International Civil Aviation Organization

THE FOURTH MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/4)

New Delhi, India, 05 – 07 February, 2014

Agenda Item 3: Review of status of States' activities

ANALYSIS OF THE EFFECT OF IONOSPHERE ON GAGAN SYSTEM

(Presented by India)

SUMMARY

The effect of the ionospheric irregularities on the GAGAN systems performance needs to be understood and ways to improve its performance needs to be identified. The main purpose of this study is to continuously examine the data collected over the Indian region and gain a preliminary understanding of the effect of ionosphere and its irregularities on the performance of the GAGAN System.

1. INTRODUCTION

1.1. GPS Aided Geo Augmented Navigation (GAGAN) is a Satellite-based Augmentation System being developed to aid navigation for civil aviation applications in India. It has been certified for RNP 0.1 and It will eventually provide Approach Precision Vertical (APV) 1.5 level of service (which corresponds to 40 meters horizontal and 50 meters vertical alert limit over India and the surrounding region. GAGAN provides accuracy, availability, integrity and continuity of service to civil aviation users. GAGAN consists of 15 Indian reference stations (INRES), 2 Indian Master Control centres (INMCCs) and 3 Indian Land Uplink stations(INLUS). INRES stations which are spread across India, collect GPS data and transmit them to the INMCCs for computation of ionospheric, clock, and ephemeris corrections to the GPS ranges of L1 along with the integrity information. These errors and integrity information are converted into messages and broadcasted using the GAGAN Geostationary satellites PRN 127 & 128 (GSAT-8 & GSAT-10) through INLUS. These messages are received by the GAGAN receivers along with the GPS signals and are used by the user to compute its position.

1.2. The study of ionosphere variability is very much essential for navigation systems like GAGAN. Magnetic storms and traveling disturbances may greatly enhance the TEC variability and affect consequently the navigation systems.Ionospheric scintillations cause loss of lock of the GPS/SBAS receivers and they affect SBAS users in four ways. They can degrade the quantity and quality of the user measurements; they can degrade the quantity and quality of reference station measurements which in turn affect the corrections; they can increase the Dilution of Precision (DOP) value and, they can disrupt the communication from the SBAS geostationary satellite (GEO) to the user receiver which will result in missed messages to the user. The performance of SBAS systems are

dependent on Horizontal Protection Limit(HPL) & Vertical Protection Limit(VPL) which in turn are dependent on User Differential Range Error(UDRE), Grid Ionospheric Vertical Error(GIVE) values and DOP. The presence of high scintillations may result in loss of lock of the receivers. This reduces the number of iono delays available for GIVE & GIVD computation.

1.3. The main purpose of this study is to continuously examine the data collected over the Indian region and derive a preliminary understanding of the effect of ionosphere and its irregularities on the performance of the GAGAN System.

2. DISCUSSION

2.1. GAGAN system data along with the scintillation S4 data & GAGAN INRES data are used for the analysis being undertaken. S4 index scintillation data is obtained from the GPS Ionospheric Scintillation and TEC Monitor (GISTM) "GSV4004" TEC receivers stationed all over India.

The following are some of the plots depicting the typical loss of lock in the INRES receivers :

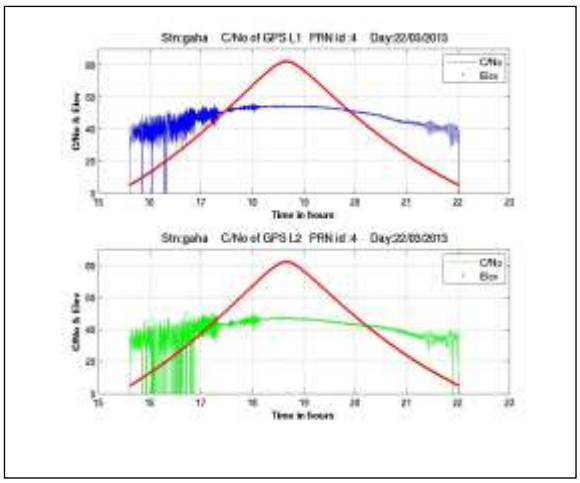

Figure 1a show the variation of L1 &L2 C/No Vs time for Ahmadabad INRES stn for PRN id 4 dated 22/03/2013.

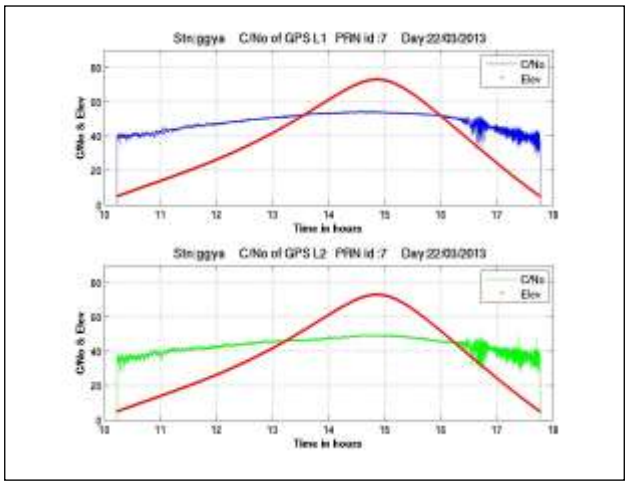

Figure 2a show the variation of L1 &L2 C/No Vs time for the Gaya INRES stn for PRN id 4 dated 22/03/2013.

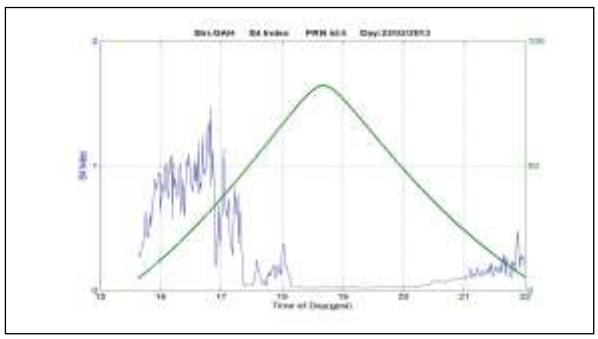

Figure 1b show the variation of S4 index wrt time for Ahmadabad PRN id 4 dated 22/03/2013.

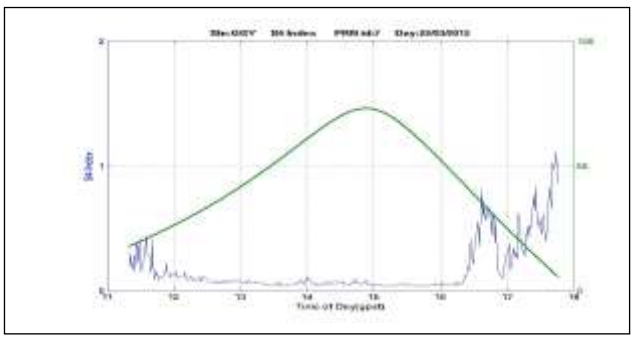

Figure 2b show the variation of S4 index wrt time for Gaya PRN id 4 dated 22/03/2013.

L1 gh, INRES. In Figures 2a & 2b it can be seen that the INRES station has not lost lock when the S4 index

was below 0.7 . It can also be seen that the L2 loss of lock is more compared to L1 during the high scintillation activity.

2.2. The performance of the GAGAN system is continuously analysed with respect to the ionospheric irregularities. The INRES receivers' L1 &L2 range observation values are continuously analysed for loss of lock and compared with the corresponding S4 index values for all the GPS PRNs. Data from Low elevation angles was discarded from the analysis. Day wise S4 index charts were generated for each INRES location and their influence on the GAGAN system performance is continuously analysed.

2.3. The performance of GAGAN over Bangalore was analysed for the days 30/01/2014 & 12/01/2014.

2.4. There were scintillations present over Bangalore on 30/01/2014 & 12/01/2014 between 15:00hrs to 19:00 hrs. It is generally expected that these scintillations would cause a loss of lock of the INRES receiver. This would reduce the number of measurements available which in turn would effect the DOP and also would reduce the number of IIPs available for the computation of GIVE and GIVD and thus would effect the performance over that period of time. The data from the "GSV4004" TEC receiver stationed at Bangalore was also used for the study of scintillation and loss of lock.

2.5. The following plot indicates the scintillations present on 30/01/2014 over Bangalore:

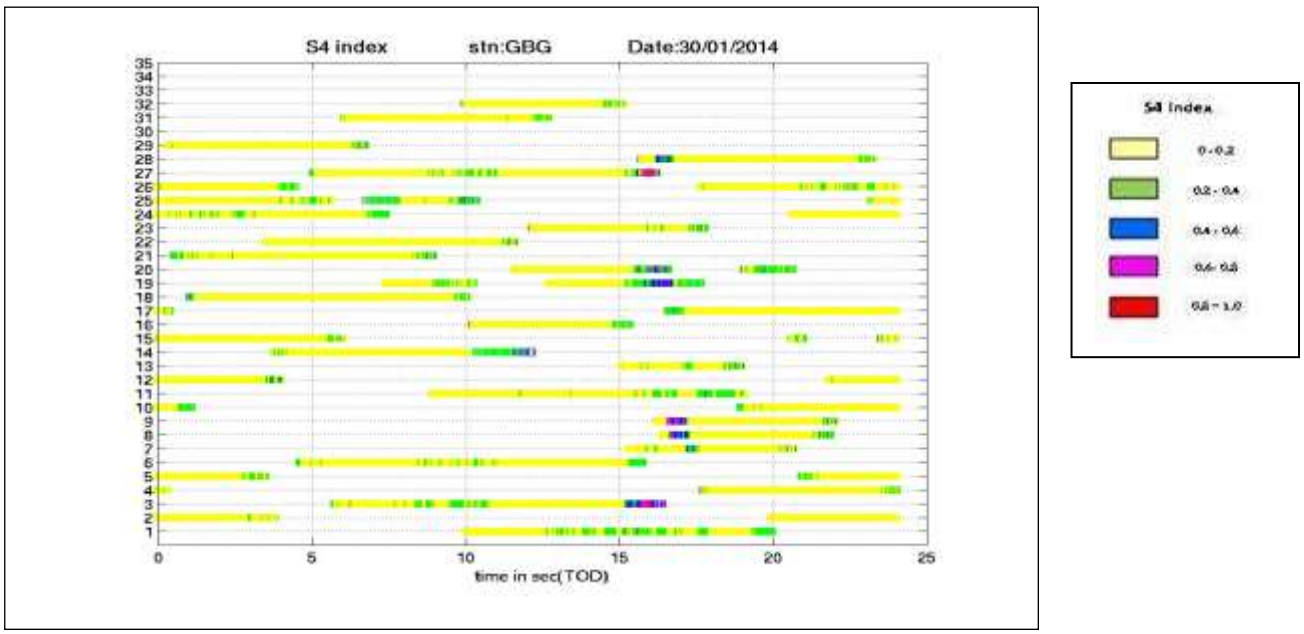

Figure 3 shows the variation of S4 index wrt time over Bangalore on 12/01/2014

2.6. In the above Figure 3 yellow colour indicates 0-0.2 S4 index value, green color indicates 0.2 -0.4 S4 index value , Blue colour indicates 0.4-0.6 S4 index value, magenta color indicates 0.6-0.8 S4 index value and Red colour indicates greater than 0.8 S4 index value. This plot depicts the s4 index values of all the visible GPS satellites for a particular location. This plot gives the summary of the scintillation activity over a day at a location.

2.7. Examining the data from the TEC receiver on both the days indicated that the TEC receiver had lost lock of many satellites which were visible over Bangalore over the period 16:00 to 19:00 due to scintillations. This sort of situation of loss of lock of many satellites in the INRES receiver would definitely affect the performance of the GAGAN system between 16:00 to 19:00 Hrs. To the contrary the performance of the GAGAN system was found to be within limits during this period.

2.8. The below is the monitored VPL/HPL of Bangalore on 12/10/2014.

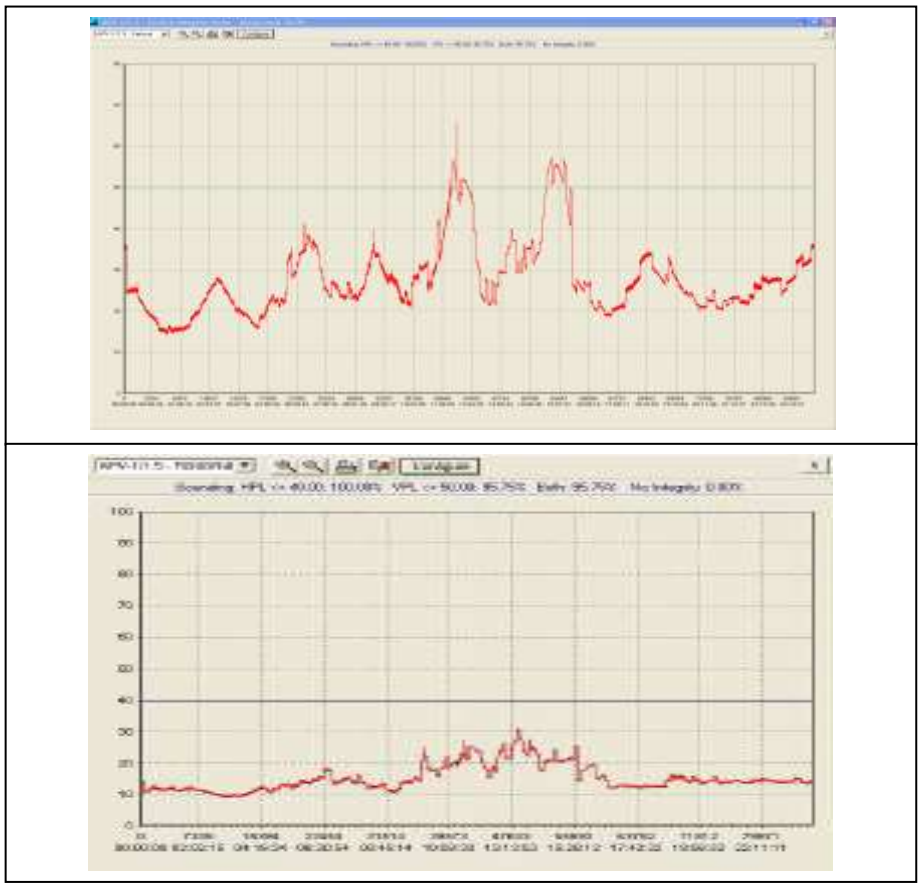

Figure 4 show the variation of VPL& HPL wrt time for over Bangalore on 12/01/2014.

2.9. The data of INRES receiver was analysed along with the TEC data and the following figures 5a to 5h , 6a to 6h & 7a to 7i are some of the plots of the INRES receiver, TEC receiver loss of lock and S4 index values.

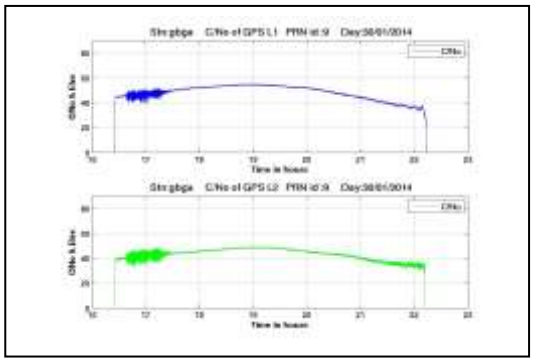

Figure 5a shows the Bangalore INRES C/No wrt time for PRN id 9 dated 30/1/14

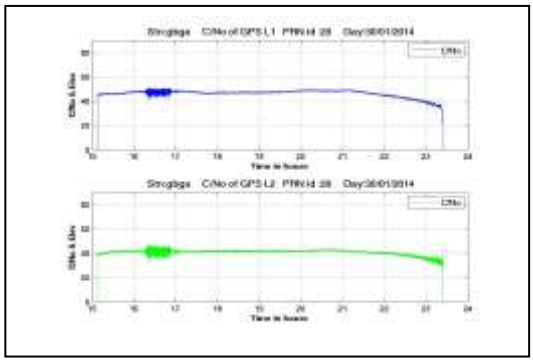

Figure 5bshows the Bangalore INRES C/No wrt time for PRN id 28 dated 30/1/14

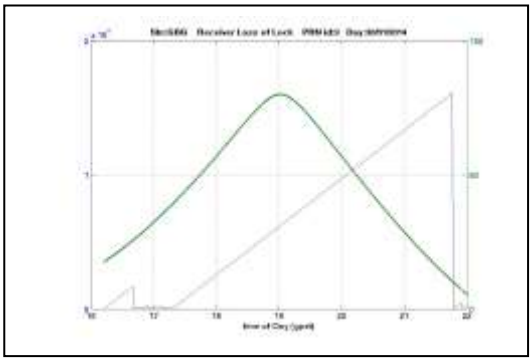

Figure 5c shows the loss of Lock of PRN 9 wrt time of TEC receiver dated 30/1/14

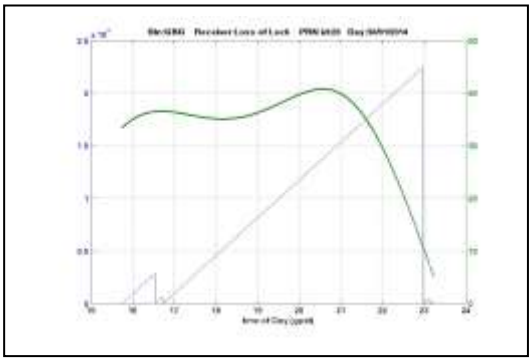

Figure 5d shows the loss of Lock of PRN 28 wrt time of TEC receiver dated 30/1/14

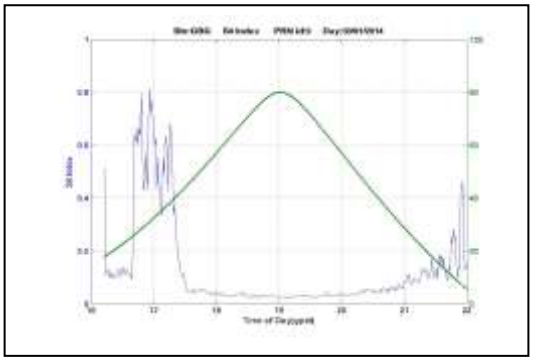

Figure 5e show the variation of S4 index wrt time over Bangalore for PRN id 9

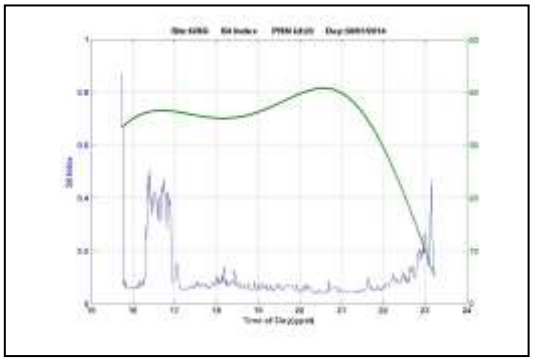

Figure 5f shows the Bangalore INRES C/No wrt time for PRN id 28 dated 30/1/14

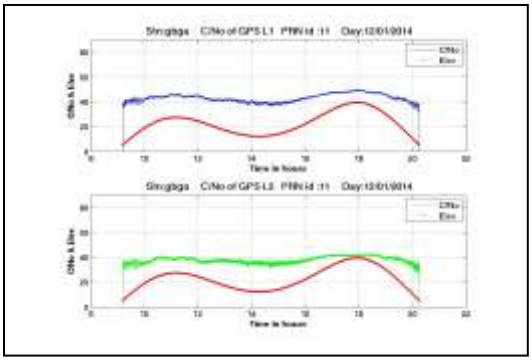

Figure 5g shows the Bangalore INRES C/No wrt time for PRN id 11 dated 12/1/14

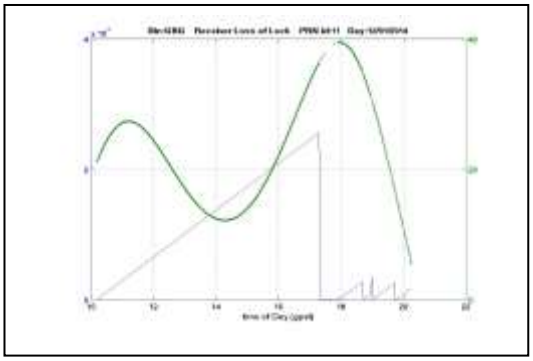

Figure 5h shows the loss of Lock of PRN 11 wrt time of TEC receiver dated 12/1/14

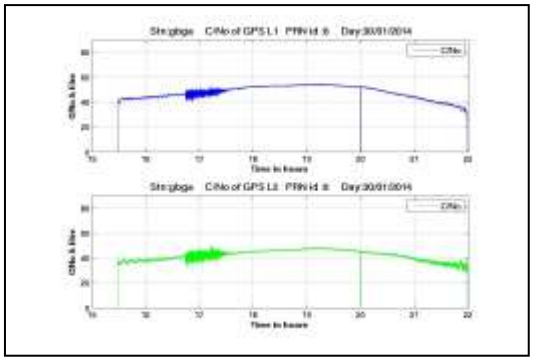

Figure 6a show the Bangalore INRES C/No wrt time for PRN id 8 dated 30/1/14

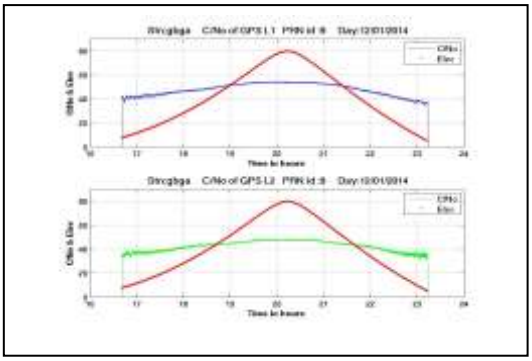

Figure 6b shows the Bangalore INRES C/No wrt time for PRN id 9 dated 12/1/14

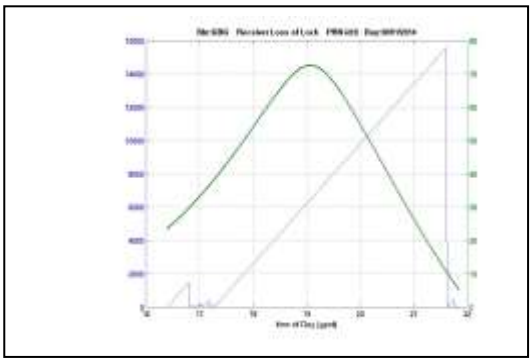

Figure 6c show the loss of Lock of PRN 8 wrt time of TEC receiver dated 30/1/14

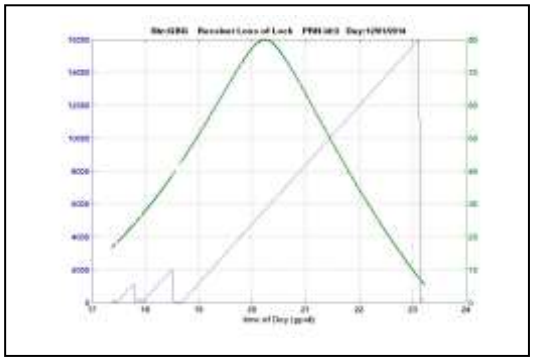

Figure 6d shows the loss of Lock of PRN 9 wrt time of TEC receiver dated 12/1/14

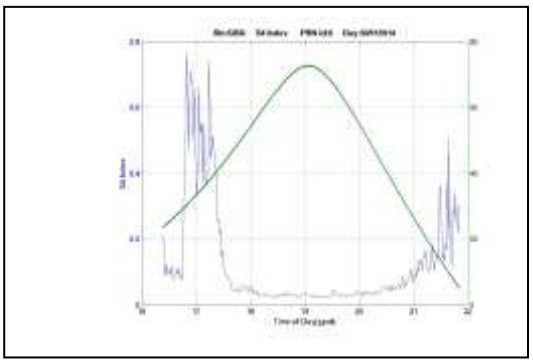

Figure 6e show the variation of S4 index wrt time over Bangalore for PRN id 8 8

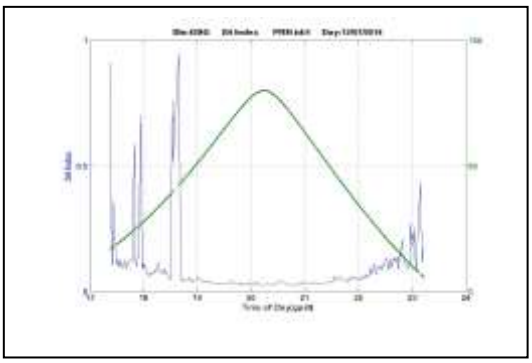

Figure 6f shows the variation of S4 index wrt time over bangalore for PRN id 9

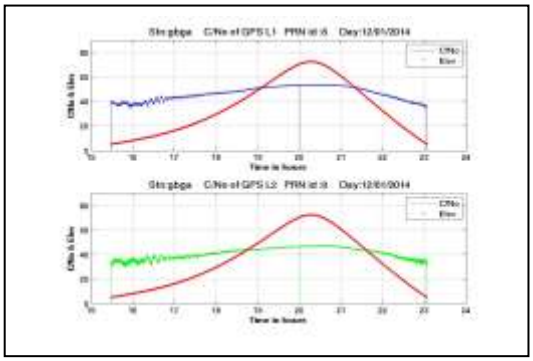

Figure 6g shows the Bangalore INRES C/No wrt time for PRN id 8 dated 12/1/14

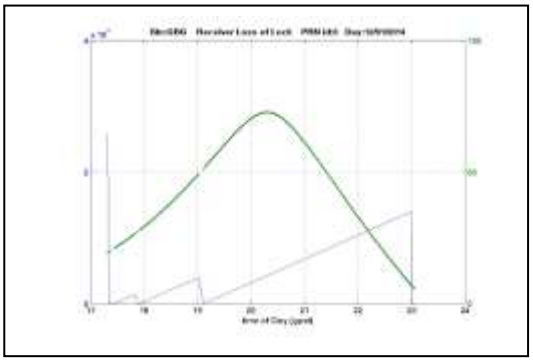

Figure 6h show the loss of Lock of PRN 8 wrt time of TEC receiver dated 12/1/14

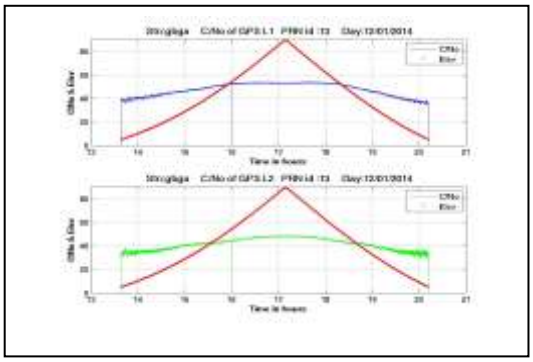

Figure 7a shows the Bangalore INRES C/No wrt time for PRN id 13 dated 12/1/14

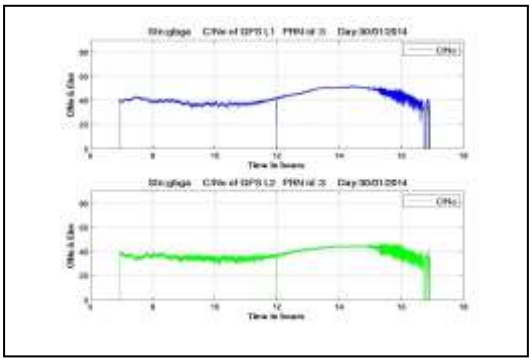

Figure 7b shows the Bangalore INRES C/No wrt time for PRN id 3 dated 30/1/14

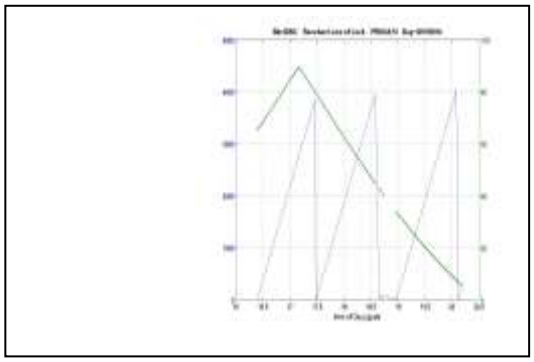

Figure 7c shows the loss of Lock of PRN 13 wrt time of TEC receiver dated 12/1/14

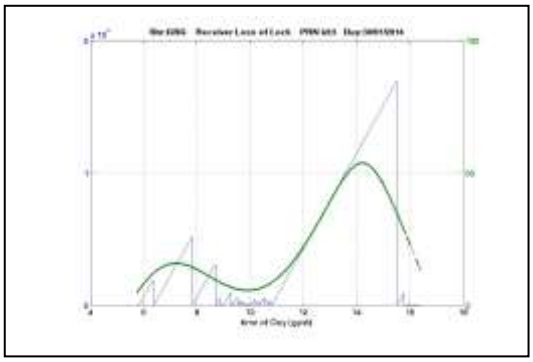

Figure 7d shows the loss of Lock of PRN 3 wrt time of TEC receiver dated 30/1/14

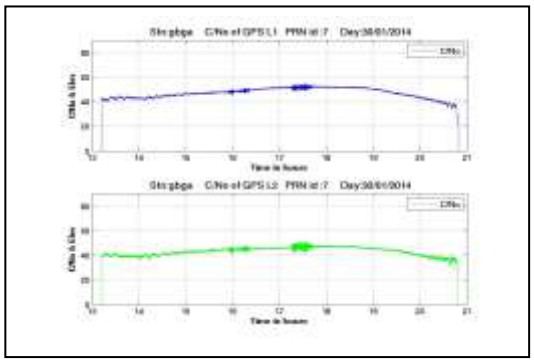

Figure 7e shows the Bangalore INRES C/No wrt time for PRN id 7 dated 30/1/14

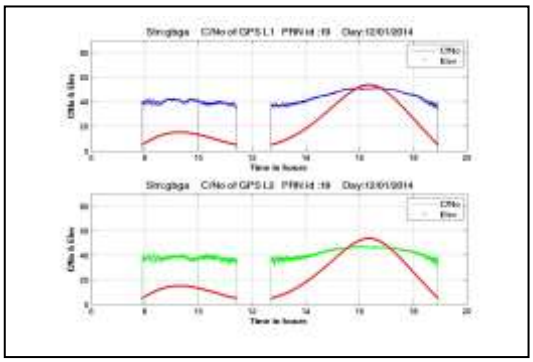

Figure 7h shows the Bangalore INRES C/No wrt time for PRN id 19 dated 12/1/14

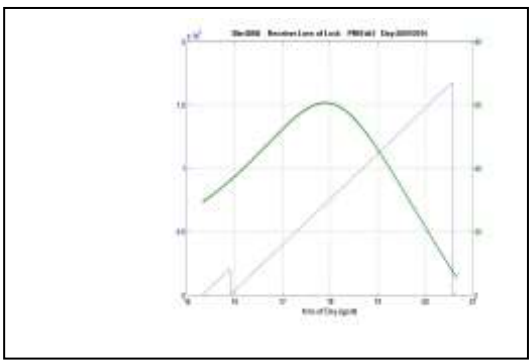

Figure 7g shows the loss of Lock of PRN 7 wrt time of TEC receiver dated 30/1/14

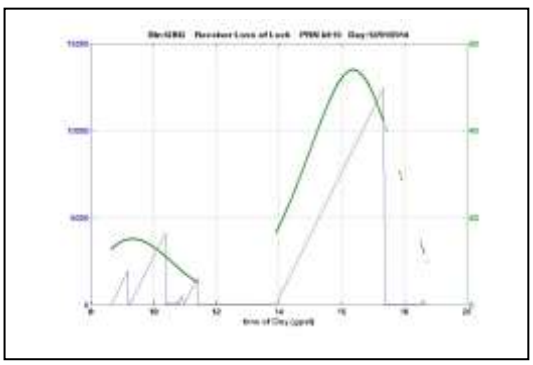

Figure 7i shows the loss of Lock of PRN 19 wrt time of TEC receiver dated 12/1/14

2.10. From the above plots it can be noticed that the Bangalore INRES receiver had not lost lock of the satellites like the TEC receiver in spite of high S4 value. The GAGAN INRES receiver is much more capable of handling scintillations compared to the other receivers and is less prone to loss of locks even during scintillations. This has helped the GAGAN system to maintain its performance with in the APV1.5 limits during the period of scintillation activity over Bangalore on 12/01/2014 and has not caused degradation in performance over Bangalore on 30/01/2014 due to scintillations.

2.11. The same cannot be said about the User receiver. The User SBAS receiver has to be rugged like the INRES receiver if it has to get the same performance as seen above. If the User receiver looses lock like the TEC receiver then the performance that it provides will be very poor during the scintillation period due to the reduction in the available measurements.

3. CONCLUSION

3.1. The GAGAN INRES receiver seem to be much more capable of handling scintillations compared to the other receivers and is less prone to loss of lock.

3.2. GAGAN system sometime is able to maintain its performance within the limits during the period of scintillation activity due to its superior receivers.

3.3. Analysis of the user SBAS receiver data needs to be carried out during the period of scintillation activity to analyse the GAGAN performance

3.4. The affect of these ionospheric variations needs to be further understood for the analysis of the GAGAN performance and also to find out ways to improve it.

4. ACTION REQUIRED BY THE MEETING

4.1. The meeting may kindly note the results of the study and provide their valuable comments.

– – – – – – – – – – – – –