered.

GALILEO CONSTELLATION ANALYSIS

Galileo constellation is different from GPS system. Galileo constellation will comprise 30 MEO navigation satellites, which has been optimized considering the various requirements. The design of the Galileo constellation can reach 99.7% availability level. The orbital parameters are showed in table 1.

Table 1 Galileo and GPS Orbital Parameters

	Galileo	GPS
Orbital plane	3	6
Number of one plane	10	4
Semi-major Axis (km)	29602	26400
Eccentricity	0	0
Inclination (deg)	56	63

In the ECI classical Frame (J 2000), it is easy to find the differences between two systems orbits. It is necessary to compare the Coordinate Reference Frame and Time Reference Frame.

Table 2 Coordinate Reference Frame

	Galileo	GPS
Name	GTRF	WGS-84
Standard	ITRS	ITRS
Established by	IERS	IERS

It is clear that the difference (Table 2) betweenWGS84 and GTRF are to be only few cm [2]. This accuracy is sufficient for our spacecraft mission research and simulation.
The Time Reference Frame is another important factor we have to consider about, especially for the spacecraft navigation and positioning mission, The two Time systems comparison is showed as table 3.The difference between the GST and TAI, GST and UTC shall be broadcasted to the users via the ephemeris and almanac.

Table 3 Coordinate Time Frame

	Galileo	GPS
Name	GST	UTC(GPS)
Standard	TAI	UTC

The situation of Galileo positioning application onboard spacecraft is quite different from that under the low dynamic environment, for example, the car and ship. The high relative velocity between the user spacecraft and Galileo satellites leads to the visibility and DOP values changes quickly. From the following figures with respect to specific satellite launching period and in-orbit period simulation, the conclusion can be got. The results are presented in Figure 1.

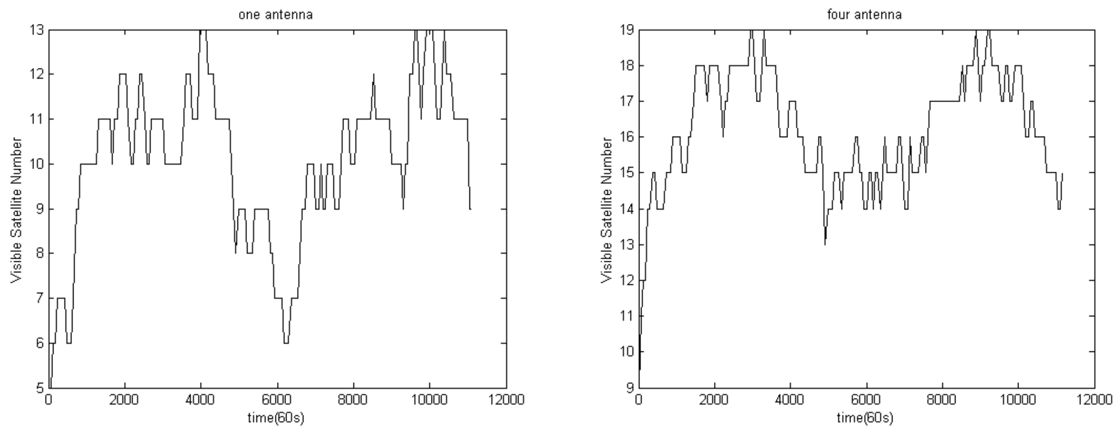

Figure 1: the number of visible satellite for the high-dynamic spacecraft launching and in-orbital periods under30-MEO Galileo constellations (one and four antenna)

From Figure 1 it is evident that the visible Galileo satellite from the spacecraft body frame is changing, which is the main reason why the fast-satellite-selection algorithm for high-dynamic should be considered in the flight mission. Comparing with the GPS, at the same situation, the results are better.

DOP (Dilution Of Precision) is also completed for the Galileo and GPS, considering the stand-alone and compatibility. Figure 3 presents the DOP values when the receiver onboard spacecraft has one antenna, Galileo shows the better positioning precision (DOP) than GPS. From this point we can improve the positioning precision for users. The compatibility of four antennas shows a very nice improvement on the accuracy.

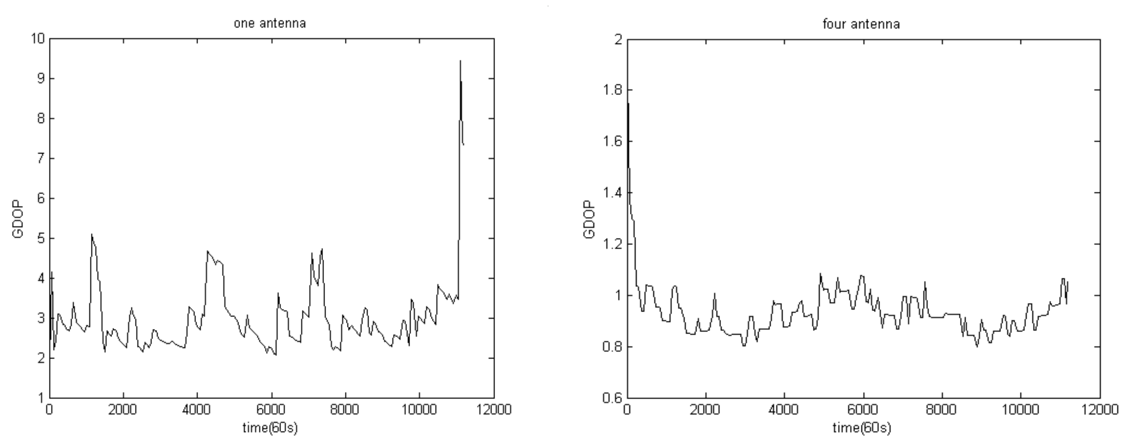

Figure 2: GDOP values for the high-dynamic spacecraft launching and in-orbital periods under30-MEO Galileo constellations (one and four antenna)

GALILEO SIGNAL IN SPACE LINK BUDGETS

Galileo will provide 10 navigation signals in the frequency ranges E5a-E5b,E6, and E2-L1-E1, Table 4 shows the carrier frequency , type of modulation, the chip rate and the data rate of each signal.

Table 4 Galileo Signal Structure

Freq. band	E5a	E5b	E6	E2-L1-E1
Range (MHz)	1164	1215	1215-1300	1559-1592
Channel	I Q	I Q	A B C	A B C
Modulation Type	TBD (BPSK)	TBD (BPSK)	A—BOC B—BPSK C—BPSK	A—BOC B—BOC C—BOC
Chip rates (Mcps)	10 10	10 10	5.115	1.023 2.046
Symbol rates (sps)	50 N/A	250 N/A	TBD	TBD
Spreading codes	CDMA			
Service mapping	OS DF OS IA SoL CS MC	OS IA SoL CS MC	PRS CS VA CS MC	OS SF OS DF OS IA SoL CS VA CS MC PRS

When the spacecraft is launching, with along the velocity is getting bigger and bigger, the relative Dopplar frequency shift is changing, which is the main reason for the Galileo receiver acquiring and tracking circuit. If the receiving signal power is too low or Dopplar frequency shift changes too sharply, the circuit will be lose the signal, how to lock the signal is one first task on the space flight mission. So the link budgets between navigation satellite and spacecraft is calculated

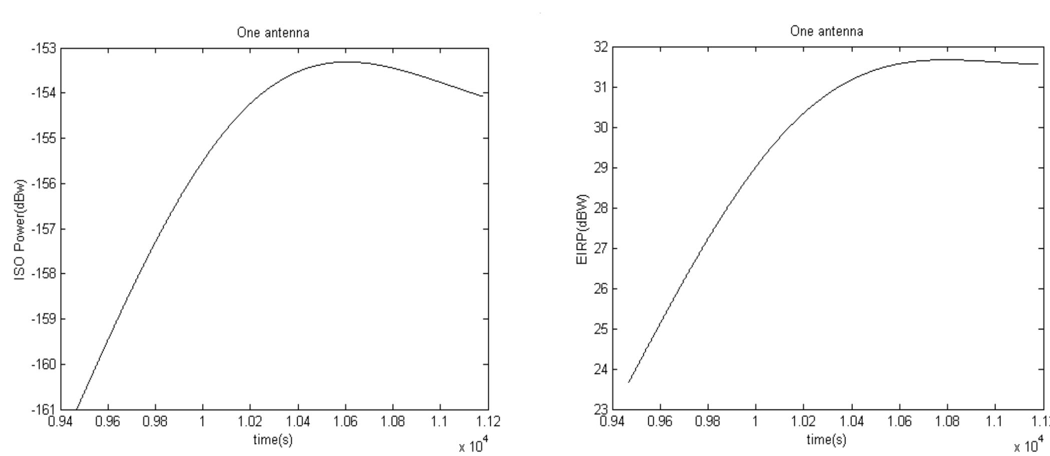

Figure 3: EIRP and Power values

Figure 3 implies that power received by spacecraft receiver ranges from –153 dBw to –160 dBw, which is similar to GPS power level comparing with the actual flight test data.

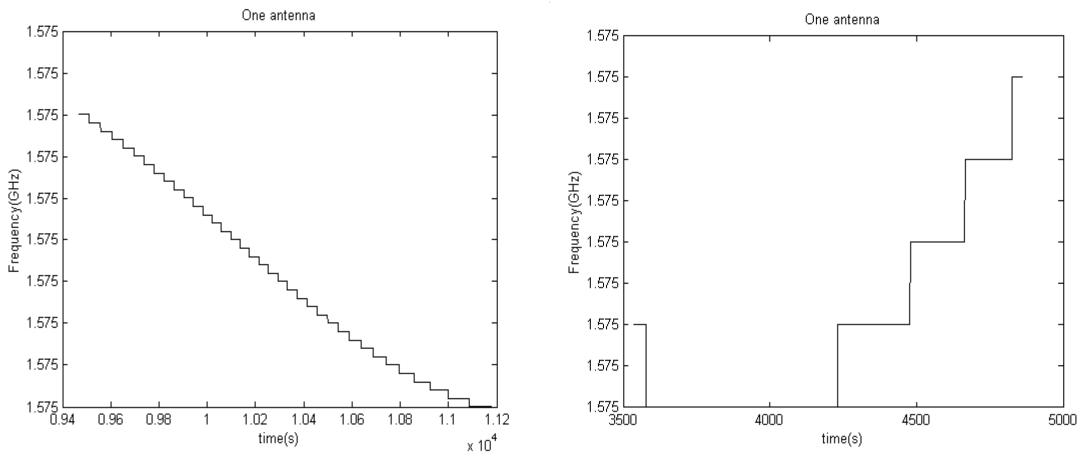

Figure 4: High-dynamic signal Dopplar frequency shift value

High-dynamic link budgets show that Dopplar frequency is a necessary factor we must consider to a spacecraft Galileo receiver loop design.

CONCLLUSION

The satellite constellation and signal link budget with respect to high dynamic spacecraft user are described in detail. The data shows that Galileo has its system advantages on satellite orbits and links design.

REFERENCES

(1) Hein G.W., J.Godet, J.-L.Issler,J.-Chr. Martin, R.Lucas-Rodriguez and T. Pratt " The Galileo Frequency Structure and Signal Design", Proc. of ION GPS 2001, Salt Lake City, September 2001,pp.1273-1282. 2001

(2) J.Benedicto, S.E.Dinwiddy, G.Gatti, R. Lucas, M. Lugert "GALILEO: Satellite System Design and Technology Developments", European Space Agency, Vov. 2000

(3) Eissfeller, B., G. W. Hein, J. Winkel and Ph. Hartl "Requirements on the Galileo Signal Structure", Paper presented at the GNSS Symposium, Edinburgh, UK. 2000