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IJIEMR Transactions, online available on 13th June 2022.
Link : https://ijiemr.org/downloads/Volume-11/Issue-06

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volume 11, Issue 06, Pages: 1603-1606

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Multi-GNSS Real-Time Data Analysis Using SBF Analyzer

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***Abstract*—GNSS constellations such as the Global Positioning System(USA), GLONASS (Russia), Galileo (European Union), and BeiDou (China) have been continually sending radio signals on numerous frequencies for PVT applications on or over the whole planet. Countries such as India (IRNSS) and Japan (QZSS), on the other hand, are developing their own regional systems with limited service areas. Position and navigation data become more robust and stable when many constellations with high-quality signals looks into signal quality to identify strong/important signals as well as satellite geometry for the combined use of global and regional constellations across the Indian subcontinent. Data from 'Septentrio PolaRx5' receiver stations deployed at GPCET, Kurnool (150.47'N,780.04E) were used to obtain real-time signal observations. The user over this region can receive signals from a minimum of 60 satellites with a Position Dilution of Precision (PDOP) value less than unity, according to the results.**

I.INTRODUCTION

Because it is more powerful technique or strategy for precise Position, Navigation and Time(PNT) estimation ,many countries have been creating their own satellite-based navigation systems. The Global Positioning Systems (GPS) of the United States and the global Navigation Satellite Systems(GLONASS),are completely operational[1,2].The European Union's(EU) Galileo and China's BeiDou are both in the works. All four systems are designed to provide PNT services anywhere on the planet. In addition to these global systems, India and Japan have been working on their own satellite navigation systems, the Indian Regional Navigation Satellite System(IRNSS) and the Quasi-Zenith Satellite System(QZSS), which have a limited service area confined to their respective countries and environs[3,4]. As a result, users in the Indian subcontinent can always receive signals from GPS, GLONASS, Galileo, BeiDou, IRNSS, and one or two QZSS satellites. Table 1 lists various GNSS signals that may be available across the Indian Latitude.

TableISignals and frequency bands of multiple GNSS constellations

Constellation	Signal	Frequency Band/ Frequency (Mhz)	No.of Satellites in Operation
GPS	L1 C/A L1 P(Y) L2 P(Y) L2C L5	L1/1575.42 L2/1227.60 L5/1176.45	31
GLONASS	L1 C/A L1 P L2 P L2 C/A L3	L1/1602+K*9/16 K=-7….+12 L2/1246+k*716 L3/1202.025	24
Gallileo	L1 BC E5a E5b E5 E6BC	L1/1575.42 E5a/1176.45 E5b/1207.14 E5/1191.795 E6/1278.75	18
BeiDou	B1 B2 B3	B1/1561.098 B2/1207.14 B3/1268.52	17
IRNSS	L5 S	L5/1176.45 S/2492.028	07
QZSS	L1 C/A L2 C L5	L1/1575.42 L2/1227.60 L5/1176.45	04

Over India, the IRNSS constellation comprises of four geosynchronous and three geostationary satellites that transmit signals in the L and S bands for location, navigation, and time purposes[6]. However, GNSS signal strength drops in metropolitan areas and dense vegetation environments, and the receiver may receive an inadequate number of signals to ensure good Dilution of Precision (DOP). Because there aren't enough satellites, services continuity is also being disrupted. The following mathematical equation [7] can be used to calculate the carrier-to-noise density ratio (C/No) of a GNSS signal.

$$C/N_0\,(dB-Hz) = C-(N-BW) \quad (1)$$

$$C-N_0 = SNR+BW$$

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Where, C is the carrier power in dBm or dBw, N is the noise power in dBm or dBw, N_O = noise power density in dBm-Hz or dBw-Hz and BW is the bandwidth of observation

The quality of GNSS geometry at a particular location and time is determined by GDOP, which may be estimated using the formulae [8,9].

Table II Mathematical expressions for various DOPs

S.No	DOP	Mathematical expression	Significance
1	PDOP	$PDOP = \frac{\sqrt{\sigma_E^2+\sigma_N^2+\sigma_U^2}}{\sigma} = \sqrt{D_{11}+D_{22}+D_{33}}$ $PDOP^2 = HDOP^2 + VDOP^2$	Provides accuracy Degradation in 3D position
2	HDOP	HDOP=$\frac{\sqrt{\sigma_E^2+\sigma_N^2}}{\sigma} = \sqrt{D_{11}+D_{22}}$	Provides accuracy Degradation in Horizontal Direction
3	VDOP	VDOP=$\frac{\sigma_U}{\sigma} = \sqrt{D_{33}}$	Provides accuracy Degradation in Vertical Direction
4	TDOP	TDOP =$\frac{\sigma_T}{\sigma} = \sqrt{D_{44}}$	Provides accuracy Degradation in Time
5	GDOP	$GDOP^2 = PDOP^2 + TDOP^2$	Provides accuracy Degradation in Position and Time

$\sigma_E^2, \sigma_N^2, \sigma_U^2$ = variances of east, north and up components of receiver position, σ_T^2 = variance of receiver clock offset, σ = standard deviation of pseudo range measurement error plus residual model error.

For healthy and sufficiently separated satellites, the GDOP value is minimal. Its also ideal for highly specific applications,. Multiple GNSS system integration with GNSS could improve DOP for quality pf service by improving availability , precision , and consistency [10,11]. However , before combining seversl GNSS or regional systems, it is necessary to understand the differences between them. The major goal of this study is to look at the visibility of several constellation satellites and find out which ones have strong signals. In addition , DOP values for the combinations of GPS+GLONASS+Galileo+BeiDou+SBAS+QZSS+IRNSS and IRNSS+GPS were estimated and analysed.

This research examines the performance of multi-GNSS systems by analysing several constellation signals with real-time data. Integer ambiguity, on the other hand, is a key issue that is managed by the inter system biases.

II.Septentrio Binary Format Analyzer

SBF Analyzer is a programme that may be used to create time graphs from an SBF(Septentrio Binary Format) file generated by a Septentrio GNSS receiver. There are 5 features in SBF Analyzer that we find are particularly helpful when generating time plots for troubleshooting and analysis.

1.Filtering Large SBF Files :

When working with large SBF files (<100MB) in SBF Analyzer, the data can be filtered to increase the speed at which plots are generated. Figure 4.1 shows the options available for filtering data when generating time plots. First select the “Filter data” checkbox to display the available options. You can then select the “Restrict time interval” and /or “Subsampling” checkboxes. The time interval can be restricted to specific start and/or end points. The subsampling interval can be changed to one of eight available options ranging from 0.2 to 60 seconds.

2.Using Plot Options :

Each available plot in SBF Analyzer offers unique options for customization. This allows the user to generate the plot in the optimal format which contains data most critical for review. To edit plot options, select the plot of interest followed by the Plot Options.

The plot options window is unique for each available plot. Figure 6 shows an example of the plot options available for the “MPx (Multipath)” plot. Up to four plots can be generated in a single window. Two plots will be generated from the example in Figure 4.3 the first for GPS satellites and the second for GLONASS. The signal combinations (ex. GPS L1-C/A-L2-P(Y)) used to compute MPx over time can be changed for each constellation.

3.Data Statistics :

You can generate a table of statistics for a dataset from an open time plot. This can be done by selecting the “view” menu, followed by “Dataset Statistic”.

4.Generate Plots from GNSS or INS Solutions only :

For users of septentrio INS products, an SBF file may contain PVT data for both the INS solution and the GNSS only solution. SBF Analyzer will automatically select either the INS or GNSS solution for generating plot. The “Heading, Pitch Roll (HPR)” plot for instance will be generated using data from the INS solution by default if data is included in the SBF file. A user may instead want to generate a timeplot for the heading computed by the GNSS only solution.An option can be selected in SBF Analyzer to generate time plots from either the INS or GNSS solutions only. To change this option, open the “File” menu and select “Preferences”.From the Preferences window, select the “Preferences” menu as shown in Figure 4.6. You will then find a dropdown menu titled “Position/Velocity/Attitude selection”, here you can change the time plots to be generated from either the INS or GNSS solutions only. Select the “OK” button, the all the plots which are generated will reference the selected PVT solution.

5.Reference Position :

The "Relative East, North, Up (ENU)" time plot provides the computed position in ENU format relative to a specified reference point. This reference point can be defined in SBF Analyzer by first selecting File > Preferences (Figure 4.5). Next select the "Reference" menu on the left-hand side of the window. Here you are able to enter the reference position using either geodetic or cartesian coordinates.The "Use Mean" button can be used to easily set the reference point at the mean position over time.

III.Results and Discussion

All the satellites of multiple constellations broadcast signals continuously towards the earth in all weather conditions. The Effective Iosotropic Radiated Power (EIRP) of the satellites trnsmitting antenna is same for all the satellites in one constellation. However, signals from different satellites will undergo different environment when broadcasting to the receivers. Satellite to receiver path length, disturbances in the propagation medium vary from satellite to satellite. Since, the pathloss is function of pathlength and propagation medium characteristics the received signal strength is not same for all the satellites. The rapid changes in the received signal strength degrades the performance of receiver code and carrier phase tracking loops by introducing error in the measurements. Sometimes, receiver losses signal lock which causes degradation of availability. In this research work, the quality of received signal strength is measured interms of C/No for multiple GNSS constellations.

A. Number of SVs tracked

The number of satellites visible to the multi-GNSS antenna at GPCET IN Kurnool, India, throughout a 24-hour period. A mininum in view over 24-hours to the muti-GNSS antenna mounted at GPCET, Kurnool, India. The users in this region can get a minimum of 60 satellite signals from all constellations, including GPS, GLONASS, Galileo, BeiDou, IRNSS, QZSS and SBAS, are available to users in this region. Typically, a receiver can track signals from 62 or 63 satellites. Sixty percent of the available satellites (62 total) have an elevation angle greater than 30 degress. The receiver, on the other hand, can receive signals from seven IRNSS satellites at an altitude of more than 250 meters. Three gepstationary and four geosynchronous satellites make up the IRNSS constellation. 8 to 12 satellites from GPS constellation are always visible. For PVT calculations, 30-40 satellite signals are available in total. The results demonstrate that combing various constellations could improve service availability by increasing the number of satellites available. So that users can continue to receive services even if there id bad weather in space or in the city. When GPS and IRNSS are combied, a minimum of 15 satellite signals will be available.

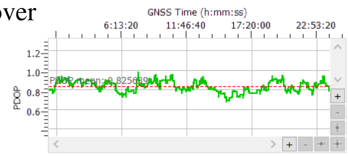
B. Carrier-to- Noise Density ratio

The IRNSS constellation signal strength variation in terms of C/No with GNSS time during a day (24 hours). IST is equal to GNSS time + 5:30 Hrs. The mathematical expressions used to calculate C/No are given in eqn (1).It can be observed that the C/No of any GEO satellite is almost constant for all the time because the orbital period of the satellites and earth is same. However, the received signal strength is not same for all GEO satellites because they are placed at three different locations in the orbit. Further, for GSO satellites C/No varies with elevation angle of the satellite. C/No is maximum at high elevation angles and it is minimum at low elevation angles. This is because of longer path length at the low elevation angles and reduced path length at high elevation angles. Users over this region can get a maximum C/No from IRNSS GEO satellites is greater than 51 dB-Hz and the minimum is 44 dB-Hz. From GSO satellites users can get signal power in between 44 dB-Hz and 51 dB-Hz. The maximum received signal strength from GPS satellites which were located in MEO is 51 dB-Hz and the minimum is 20 dB-Hz. The results show that the IRNSS satellites signals are stronger than the GPS satellites though the GPS satellites were located at shorter distance (20100 Kms) compared to the IRNSS satellites (36000 Kms). For other constellations (GLONASS & Galileo) also the maximum C/No is 50 dB-Hz minimum is 20 dB-Hz.This variation is due to the change in elevation angle of satellites.

Therefore, the C/No for IRNSS satellites is high compared to other constellations over the selected GNSS station with continuity greater than 99.9%.

C. Dilution Of Precision (DOP)

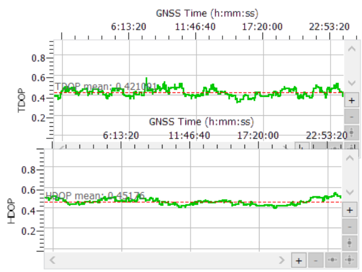
The majority of the real-time applications now require services that are available at all times and have a high DOP value. Because DOP is one of the key factors that influences GNSS accuracy. It displays the geometric strength of the satellites used in the PVT computation. Figure 1 shows how multi constellation geometry (PDOP, TDOP, HDOP, and VDOP) changes over time as a function of GNSS time.



(a)

(b)

(c)



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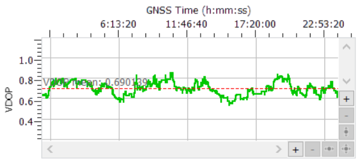

(d)

Figure 1 : Geometry of multi-Constellations (a) PDOP; (b) TDOP; (c) HDOP and (d) VDOP

Results show that PDOP value lies in-between the 0.8 and 1, means that the geometry of considered satellites is ideal and the accuracy of estimated position is high. The statistics of various DOPs are presented in the Table III.

Table III Statistics of multi- constellation DOP values

Dilution of Precision			
	Minimum	Maximum	Mean
PDOP	0.69	0.97	0.82
TDOP	0.32	0.56	0.42
HDOP	0.4	0.54	0.45
VDOP	0.53	0.84	0.69

Also, the PDOP value becomes greater than 2, if only greater than 30^0 elevation angle satellites are considered. Since, the GNSS users over the Indian region get signals from IRNSS, investigation on GDOP variation is done for GPS+IRNSS constellation (combined). It is noted that the geometry is excellent (greater than 2) rather than ideal to compute PVT.

IV. CONCLUSIONS

Conclusions about satellite visibility, signal intensity , and DOP are drawn from the study work done in this paper. Over the Kurnool region, GNSS users can see at least 60 satellites from several constellations. The combined IRNSS+GPS constellation accounts for 15 of them. In addition, the IRNSS constellation produces powerful signals with C/No range of 44 to 51 dB-Hz. Furthermore , thecombined PDOP of the IRNSS+GPS constellation was lower than that of the individual constellations.

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