International Civil Aviation Organization

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

New Delhi, India, 05 – 07 February, 2014

Agenda Item 03: Review of status of States' activities

PERFORMANCE OF SBAS SYSTEM AND CHALLENGES IN MAINTAINING UPLINK STATION IN THE EQUATORIAL REGION FOR THE SATELLITE BASED AUGMENTATION SYSTEMS - GAGAN EXPERIENCE

(**Presented by AAI, India**)

This paper presents the results of the analysis done to study the effect of scintillation on the continuity of service of the GAGAN system. The challenges of integrating uplink station with GEO stationary satellite and maintaining the uplink station in the equatorial region

1. INTRODUCTION

1.1. The GAGAN system has been certified for RNP 0.1 Level of Service by DGCA, India. The GAGAN SIS is available on a test basis since December 2011.

1.2. The major technical challenge was the integration of the Indian Land Uplink Station (INLUS) with the Indian Geostationary satellite. This is the first time that a GEO is integrated with a ground station in the equatorial region for an operational SBAS

1.3. The continuity for APV1 level of service is analysed from the data collected from the 15 Indian Reference Stations (INRES). It is observed that the continuity of service is affected by the ionospheric disturbances experienced in the North and North-Eastern region of India. The effect is predominant during the equinox. The MLDF algorithm currently running in the GAGAN system is being modified to address these issues

2. DISCUSSION - Effect of Ionosphere on Continuity

2.1. The continuity figure for the reference stations are computed using the data recorded at the master control centre. GAGAN is planning to have a network of independent certified SBAS receivers installed at identified airports for computing the continuity figures in a realistic way.

2.2. The plots below shows the continuity computed at different reference stations with recorded data. From the plots it is evident that the continuity is affected mostly in the North and North-East region of India.

2.3. The continuity is also affected in North-East due to GPS- DOP hole which suddenly reduces the number of satellites used for navigation solution, causing spike in the VPL / HPL (Fig 3).

2.4. The ionospheric effect is predominant during the equinox period and hence during the months of June/July performance is better, but as equinox period is nearer the performance is considerably reduced. This is evident from the continuity figures computed during the 30 days stability run of GAGAN system in June '13, which showed consistent performance. But during August to November 2013, the performance was affected due to the ionospheric disturbances.

2.5. The figure (Fig1) shows the continuity figures at different reference stations under disturbed ionospheric conditions. The Fig 2 shows the scintillation plots for September and October 2013.

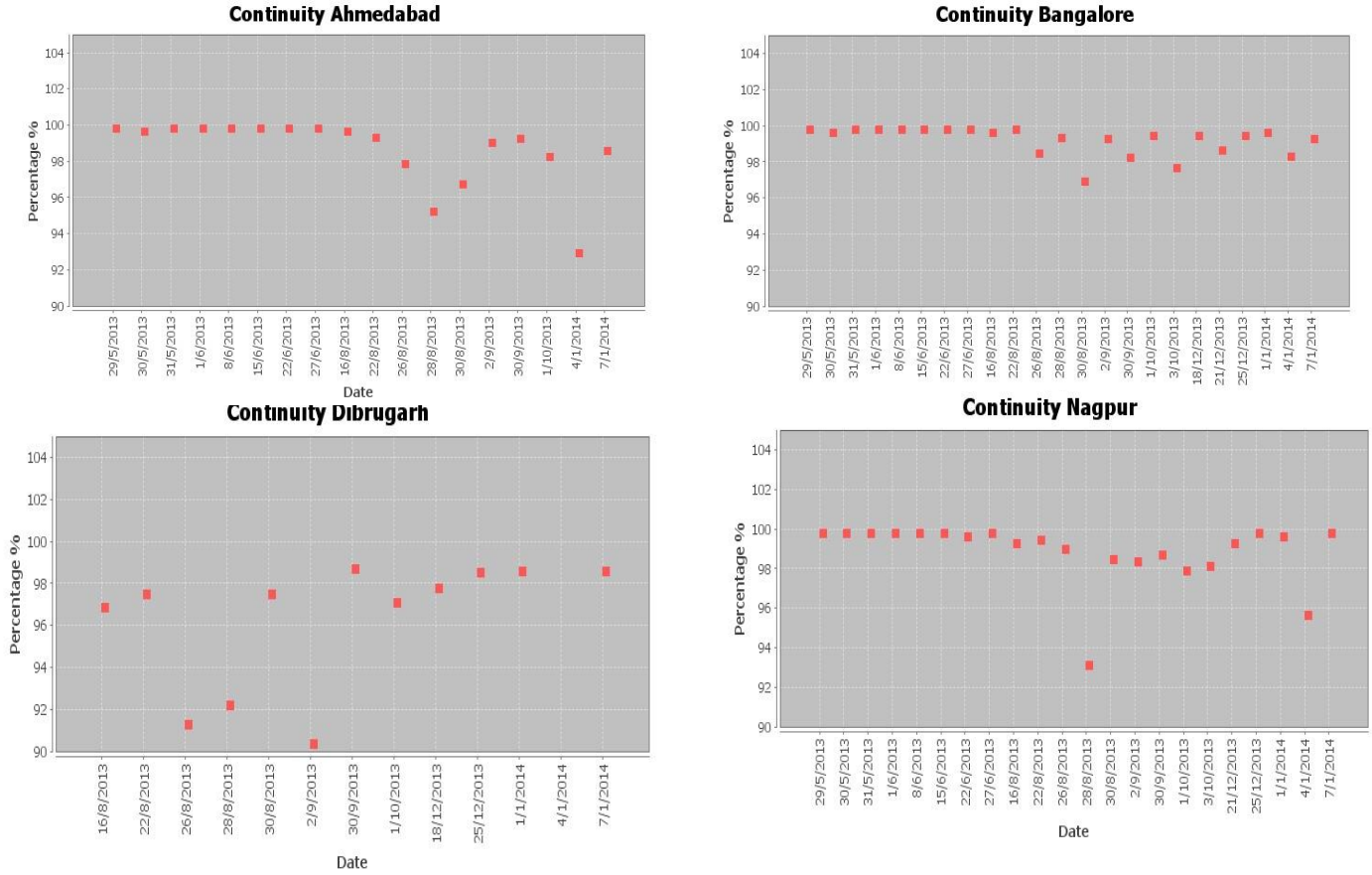
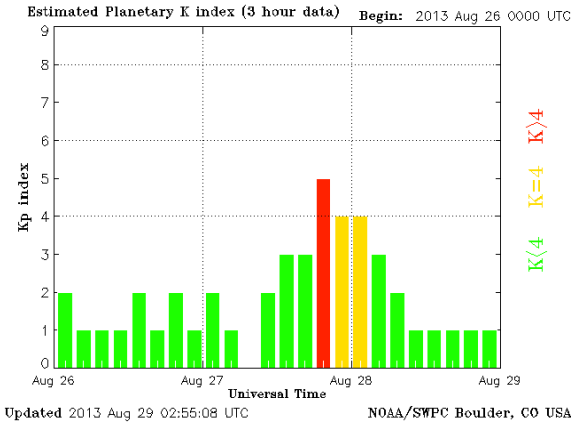
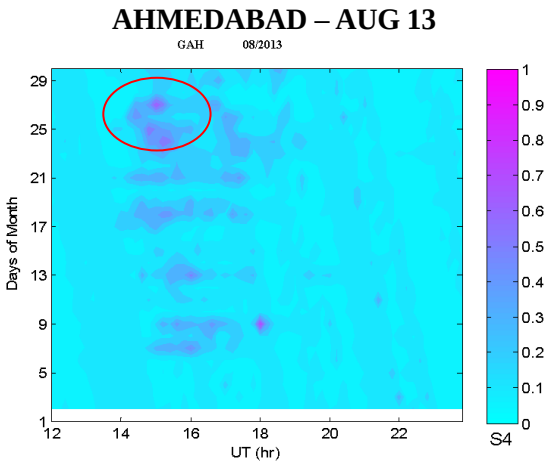


Figure 1 Continuity at INRES sites





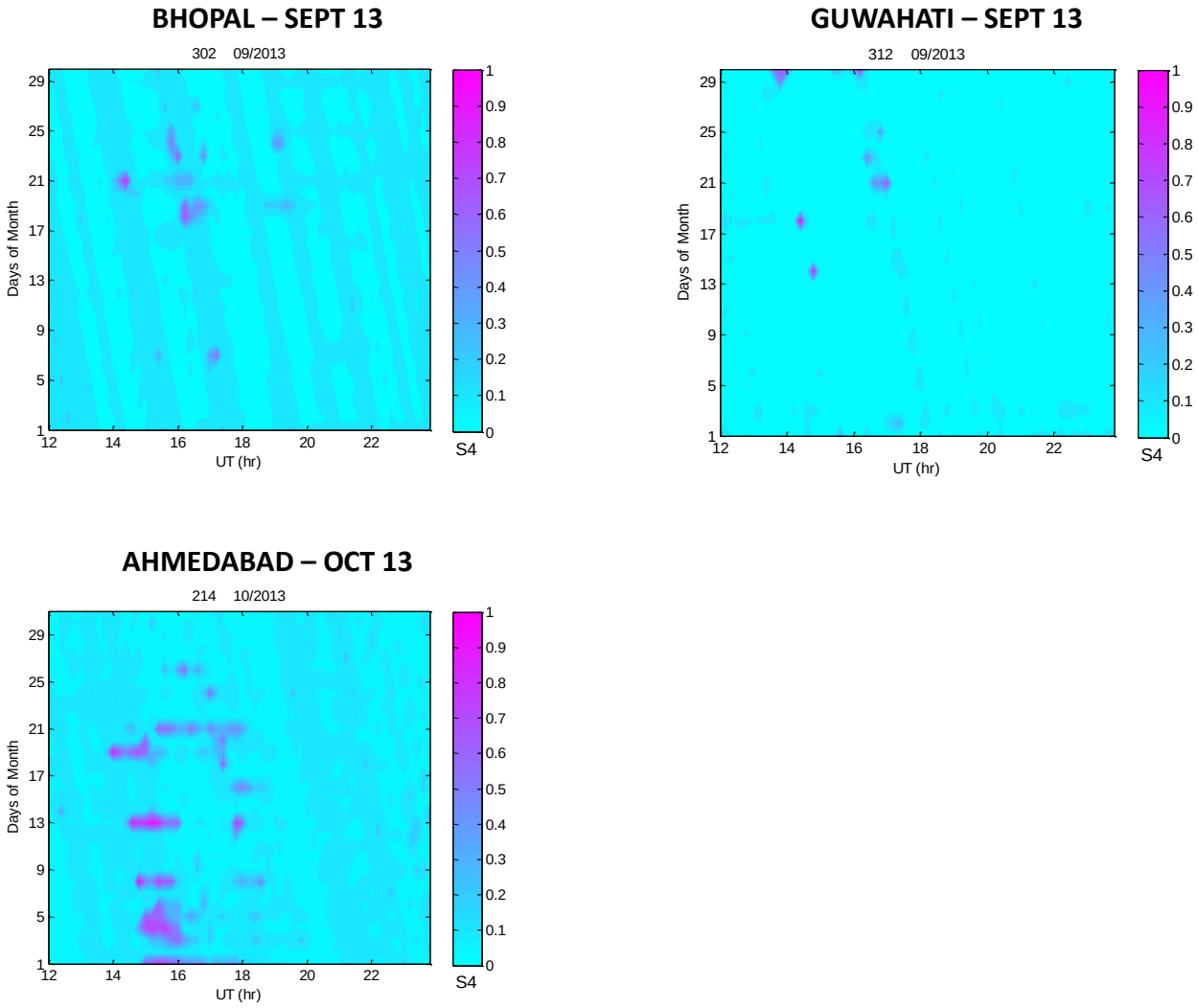


Figure 2 - Scintillation Plots (Aug/Sept/Oct -13

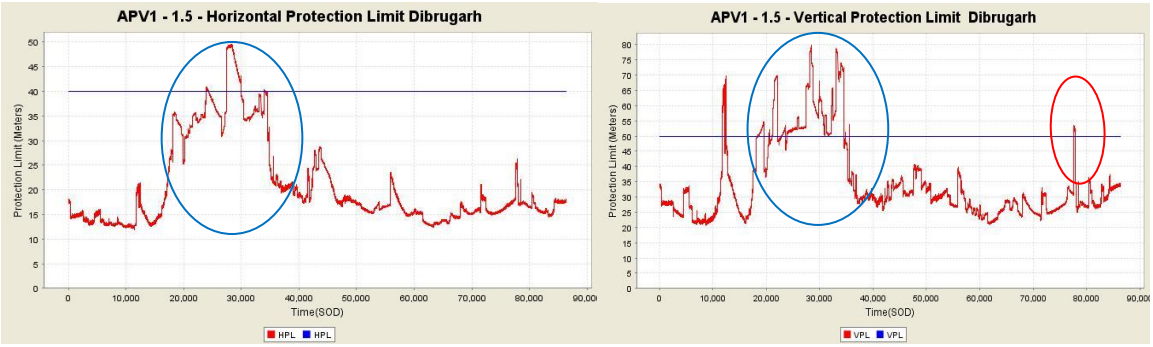


Fig 3 HPL/VPL Plot

2.6 Figure 4 shows continuity figures under benign ionospheric conditions

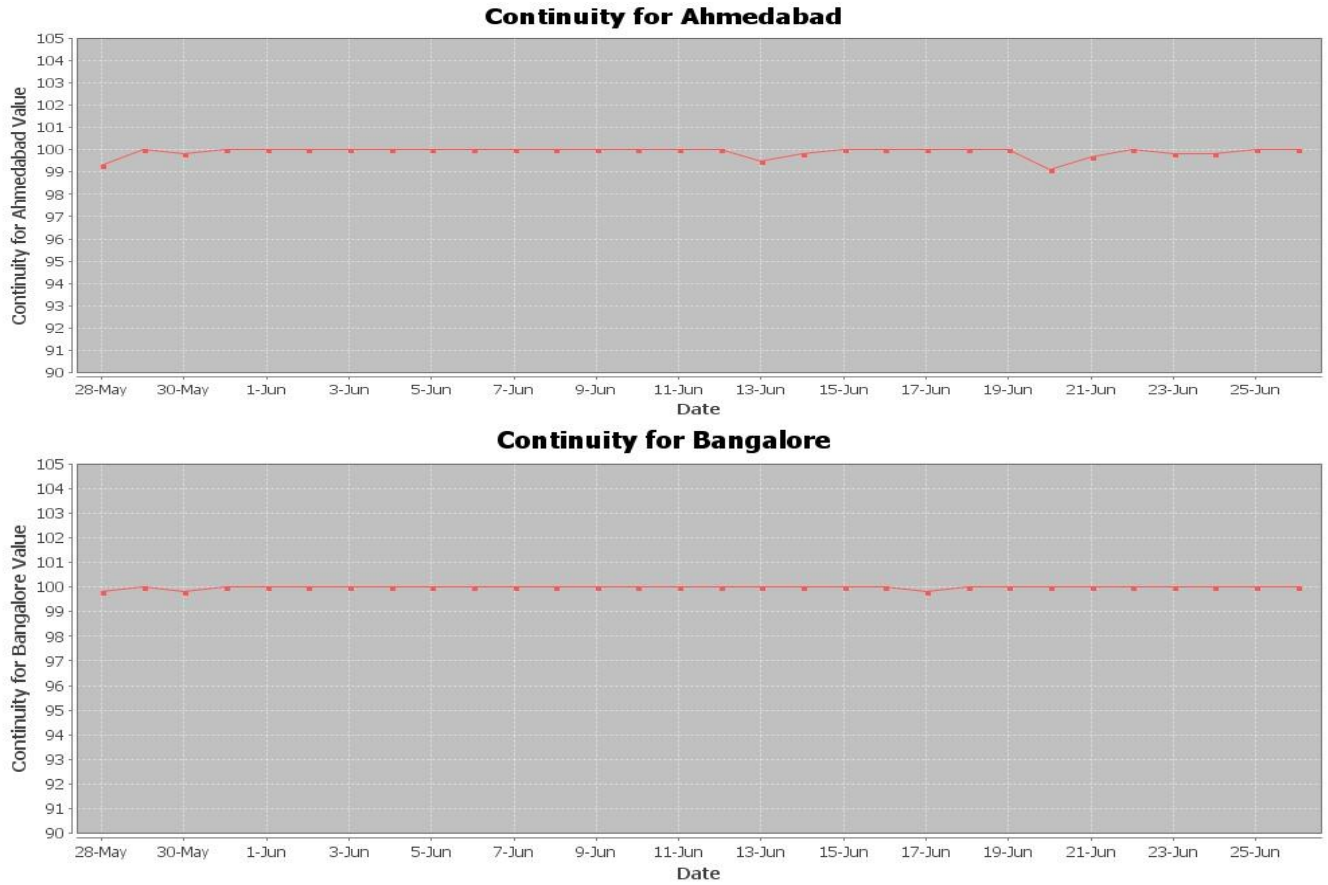


Figure 4 – Continuity (June 2013)

2.7 Effect of Ionosphere on the Uplink Stations –

2.7.1 CHALLENGES DURING GEO INTEGRATION

2.7.1.1 The GEO integration process, for the first GEO satellite (GSAT-8) started from August 2011 onwards. L5 (1176.45MHz) downlink signal were affected and the carrier to noise ratio were falling so low as to unlock the GUS receiver used in the uplink station. The drop in the C/N0 for L5 was about 25-30dB from the nominal value of 67dBHz. This drop was experienced daily from 1600UTC to 1900UTC. The effect became more and more predominant during the equinox period starting from end of September to beginning of October 2011.

2.7.1.2 The same problem was experienced during the integration of GSAT-10 with the second uplink station at Bangalore in 2012.

2.7.1.3 But when the integration was done for Delhi uplink station in 2013, this problem was not observed since Delhi (Latitude 27 Degrees) is beyond anomaly crest region.

2.7.1.4 Fig 5 shows the drop in C/N0 as seen by the uplink station receivers at Bangalore and Fig 6 C/No as seen by uplink station receivers at NewDelhi.

2.7.1.5 Inorder to avoid loss of lock the C/N0 threshold has been reduced to 27dBHz. This change has been made with the experience and data analysis. The performance is being continuously monitored.

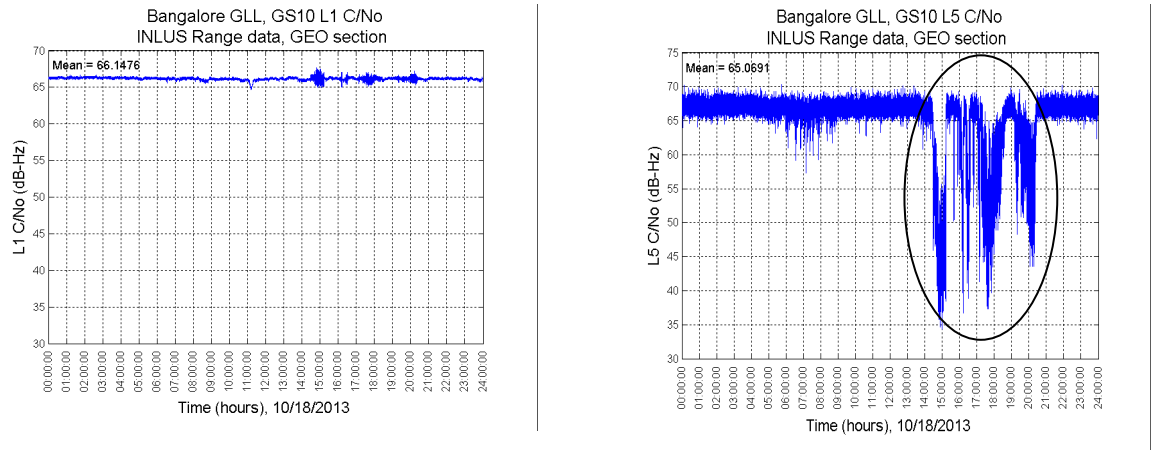


Figure 5 – L1/L5 C/N0 for Bangalore

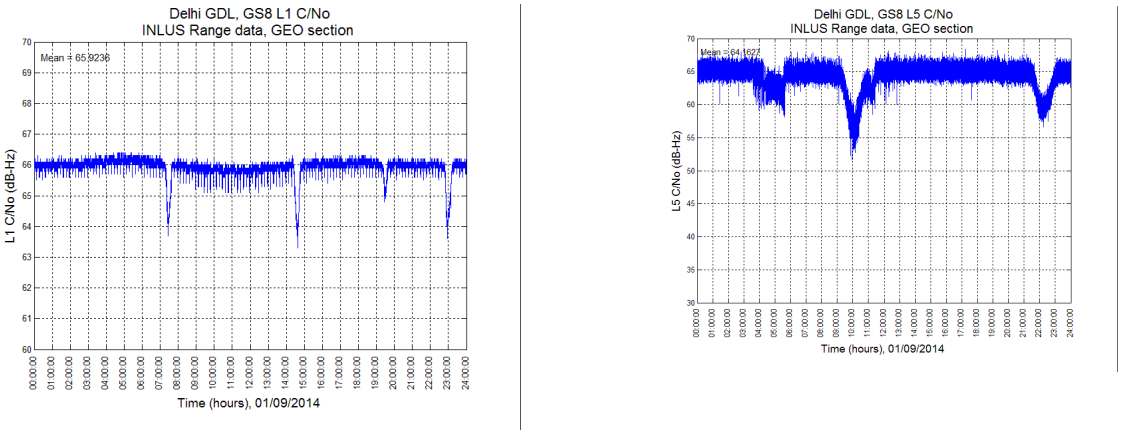
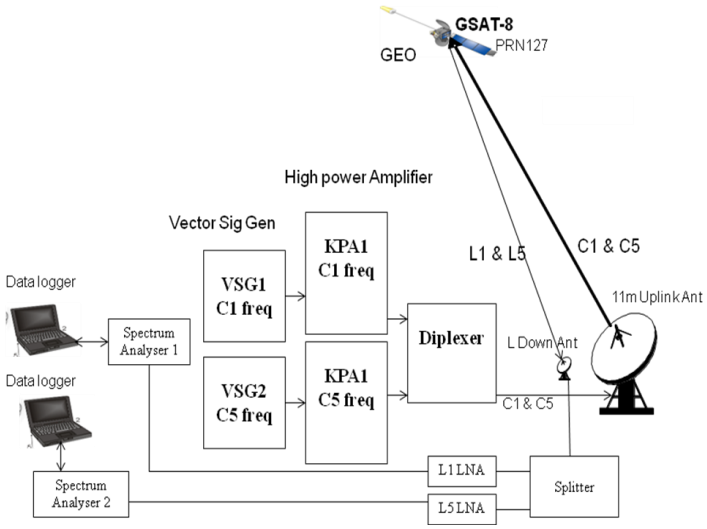


Figure 6 L1/L5 C/N0 for Delhi

2.7.2 Study of Scintillation on pure carrier

2.7.2.1 The affect of scintillation on the modulated L1 and L5 signals could not be concluded due to the large impact it had on the L5 compared to the L1. It is always better to study the effect of ionosphere on pure carrier than the modulated and spread signals. This is because it will be inconclusive to analyze the results when the signal received is a modulated spread spectrum signals.

2.7.2.2 The setup used for studying the effect of scintillation on pure carrier is shown in Figure 7



2.7.2.3 Here the nominal up-link frequency signal (For both L1 and L5 frequency) in the extended C-band is uplinked to the Navigation payload (PRN127). The uplink signal is adjusted to drive the SSPA in the navigation payload to operate in saturation. The down-linked signals are received through a dish antenna and after proper amplification are monitored on two spectrum analyzers set for L1 and L5 frequency. The output of the spectrum analyzer is continuously recorded for post-offline analysis.

2.7.2.4 The plot of the C/N0 and the signal level observed during the period is given in the plots shown in Figures 8 and 9.

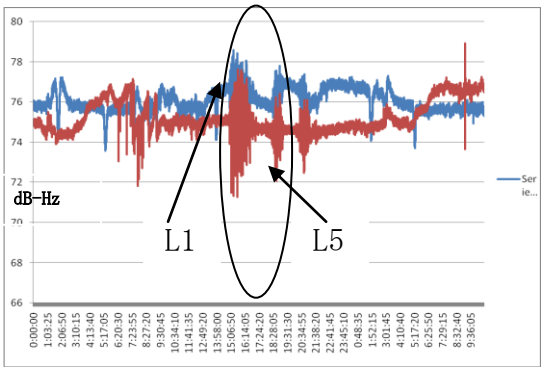


Figure 8: L1 & L5 C/N0 (dB-Hz)

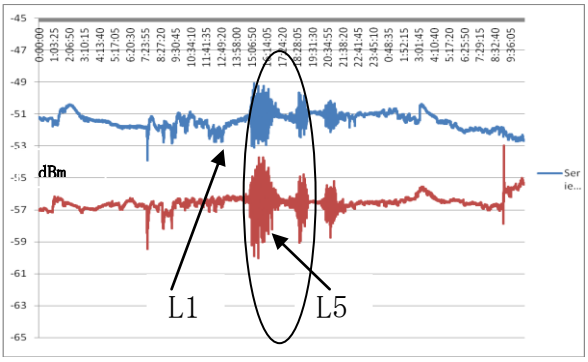


Figure 9: L1 & L5 Signal Level (dBm)

2.7.2.5 The analysis of the results shows that the effect of the scintillation on L1 and L5 carrier are as per the frequency difference in frequency between the L1 and L5. That is the higher frequency gets less affected and the lower frequency gets more affected due to the propagation through ionosphere. Also the drop in C/N0 is not as severe as it was when the carrier was modulated.

2.7.3 The study concluded that the modulation and chipping rate plays very important role in this phenomena which is due to the scintillation. Also the effect is more predominant on L5 due to the higher chipping rate of 10MHz and less predominant due to the less chipping rate of 1MHz.

3. CONCLUSION

3.1 The following are the conclusion of the study conducted during the Geo integration of the GAGAN navigation payload with the uplink station:

a) The scintillation effect is predominant in the equatorial region and is post dusk phenomena.

b) The continuity of service is affected by the scintillation and other ionospheric effects

c) The performance of uplink station is also prone to scintillation effects.

4. ACTION BY THE MEETING

4.1 The meeting is invited to:

a) note the results of the study;

b) note that further analysis is required to fix the maximum C/N0 drop for L5 signal, which would be useful for the uplink stations in the equatorial region; and

c) discuss any other relevant matters as appropriate.

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