ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Robustness of GLONASS Constellation and GPS Constellation

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Manuscript Info

Manuscript History:

Received: 17 August 2015
Final Accepted: 26 September 2015
Published Online: October 2015

Key words:

GLONASS and GPS Constellation, Scintillation and EIA

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Abstract

In the equatorial region, due to the presence of intense irregularities in electron density and its variability with geophysical conditions, the occurrence of scintillation is more. The median value of CNO deviation and S_4 are plotted at each 3 minutes frequency interval during each one hour duration. Analyzing the CNO and scintillation over the whole month of March 2014, it is found that during 14-15 UT maximum value up to which fluctuation in CNO for GPS is 1.35 units, which is greater than the peak values of GLONASS, 1.065 units for the same hour. Except 15-16 UT during hours 13-14, 14-15 and 17-18 UT peak value of fluctuation of CNO deviation from GPS is always greater than that of CNO deviation from GLONASS. So it can be concluded that fluctuation in CNO is more in GPS than for GLONASS as calculated from Septentrio Receiver during March, 2014 data of Calcutta Station. While on checking out scintillation, peak value of scintillation on observing all the plots (13-18 hours) is found to be 1.311, which is for GPS in the 16-17 UT, while peak value of scintillation for GLONASS is found to be 1.28 in the 15-16 UT. On observing various variables values, one can conclude that, "GLONASS constellation is more robust than GPS constellation" although fluctuations are more in the beginning and ending hours but still on the whole GLONASS has much more good signal performance.

INTRODUCTION

Study of the carrier-to-noise (CNO) ratios during daytime when irregular ionospheric perturbations are minimal will help characterize the medium of propagation. During the post-sunset hours when the equatorial ionospheric irregularities developed over the magnetic equator move to off-equatorial locations, transionospheric satellite links are disrupted particularly at locations like Calcutta situated underneath the northern crest of the EIA. Information related to the CNO ratios during daytime when the regular features of the equatorial ionosphere dominate and study of ionospheric scintillation parameters during the night when the irregular features are present will help system designers of the Indian regional SBAS to determine optimum look angles to establish satellite links to minimize satellite signal outages. Earlier during 1999-2002, combined GPS-GLONASS receivers were operated at some locations in India where it was reported that availability of GLONASS satellites were limited from equatorial locations [1]. It has been observed through studies conducted earlier [2,3] that the detrimental effects of the sharp latitudinal gradients of ionization occurring in the equatorial region may be limited if sufficient number of satellite links are available at high elevation angles in excess of 60°. Intense scintillations are also noted south of the station which may be attributed to geomagnetic field-aligned irregularity observations [4].

Ionospheric scintillation directly affects the CNO of all the satellites of GNSS. The nominal CNO for the L1 signal 45db-Hz and tracking may be lost if the CNO signal drops below ~25db-Hz., dependent on the receiver-specific tracking loop. Although the signal power on the GPS L2 frequency is significantly low (~6db-Hz).CNO are functions of the transmitted power, frequency, system noise and separation distance.

CNO is an absolute indicator primarily of antenna-plus-front-end performance. CNO is the ratio of carrier power to the noise power mixed with the signal, in a 1Hz bandwidth. This ratio defines a limit for the sensitivity of a given GPS receiver. If the value of CNO is diminished for any cause, be it bandwidth limitations, or increased LNA noise figure, GPS sensitivity will be reduced by the same amount. Once impaired, there is no way to recover CNO. Even additional gain does nothing because Carrier and Noise are amplified equally, and so is to no avail.

The S_4 index is the standard deviation of the Signal Intensity (SI) normalized by its mean value. It is calculated from the in-phase and Quadrature-phase accumulation samples of the prompt correlator. The total S4 is calculated as:

$$S4_T = \sqrt{\frac{\langle SI^2 \rangle - \langle SI \rangle^2}{\langle SI \rangle^2}} \qquad S4_n = \sqrt{\frac{100}{C/N_0}\left(1 + \frac{500}{19 * C/N_0}\right)} \qquad S4 = \sqrt{S4_T^2 - S4_n^2}$$

Where <> represents the expected (or average) value over Tobs. If the carrier to noise density.C⁄N0 can be estimated during Tobs, it is possible to have an estimate of the S4 due to noise. The revised S4 without the noise contribution is obtained as S_4.

GNSS (Global Navigation Satellite System)

GNSS is used to refer to the collection of the world's global positioning systems including the USA's GPS, Russia's GLONASS, European Union's Galileo satellite system and china's COMPASS.

GPS AND GLONASS

Table 1 shows the orbital characteristics of GPS and GLONASS. Each GLONASS satellite like GPS satellite transmits a signal having two bands: one is C/A-code on L1, P-code. GLONASS satellites transmit the same code at different frequencies, a technique known as FDMA, for frequency division multiple access, whereas GPS and Galileo uses a code division multiple access technique (CDMA). However this technique is not used in GPS. GLONASS signals have the same polarization (orientation of the electromagnetic waves) as GPS signals, and have comparable signal strength.

FUGRO Orbital characteristics

System	Glonass	GPS
Number of satellites	24	30+
Number of orbital planes	3	6
Semi-major axis	25500 km	26550 km
Eccentricity	< 0.01	< 0.01
Inclination	64.8°	55°
Period of revolution	11h16m	11h58m
Repeat period	8 days	1 day

Table 1

Methodology

After the unusually prolonged solar minima spanning 2006-2010, scintillation activities were dramatically enhanced during the equinox of 2014 as observed from Calcutta (22.58° N, 88.38° E geographic; 32° N) magnetic dip, a station situated virtually underneath the northern crest of EIA in the geo physically sensitive Indian longitude sector. Figure 1 shows the statistics of GNSS L-band scintillations and CNO deviations recorded from Calcutta during the equinox of 2014 above an elevation of 20°. One of the major ionospheric propagation effects, deviations in CNO and scintillations between the CNO deviations of GPS and GLONASS satellite systems for post-sunset hours are the main objective for this study. This study will help to know the efficiency of transmitted signals via both two different constellations. In order to fulfill this scientific objective, CNO and S_4 measurements are achieved from the receiver Septentrio during the month of March, 2014 installed at Institute of Radio Physics and Electronics

(I.R.P.E), University of Calcutta, Calcutta. During the evening and post sunset hours (12:00 UT to 18:00 UT) maximum scintillation occurs at equatorial region.

In this study the patches of scintillations are made by considering those occurrences of scintillation which continues at least for four minutes or more for both the satellite constellations. CNO fluctuations results in showing us which satellite constellation is more robust. In a present, comparative study of CNO fluctuations along with scintillation of satellites SV 1-37 (stand for GPS) & SV 38-61 (stand for GLONASS) is done. Raw data collected from Septentrio which is installed in Calcutta (22.58° N, 88.38° E geographic; 32° N magnetic dip), a station situated virtually underneath the northern crest of EIA in the geo physically sensitive Indian longitude sector is in **".ismr"** format (default format) is not readable. Editing file extension to "**.txt"** and opening it into Microsoft excel worksheet make it easier to understand.

Experimental Results –

In fig 1(a), the mean value of UT is plotted along x-axis where as all the median of CNO deviation & scintillations for both the constellations GPS & GLONASS are plotted along y-axis, only for the time interval 13-14 UT. In this fig. blue bar denotes median of CNO deviation of GPS where as red bar denotes median of CNO deviation GLONASS. Green bar shows deviation of scintillation in GPS and purple bar depicts median of Scintillation for GLONASS

It is seen from this figure that, while comparing CNO deviation (dev) GPS shows more robustness whereas in case of Scintillation (S4) GLONASS shows robustness.

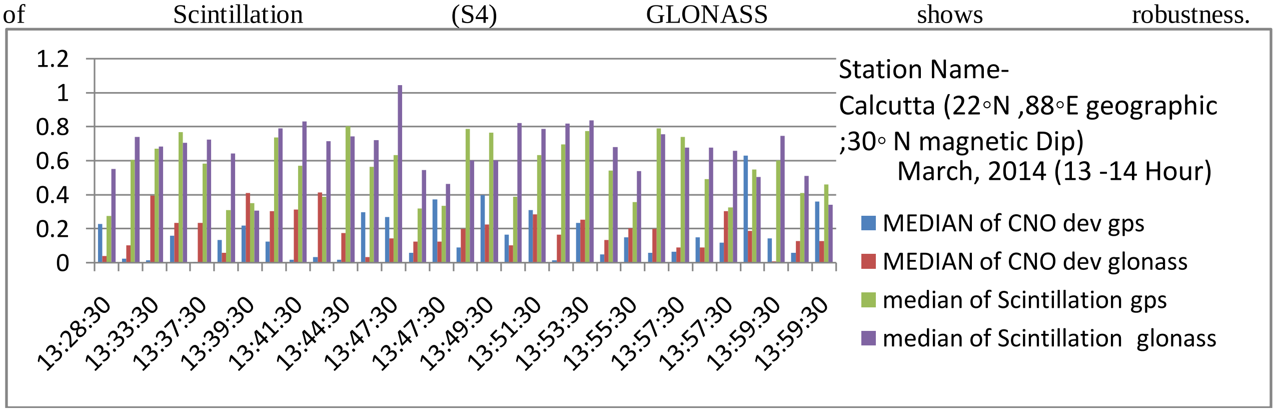

Fig. 1(a)

In fig 1(b), bar colour have r... the fig 1(a), here the mean value of UT is plotted along x-axis where as all the median of CNO deviation & scintillations for both the constellations GPS & GLONASS are plotted along y-axis, only for the time interval 14-15 UT.. It is seen from this figure that, while comparing CNO deviation (dev) GPS shows more robustness whereas in case of Scintillation (S4) again by a small difference GLONASS shows robustness more than the GPS.

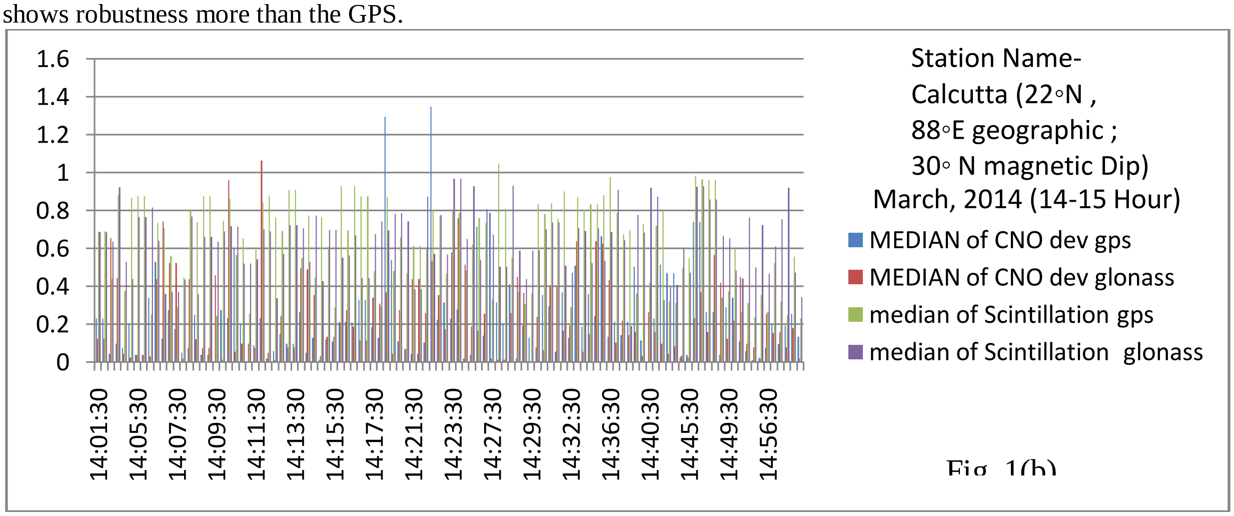

Fig. 1(b)

In fig 1(c), mid value of UT is plotted along x-axis (abscissa) where as all the median of CNO deviation & scintillations for both the constellations GPS & GLONASS are plotted along y-axis (ordinate), only for the time interval 15-16 UT.In this fig. green bar denotes median of scintillation deviation of GPS where as red bar denotes median of CNO deviation GLONASS. Purple bar denotes median of scintillation of GLONASS. It is seen from this figure that, while comparing CNO deviation (dev) GLONASS shows more robustness whereas in case of Scintillation (S4) again GLONASS wins and it is far from fluctuation like GPS.

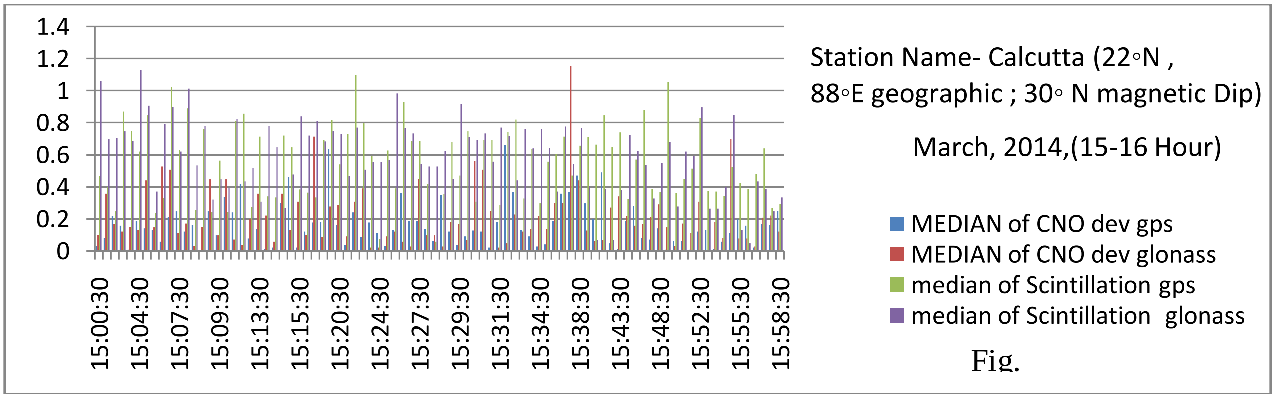

Fig.

In fig 1(d) Similar colour scheme is used here like the earlier figures, CNO deviation (dev) GLONASS shows more fluctuations while CNO deviation (dev) GPS shows robustness whereas in case of Scintillation (S4) GPS is in ahead and is more robust. As seen in fig 1(e) we observe here that CNO deviation (dev) GLONASS shows more fluctuations while CNO deviation (dev) GPS shows robustness whereas in case of Scintillation (S4) again GLONASS wins and it is far from fluctuation like GPS.

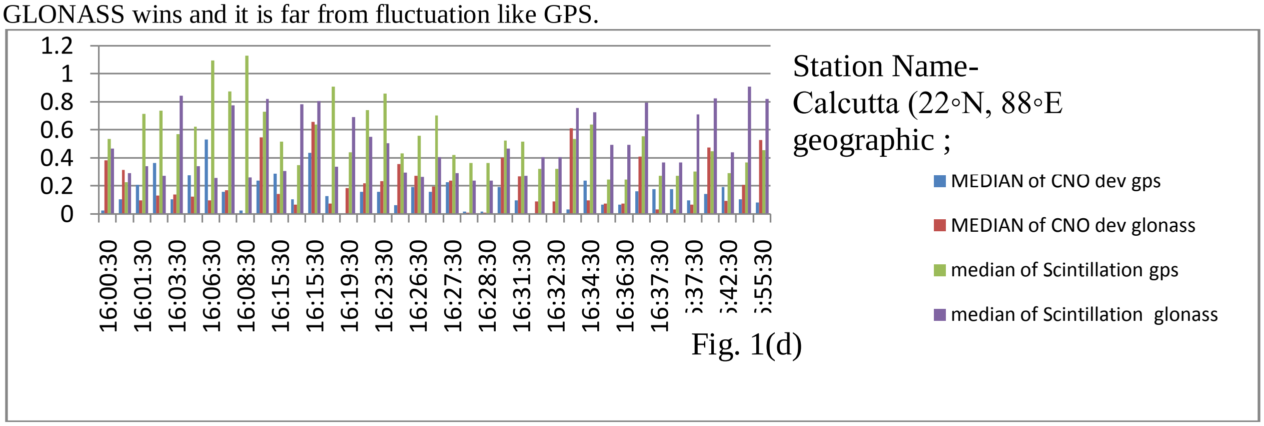

Fig. 1(d)

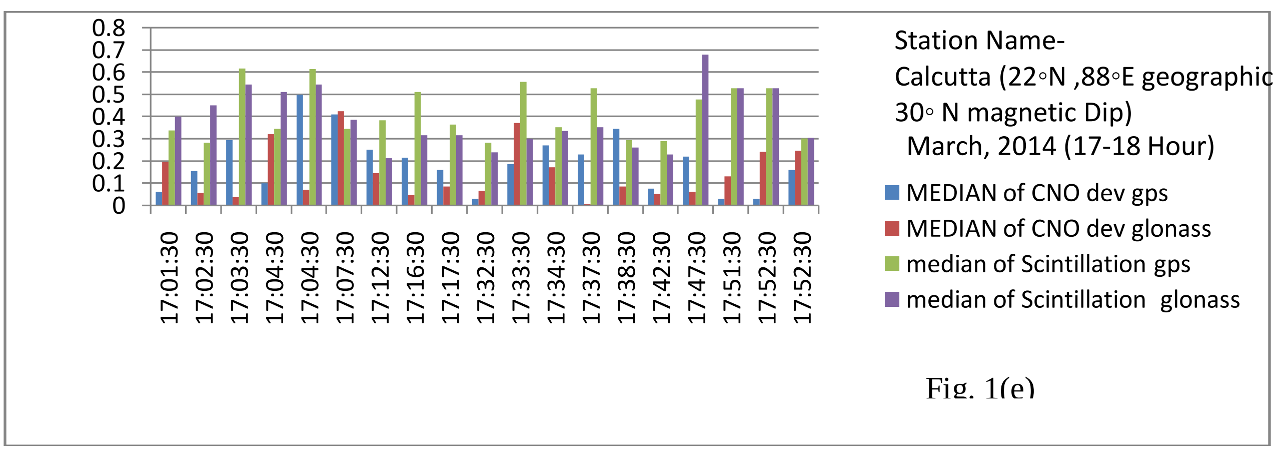

Fig. 1(e)

Below plots are shown which are generated using Origin software. In below fig 2(a) , UT is taken along x-axis while the curves or panels 1,2,3 and 4 have respective identities, panel 1 denotes variation of GLONASS scintillation, 2 denotes GPS Scintillation, 3 denotes GLONASS CNO Deviation and 4 denotes GPS CNO Deviation with UT.

Figure clearly depicts that CNO deviation (dev) GPS shows more robustness as fluctuations experiencing by it is low as comparison to GLONASS, whereas in case of S_4 figure depicts that GLONASS signal performance is good.

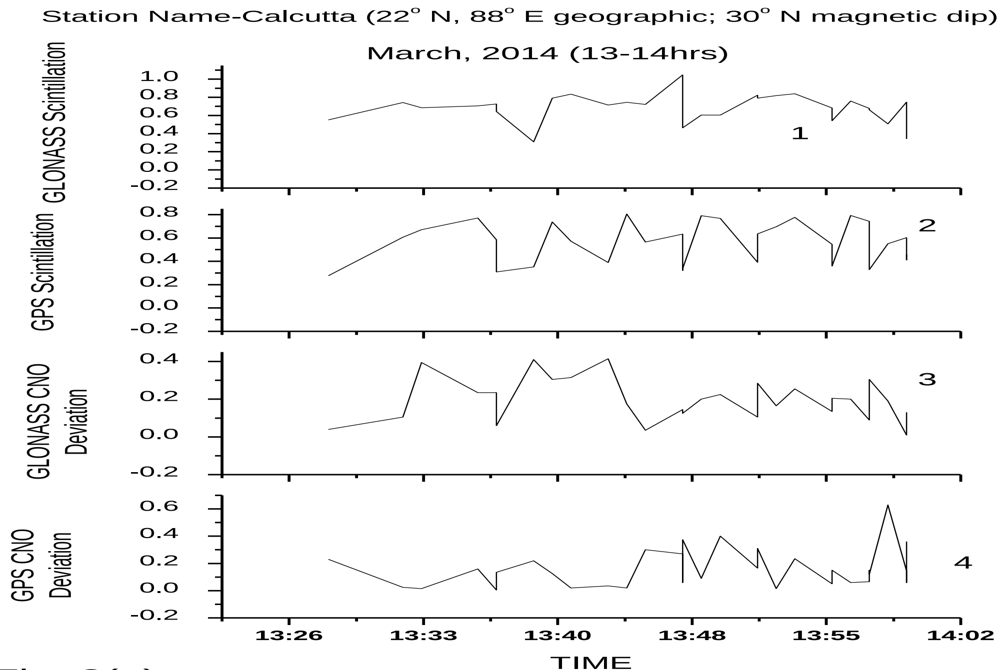

Fig. 2(a)

fig 2(b), one can observe CNO deviation (dev) GPS shows more robustness. In case of Scintillation (S_4) we can observe from fig. 2(b) that GLONASS shows more robustness than the GPS.

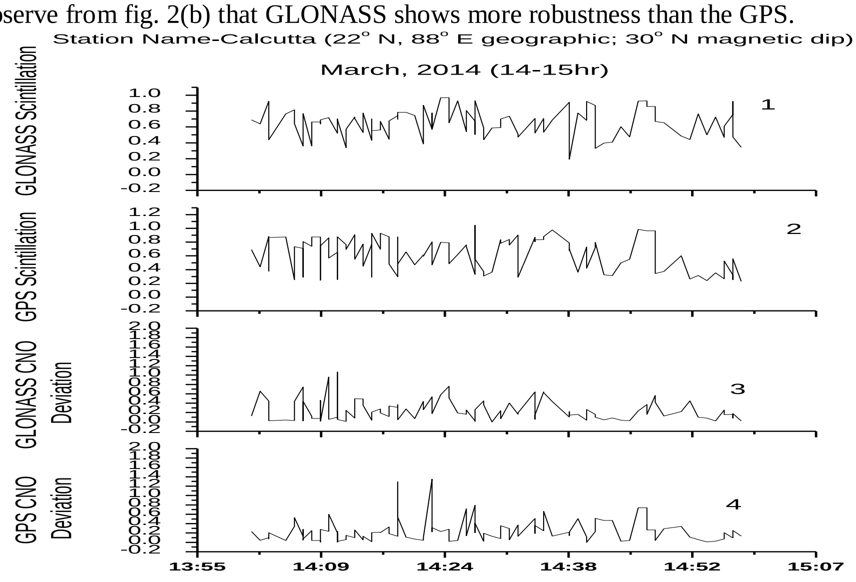

Fig. 2(b)

In fig. 2(c), on comparing panel 3 & 4, one can see that CNO of GPS is experiencing more fluctuations than CNO of GLONASS .While panel 1 & 2 shows that GPS signal performance is weak as compare to GLONASS. By observing fig. 2(d) variation of curves in four panels shows that GLONASS experience more scintillation effect than GPS and in CNO comparison GLONASS has more fluctuations in its signal performance than GPS.

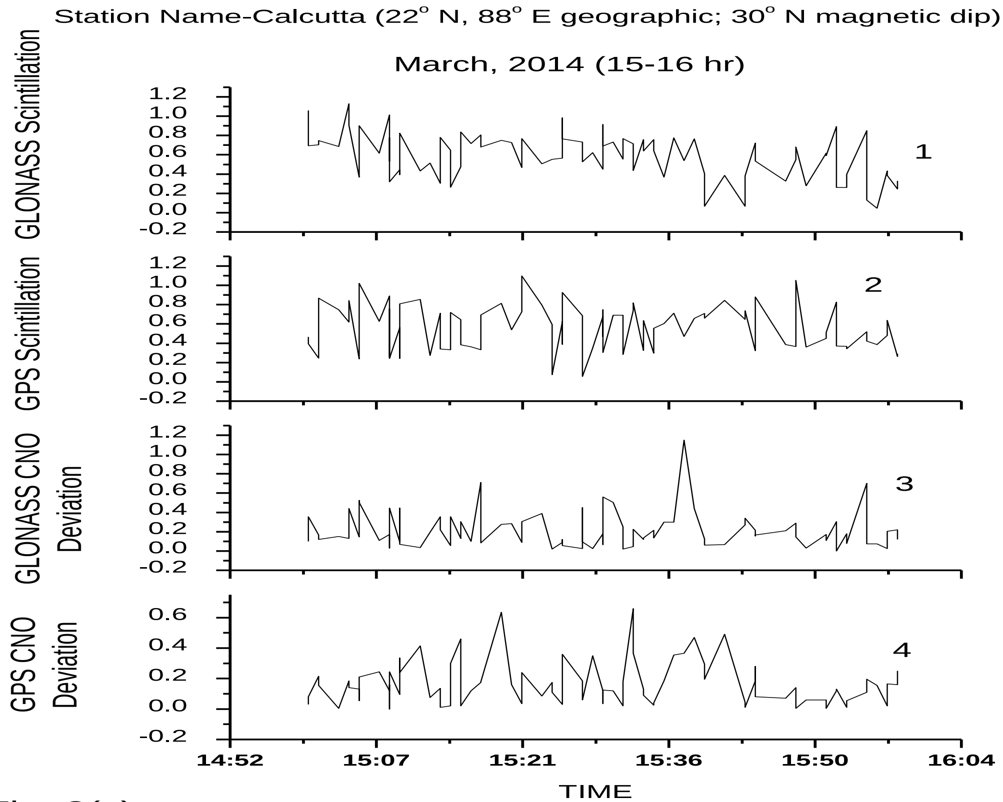
Station Name-Calcutta (22° N, 88° E geographic; 30° N magnetic dip)
March, 2014 (15-16 hr)
GLONASS Scintillation
GPS Scintillation
GLONASS CNO Deviation
GPS CNO Deviation
1
2
3
4
14:52
15:07
15:21
15:36
15:50
16:04
TIME

Fig. 2(c)

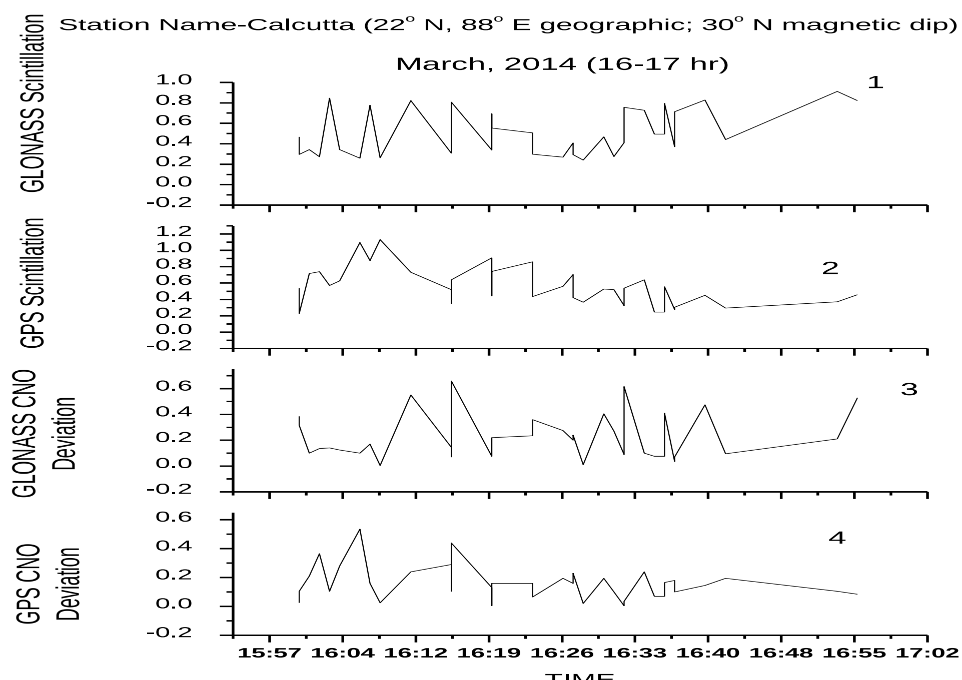
Station Name-Calcutta (22° N, 88° E geographic; 30° N magnetic dip)
March, 2014 (16-17 hr)
GLONASS Scintillation
GPS Scintillation
GLONASS CNO Deviation
GPS CNO Deviation
1
2
3
4
15:57 16:04 16:12 16:19 16:26 16:33 16:40 16:48 16:55 17:02
TIME

Fig. 2(d)

Last fig. 2(e) indicates clearly that GPS have large scintillation values than GLONASS, while CNO fluctuation is also more in GPS resulting in weak performance of GPS. Therefore this figure depicts that GLONASS is far better than GPS both in terms of CNO and scintillation.

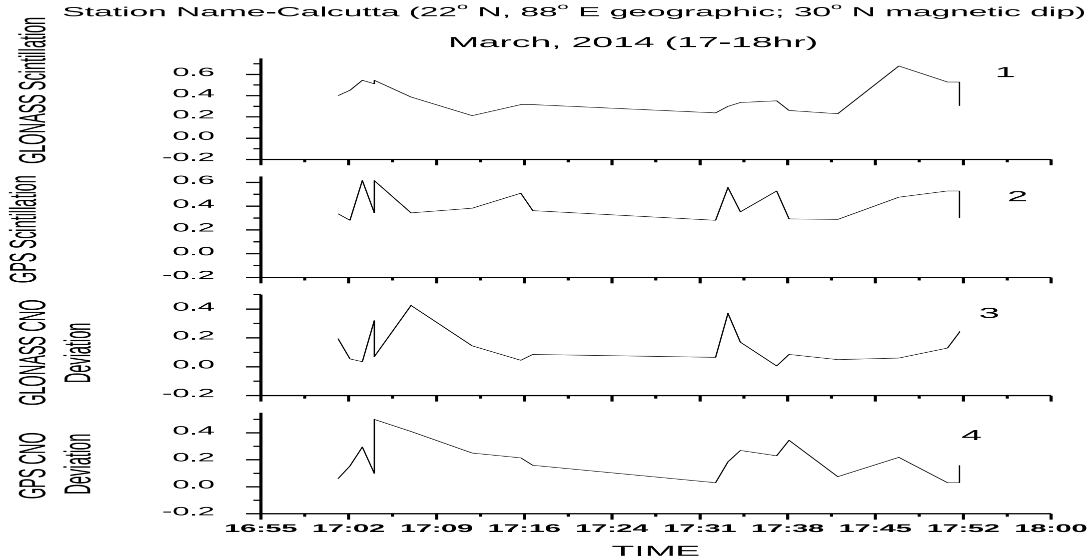

Fig. 2(e)

Conclusions:

The median value of CNO deviation and S_4 are plotted at each 3 minutes frequency interval during each one hour duration. The x-axis is time and median values of S_4 and CNO deviation is plotted along y-axis. Analyzing the CNO and scintillation over the whole month of march 2014, it is fount that during 14-15 UT (fig 1(b), fig 2(b) maximum value up to which fluctuation in CNO for GPS is 1.35 units, which is greater than the peak values of GLONASS, 1.065 units for the same hour . Except 15-16 UT during hours 13-14, 14-15 and 17-18 UT peak value of fluctuation of CNO deviation from GPS is always greater than that of CNO deviation from GLONASS. So it can be concluded that fluctuation in CNO is more in GPS than for GLONASS as calculated from septentrio receiver during March, 2014 data of Calcutta Station Plots created in Microsoft excel give a good idea about the variation of CNO and scintillation. Below pictures depict peak of particular quantity whether it is CNO or Scintillation for the GPS and GLONASS in different hours. While on checking out scintillation, peak value of scintillation on observing all the plots (13-18 hours) is found to be 1.311, which is for GPS in the 16-17 UT, while peak value of scintillation for GLONASS is found to be 1.28 in the 15-16 UT. On comparing, peak values of scintillation for each hour one can find that for the whole month peak value of Scintillation for GLONASS remains a head. Therefore transmission of signal from GLONASS should be better than GPS.

Time Interval (UT)	Maximum Value During March, 2014

Observing all plots on the same screen, one can say that in between the time period 13-18 hours CNO and Scintillations deviations are much more affected of GPS than the GLONASS. The only thing which should be notice is that in 13-14 UT and 16-17 UT, the fluctuations in CNO and Scintillation are not behaving like in a general trend as what seen in the middle hours. In 13-14 UT, Scintillation Deviation of GPS has more fluctuations than GLONASS, while CNO deviation of GLONASS has more fluctuations than GPS.
The uppermost panel (1) is the variation of S_4 with respect to time , from GLONASS, panel (2) describes the variation of S_4 observed from GPS, Panel (3) is the plot of CNO deviation during a particular UT and last panel (4) shows plot of CNO deviation from GPS during the same interval of time. This scheme is followed by two set of plots, i.e. is for fig.1 (a), fig.1(b)…….fig. 2(e).
In addition to the intensity of scintillations, the number of satellites affected by scintillations is also a very important factor since a greater number of satellites under lower scintillation intensity may be more problematic for GNSS-based aviation than less number of satellites with much higher scintillation intensity [5].On observing various variables values in the below table 2 one can conclude that, "GLONASS constellation is more robust than GPS constellation".

	GPS CNO Deviation	GLONASS CNO Deviation	GPS S_4	GLONASS S_4
13-14	0.63	0.418	0.8055	1.0465
14-15	1.35	1.065	1.0475	0.968
15-16	0.66	1.15	1.097	1.128
16-17	0.535	0.60	1.131	0.982
17-18	0.5	0.425	0.616	0.679

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