MULTI FREQUENCY GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

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ABSTRACT

Multi frequency Global Navigation Satellite System (GNSS) is an important tool for using and investigating earthquakes, ionosphere, and communications. It is very significant understanding and applying on the multi frequency GNSS for supporting and solving in positioning and locating around and everywhere on the earth. GNSS is used as a support for seismo-ionospheric coupling for earthquake monitoring. GNSS finds the Total Electron Content (TEC) in the ionosphere. In communications, GNSS solves the delay time which is depended on the signal path from space to the earth. So, it is very significant understanding and applying on the multi frequency GNSS.

Keywords: GNSS; Multi frequency GNSS; GNSS frequency

I. INTRODUCTION

GNSS satellite is a key role in positioning and locating around and on the earth. At the present, rarely in research, GNSS is a main technique to classify geodetic methodology. Three types of research using GNSS are presented in earthquakes, ionosphere, and communications. For earthquake monitoring, GNSS is used as a support for seismo-ionospheric coupling. For ionosphere, GNSS is used for finding the Total Electron Content (TEC) in ionosphere. In communications, GNSS is used for solving the delay time which is depended on the signal path from space to the earth.

An et al. (2020, p. 7) researched on the multi-constellation GNSS precise point positioning with multi-frequency raw observations and dual-frequency observations of ionospheric-free linear combination. Huang et al. (2020, pp. 21-24) studied on efficient FPGA implementation of a dual-frequency GNSS receiver with robust inter-frequency aiding. Kim et al. (2021, pp. 10-20) reported the area-efficient universal code generator for multi-GNSS receivers. Krypiak-Gregorczyk (2019, pp. 931-951) found that the ionosphere response to three extreme events occurring near spring equinox in 2012, 2013, and 2015, observed by regional GNSS-TEC model. The fact is found out about carrier phase bias estimation of geometry-free linear combination of GNSS signals for ionospheric TEC modelling (Krypiak-Gregorczyk & Wielgosz, 2018, p. 45). Li et al. (2019, pp. 399-417) investigated the geometry-based cycle slip and data gap repair for multi-GNSS and multi-frequency observations. Lyu and Gao (2020, pp. 20-24) worked in an SVM based weight scheme for improving kinematic GNSS positioning accuracy with low-cost GNSS receiver in urban environments.

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In addition, Odolinski and Teunissen (2020, p. 91) analyzed on the best integer equivariant estimation: performance analysis using real data collected by low-cost, single-and dual-frequency, multi-GNSS receivers for short- to long-baseline RTK positioning. Moreover, Sreeja (2016, p. 24) found the impact and mitigation of space weather effects on GNSS receiver performance.

Above research about GNSS information is advantages in using multi frequency for earthquake, ionosphere, and communications. The main advantages associated with the use of GNSS systems in the study of anthropogenic and natural phenomena monitoring are widely used with a network of permanent reference stations. In addition, differential solutions which are required the use of a permanent stations are often used in above studies.

Multi frequency GNSS is an important tool for using and investigating earthquakes, ionosphere, and communications. It is very significant understanding and applying on the multi frequency GNSS for supporting and solving in positioning and locating around and everywhere on the earth.

II. GNSS REVIEW

GNSS is Global Navigation Satellites System which is the satellite network for positioning the location around and on the earth. GNSS has continuedly transmitted the signal to the GNSS receiver which can be received the data 24 hours a day. At the present, there are six GNSS systems, GPS (USA), GLONASS (Russia), Galileo (Europe), BeiDou (China), Quasi-Zenith Satellite System: QZSS (Japan), and Regional Navigation Satellite System: IRNSS (India) as shown in Table 1.

Table 1: GNSS information.

System	Country	Frequency	Number of Satellites	Orbit height (km.)	Covered Area
GPS	USA	- L1/1575.42 MHz - L2/1227.60 MHz - L5/1176.45 MHz	24 reserved 8	20,200	World
GLONASS	Russia	- G1/ 1602 MHz - G1a/ 1600.995 MHz - G2/ 1246 MHz - G2a/ 1248.06 MHz - G3 / 1202.025 MHZ	24 reserved 3	19,100	World
GAlileo	Europe	- E1 / 1575.42 MHz - E5a / 1176.45 MHz E5b / 1207.140 MHz - E5(E5a+E5b) / 1191.795 MHz - E6 / 1278.75 MHz	24 reserved 6	23,222	World
QZSS	Japan	- L1 / 1575.42 MHz - L2 / 1227.60 MHz - L5 / 1176.45 MHz - L6 / 1278.75 MHz -	4	32,000 - 40,000	Japan and Eastern Asia

Table 1: GNSS information (Cont.).

System	Country	Frequency	Number of Satellites	Orbit height (km.)	Covered Area
BeiDou	China	- B1 / 1561.098 MHz - B1C / 1575.42 (BDS-3 Signals) - B1A / 1575.42 MHz (BDS-3 Signals) - B2a / 1176.45 MHz (BDS-3 Signals) - B2 / 1207.140 MHz (BDS-2 Signals) - B2b / 1207.140 MHz (BDS-3 Signals) - B2(B2a+B2b)/1191.795 MHz (BDS-3 Signals) - B3/1268.52 MHz (BDS-2/3 Signals) - B3A / 1268.52 MHz (BDS-3 Signals)	41	7 GEO 35,786 7 IGSO reserved 3 35,786 21 MEO reserved 6 21,528	World
IRNSS	India	- L5 / 1176.45 MHz - S / 2492.028 MHz	6 reserved 1	36,000	India and neighbouring in 1,500 km.

III. MULTI FREQUENCY GNSS

GNSS composes of the Global Positioning System (GPS) of the United States, the Global Navigation Satellite System (GLONASS) of Russia, the Galileo system of the European Union, the BeiDou Navigation Satellite System (BDS) of China, Quasi-Zenith Satellite System (QZSS) designed by Japan, and India Regional navigation Satellite System (IRNSS) operated by India. GNSS has the advantages of earthquakes, ionosphere, and communications. GNSS provides highly precise positioning, navigation, and timing services for users all over the world. GPS uses L5 (1176.45 MHz) apart from L1 (1575.42 MHz) and L2 (1227.60 MHz). Besides, some GLONASS satellites can transmit the signal G1 (1602 MHz) and G2 (1246 MHz). The Galileo system run by the European Space Agency (ESA) provides services through frequency signals centered at E1 (1575.42 MHz) and E6 (1278.75 MHz). The BDS uses B1 (1561.098 MHz) and B2 (1207.14 MHz) signals. The QZSS designed by Japan transmits frequency signals centered at L1 (1575.42 MHz) and L2 (1227.60 MHz). Moreover, IRNSS operated by India transmits two frequency signals centered at L5 (1176.45 MHz) and S (2492.028 MHz) as shown in Table 2 and Table 3.

Table 2: GNSS Carriers.

GNSS	Carrier
GPS	L1CA, L1P, L1C, L2C, L2P, L5
GLONASS	G1CA, G1P, G2CA, G2P, G3 CDMA
Galileo	E1, E1b, E5a, E5b, E6, E5-AltBoc
BeiDou	B1I, B1C, B2a, B2b, B2I, B3I
QZSS	L1CA, L1C, L1S, L2C, L5, L6
IRNSS	L5, S

Table 3: GNSS frequency and frequency length.

GNSS	Frequency		Frequency length	
	f_1	f_2	λ_1	λ_2
GPS	1,575.42	1,227.60	0.1902	0.2442
GLONASS	1,602.00	1,248.60	0.1871	0.2401
Galileo	1,575.42	1,278.75	0.1902	0.24344
BeiDou	1,561.098	1,207.140	0.1920	0.2483
QZSS	1,575.42	1,227.60	0.1902	0.2442
IRNSS	2,492.028	1,176.45	0.1203	0.25482

IV. GNSS RECEIVER

In order to receive signals from GNSS satellites, GNSS receivers are needed for this purpose. There are many GNSS receivers in the markets that can be used. However, the full function of GNSS receiver has to use as a multi frequency GNSS receiver. In Table 4, GNSS receivers are shown in different supports and manufacturers.

Table 4: GNSS receiver.

GNSS receiver	GNSS support
 SATLAB GNSS SLX1-NG	- GPS (L1C/A, L1C, L2C, L2P, L5) - GLONASS (L1C/A, L2C/A, L2P, L3, L5) - Galileo (E1, E5 AltBOC, E5A, E5B, E6) - BeiDou (B1, B2, B3) - IRNSS (L5) แบบ QZSS (L1C/A, L1C, L2C, L5, L6) - SBAS (L1, L5) - L-Band (up to 5 channels)
 ComNav GNSS M300 Pro	- GPS (L1, L2, L2C, L5) - GLONASS (L1, L2, L3) - Galileo (E1, E5 AltBOC, E5a, E5b) - BeiDou (B1, B2, B3)

Table 4: GNSS receiver (cont.).

GNSS receiver	GNSS support
 Novatel GNSS PwrPak7D™	- GPS (L1 C/A, L1C, L2C, L2P, L5) - GLONASS (L1 C/A, L2 C/A, L2P, L3, L5) - Galileo (E1, E5 AltBOC, E5a, E5b) - BeiDou (B1I, B1C, B2I, B2a, B2b) - QZSS (L1 C/A, L1C, L1S, L2C, L5) - IRNSS (L5)
 VERIPOS GNSS receiver LD900	- GPS (L1 C/A, L1C, L2C, L2P, L5) - GLONASS (L1, L2, L3) - Galileo (E1, E5 AltBOC, E5a, E5b) - BeiDou (B1I, B1C, B2I, B2a, B2b) - QZSS (L1 C/A, L1C, L1S, L2C, L5)
 Bynav Technology GNSS receiver X1-6 RTK	- GPS (L1 C/A, L2C, L2P) - GLONASS (G1,G2) - Galileo (E1, E5b) - BDS (B1I,B2I) - BDS-3 (B1C, B2a) - QZSS (L1 C/A, L2C) IRNSS (L5)
 CHCNAV AVAZADA GNSS P5E	- GPS (L1 C/A, L2C, L2E, L5) - GLONASS (G1,G2) - Galileo (E1, E5A, E5B, E5AltBOC, E6(2)) - BDS (B1, B2, B3(2)) - BDS-3 (B1C, B2a) - QZSS (L1 C/A, L2C)

V. CONCLUSION

The study on multi frequency GNSS is very important understanding for supporting and solving in positioning and locating around and everywhere on the earth. GNSS is used as a support for seismo-ionospheric coupling for earthquake monitoring, finding TEC for the ionosphere study, and solving problems in communications. In the future, the number of multi frequency GNSS will increase, the number of GNSS users will add more, too. So, it is not too late to get the knowledge on the multi frequency GNSS.

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