The Land Based Positional Accuracy Of Gps And Gps Augmented By Gagan Over The Indian Geographical Region

Bala Murugan

ABSTRACT: The Global Positioning System, which was commonly known by the North American implementation called GPS; the GPS fails to provide an accurate Position, Navigation, and Time (PNT) signal over the Indian region. The positional accuracy of GPS is not up to the mark over the Indian region because the India is located near the equator. Moreover, the equatorial ionospheric grid point (IGP) of India differs from the ionospheric grid point of North America so in order to improve the positional accuracy of GPS over Indian region, the Indian Space Research Organization along with the Airport Authority of India has launched the space based augmentation satellite called **G**PS aided and **G**eo **A**ugmented **N**avigation satellite (GAGAN) with PRN number 127 and 128. The GAGAN will make corrections in the ionospheric, ephemeris, and satellite clock errors in the navigation messages received from the GPS satellites; the certification of GAGAN is under progress. The objective of this research is to analyze the positional accuracy of GPS and GPS augmented by GAGAN over the Indian geographical region by using differential correction technique.

Index Terms : GPS, PNT, GAGAN satellite, GAGAN augmentation, differential correction technique.

1 Introduction

The Navigation scientists from all over the world were looking for a navigation system that should be available for service all over the globe. Finally, the system arrived in 21st century called Global Navigation Satellite System (GNSS) [14]. The GPS is the part of GNSS systems where the other systems include: GLONASS, Galileo, and Beidou. The Global Positioning System is the space based augmentation system, which provides the position, navigation, and the time signals to all over the globe [3]. The positional accuracy of GPS is not sufficient for civil navigation [14]. The satellite based augmentation systems (SBAS) are evolved to improve the positional accuracy of GPS. The **G**PS **A**ided and the **G**eo **A**ugmented **N**avigation system, shortly called as GAGAN. The GAGAN is one among the SBAS systems. The GAGAN was developed and operated by the Indian Space Research Organization along with the Airport Authority of India [14]. The prominent errors affecting the accuracy of the GPS are ionospheric delay, satellite clock, ephemeris, multipath, and dilution of precision. The GAGAN is operated to reduce the ionospheric, satellite clock errors and the ephemeris errors from the GPS satellites. For an accurate positioning, we need four or more than four satellites; the best four satellite signals are identified by the dilution of precision approach (DOP). The GAGAN is under certification process [12]. The GAGAN have to be certified by the international civil aviation organization based on its positional accuracy [12]. This research will analyze about the position accuracy of the GPS and the GPS augmented by GAGAN over the India region.

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2 The Global Positioning System

The Global Positioning System is the space based navigation system, which was developed by the US Department of Defense in 1970 [11]. The GPS satellites transmit signals to the earth and it was used by the GPS receiver to calculate the position, navigation, and the time signal. Initially, the GPS is designed for the US military, but later, it was used for the civil applications also [11]. The GPS modernization program took place in may 2000. President Bill Clinton, who was the former president of United States, has ordered the US Department of Defense to turn off the GPS selective availability feature [11]. The civil GPS accuracy was improved due to the deactivation of selective availability feature. The GPS constellation is the mixture of new and the old satellites. The new satellites include: GPS block IIR (M), GPS block IIF, and GPS block III [7].

2.1 The Global Positioning System service and Signal

The GPS has two types of service: the standard positioning service, which is used by the civil users and the precise positioning service, which is used by the US defense [3]. The standard positioning service uses the C/A code with the L1 signal [3]. The GPS satellites currently transmits signal in L1 and L2 band. The frequency of L1 band is 1575.45MHZ and the frequency of L2 band is 1227.6 MHZ [7]. Both L1 and L2 frequencies are used to determine the ionospheric delay. The ionospheric delay can contribute the ranging error up to 40 meters.

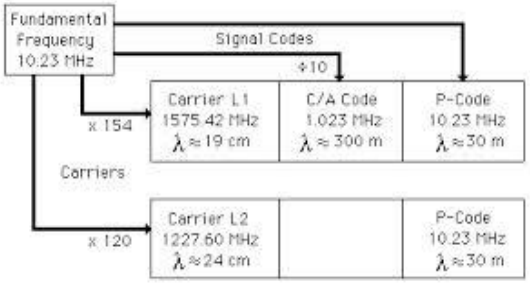

Fig. 1. GPS signals and Service

2.2 THE GLOBAL POSITIONING SYSTEM ACCURACY

The accuracy of GPS is low due to the error sources. One of the prominent contributors of the errors is ionosphere [10]. The ionospheric delay affects the accuracy of the GPS. The ionospheric delay varies over time. The magnitude of ionospheric delay will be more during solar emission. The figure 2 shows the giant solar emission that affected the earth's ionosphere. The ionospheric delay can be removed by comparing the L1 and the L2 band frequencies [3]. The receiver noise affects the GPS accuracy. The receiver noise is susceptible to the multipath. Generally, the receiver noise error will be of 0.5-2mm. The Dilution of precision (DOP) often known as Geometrical Dilution of Precision (GDOP) is used to measure the satellite geometry [13]. The GDOP is calculated by choosing the optimum number of satellites. The poor GDOP value results in the poor accuracy and it affects the positional accuracy of GPS system [13]. The control segment is responsible for calculating the GPS orbital and timing data [7]. These data are uplinked to the satellite and transmitted to the users via GPS message. The orbital and the timing data affects the accuracy of the GPS positioning. The up gradation of the GPS control segment will maintain the ephemeris accuracy at 1-2 meters [7].

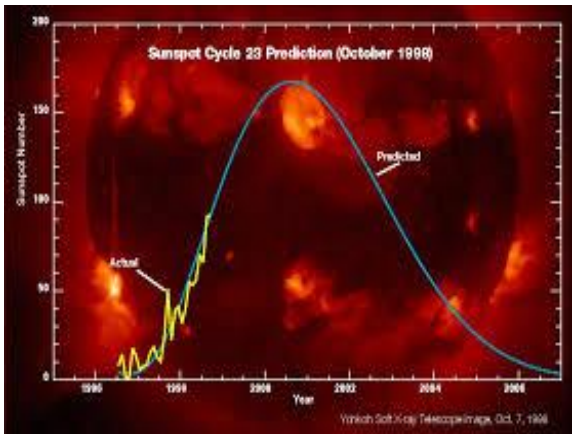

Fig. 2. Sunspot Cycle – 1999

2.3 SATELLITE BASED AUGMENTATION SYSTEM

The space based augmentation system aids the GPS system in order to increase the accuracy, availability, and the integrity [14]. The augmentation system helps to remove the errors from the GPS signal. The United States developed its own augmentation system called WAAS (Wide Area Augmentation System). In 1996 the European Space Agency developed its own augmentation system called EGNOS (European Geostationary Navigation Overlay System). The Japan has developed its own navigation system called MSAS (Multi- Functional Satellite Augmentation System). Finally, India has developed its own augmentation system called GAGAN (GPS Aided and Geo Augmented Navigation system).

Fig. 3. Different Augmentation System

2.4 THE GAGAN AUGMENTATION SYSTEM

The GPS Aided and Geo Augmented Navigation (GAGAN) is operated and maintained by ISRO along with the Airport Authority of India. The GAGAN system was placed in the GEO stationary orbit. The GAGAN system undergoes three phases: Technical Demonstration Phase, Initial Experimental Phase, and Final operational Phase [8]. Fifteen reference stations are being installed in all over India [15]. The Indian reference stations (INRES) are used to collect the data from the GPS and GAGAN satellites and these data will be send to the master control station (INMCC) [8]. The master control station corrects the errors from the GPS system. The corrected navigation messages are uplinked to the GAGAN satellites through the uplink antenna in the master control station. The accuracy of GAGAN is being monitored in master control station. The GAGAN architecture is been showed in the figure 5.

Fig. 4. GAGAN Systems

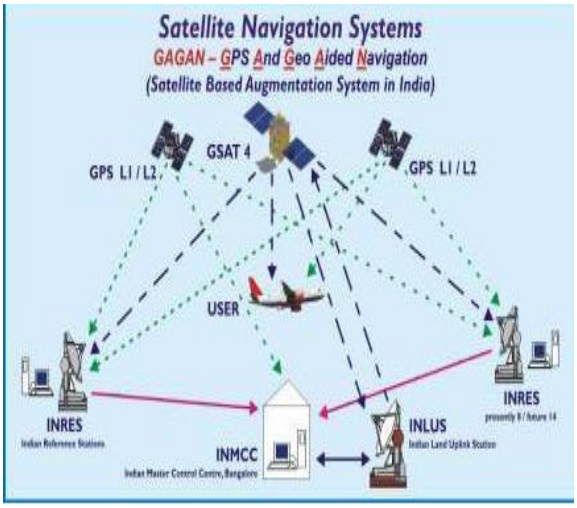

Fig. 5. GAGAN System Architecture

2.5 Differential Correction Technique

The differential correction technique (DGPS) uses the ground reference station to determine the difference between the position indicated by the navigation satellites and the know reference position [6]. The DGPS receiver is acts as a reference station. The data received from the GPS and the GAGAN satellites are mathematically analyzed by the receiver. The both GPS and GOS aided GAGAN data is analyzed to find the position indicated by the GPS and GPS aided GAGAN satellites and these positions are compared with the actual position of the receiver. This technique is used to investigate about the positional accuracy of GPS and GPS aided GAGAN over Indian region. The positional accuracy is determined by analyzing the degree of closeness of the position indicated by the receiver with the know reference position [6].

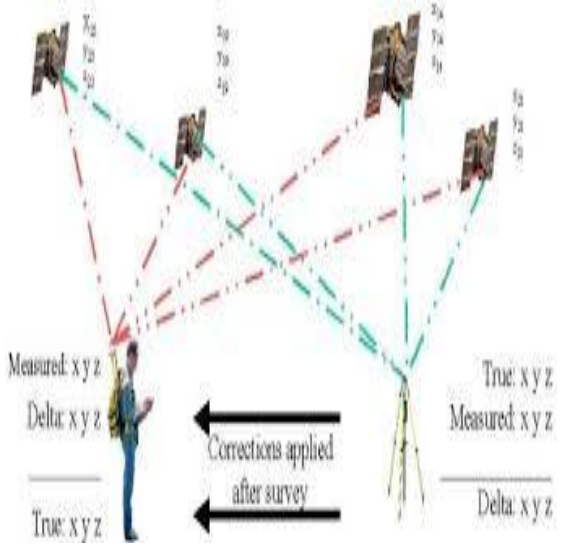

Fig. 6. Differential Correction Technique

3 Results and Discussion

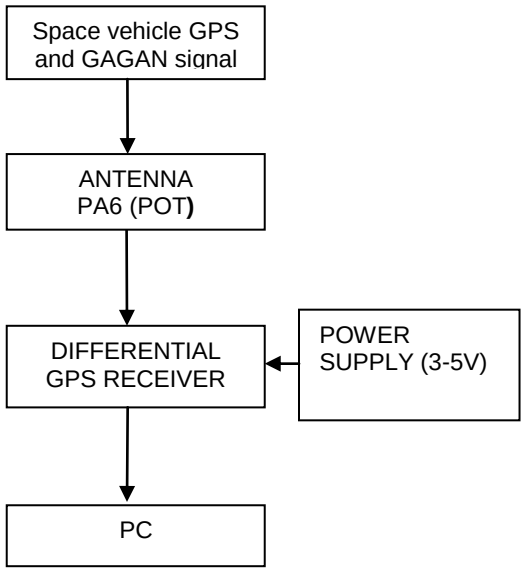

Fig. 7. Reference Station

The navigation signal from the GPS and the GAGAN satellites are received by the ground receiver antenna. The navigation message from the antenna is passed to the GPS chipset. The Trimble Studio software receives the navigation message from the chipset in the NMEA 0183 format [5]. The data collected from the software is analyzed to find the positional accuracy of GPS and GPS aided GAGAN with the known position of reference station.

3.1 Differential GPS Receiver Description

Fig. 8. Differential GPS Receiver

The GPS module has an automatic antenna switching function and short circuit protection function. The GPS chipset is powered by the Media Tek Inc and it can support up to 66 channels [1]. This receiver is enabled to receive the signal from the augmentation satellites, like WAAS, EGNOS, MSAS, and GAGAN [1].

3.2 ACCURACY ANALYSIS

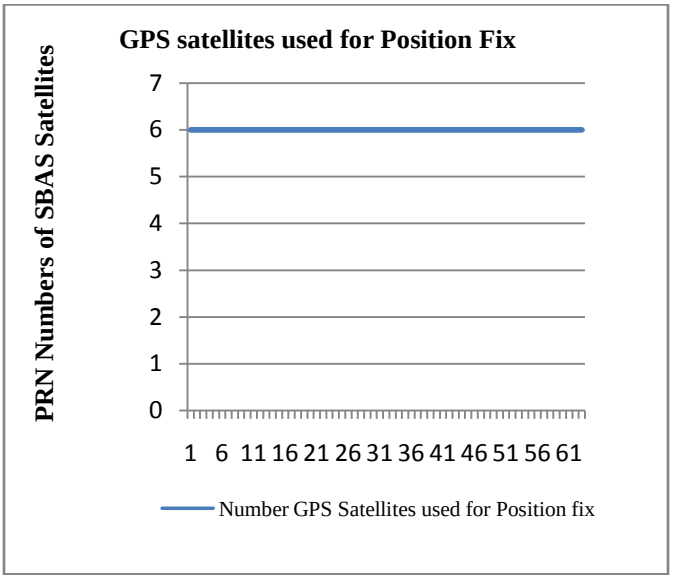

Fig. 9. GPS Satellites Number for Position Fix

For the good positioning accuracy, the receiver should get signal from four or more than four satellites [9]. The analysis from figure 9 shows that there are six GPS satellites used for position fix so it is possible for the receiver to provide three Dimensional positioning. Moreover, if the availability of the satellites increases, then the positional accuracy will increase [02].

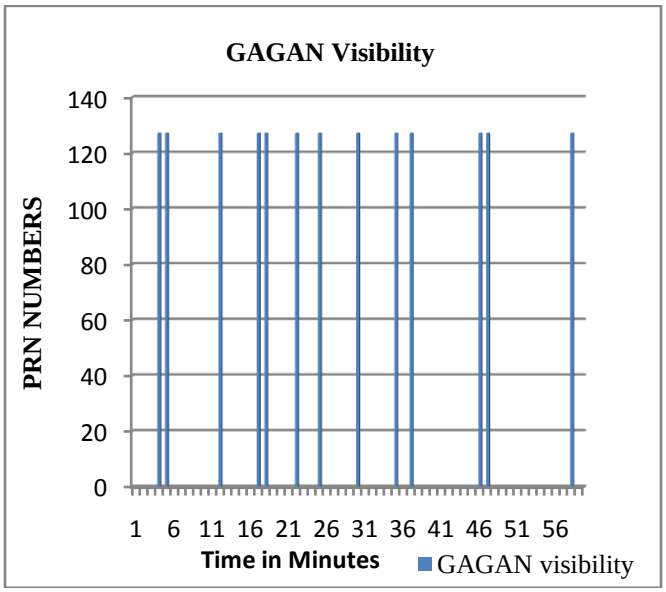

Fig. 10. GAGAN Visibility

The GPS Aided and GEO Augmented Navigation (GAGAN) satellite with PRN number 127 and 128 was developed and operated by ISRO along with the Airport Authority of India [15]. The GAGAN will help to increase the positional accuracy, availability, and integrity from the error porn GPS signal. [14]. The GAGAN corrects the ionospheric, ephemeris, and satellite clock errors from the GPS signal; the GAGAN with the GPS satellites will help to maintain the good positional accuracy than using the GPS alone for positioning [14 - 4]. From the figure 10 the GAGAN was frequently available to aid GPS.

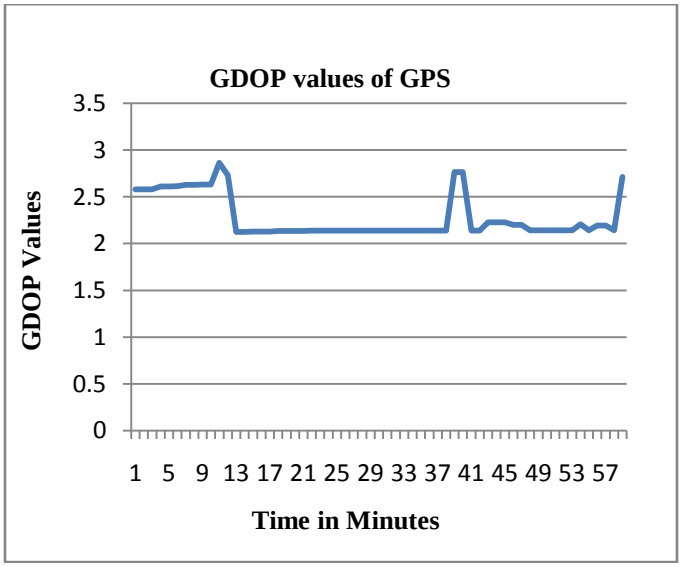

Fig. 11. GDOP Analysis

The Geometrical Dilution of Precision (GDOP) also decides the positional accuracy. The Dilution of Precision (DOP) value should be within the limit in order to maintain a good positional accuracy. The analysis from the figure 11 shows that the GDOP is within the value 3 so that the confidence level for positioning will be good [16]. The GDOP value within 3 has very less effect on positional accuracy [16]. These DOP errors can be removed by using differential corrections technique.

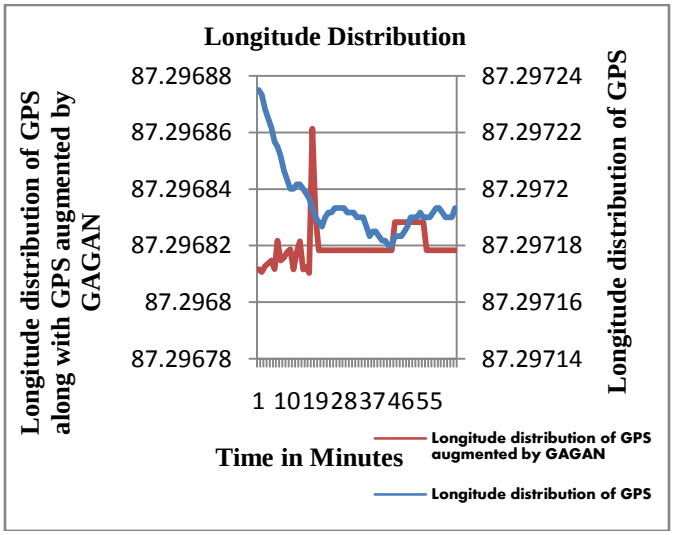

Fig. 12. Longitude Distribution of GPS and GPS along with GAGAN

The GPS signals received by the receiver are subjected to the lot of errors. Due to these errors, users are getting various positions even though the receiver was kept in the static position (Reference Station).The analysis from figure

12 shows that the longitude varies largely in time domain even though the receiver was kept in the static position. Furthermore, the longitude information from the GPS along with the GAGAN satellites is constant in some period of time domain, but at the same time the longitude information from the GPS satellite varies largely with the time domain.

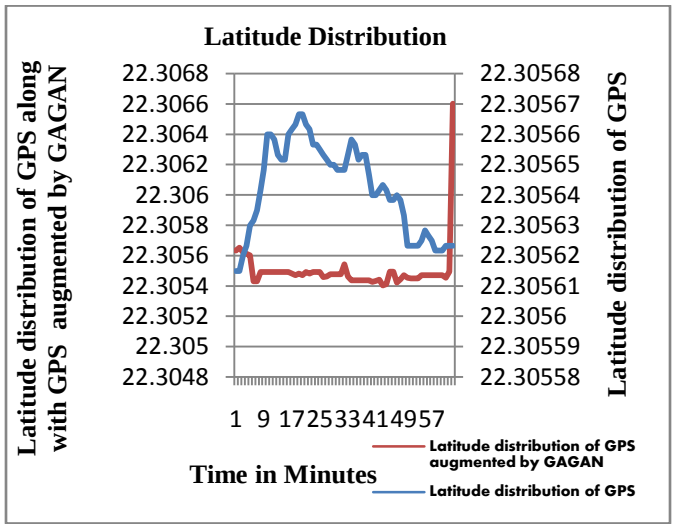

Fig. 13. Latitude Distribution of GPS and GPS along with GAGAN

The analysis from figure 13 shows that the latitude information from GPS varies largely in time domain even though the receiver was kept in the static position, but the latitude information from the GPS and GPS augmented by GAGAN varies slightly with the time domain so that the positional accuracy will be better than the GPS alone.

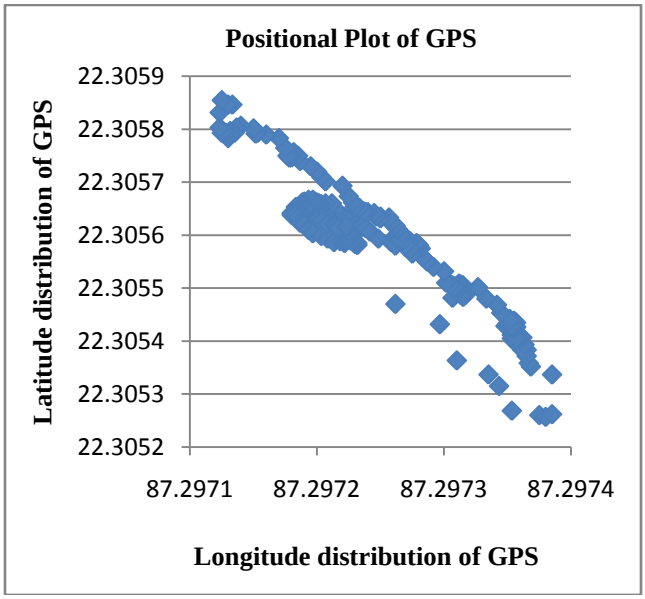

Fig. 14. Positional Plot of GPS

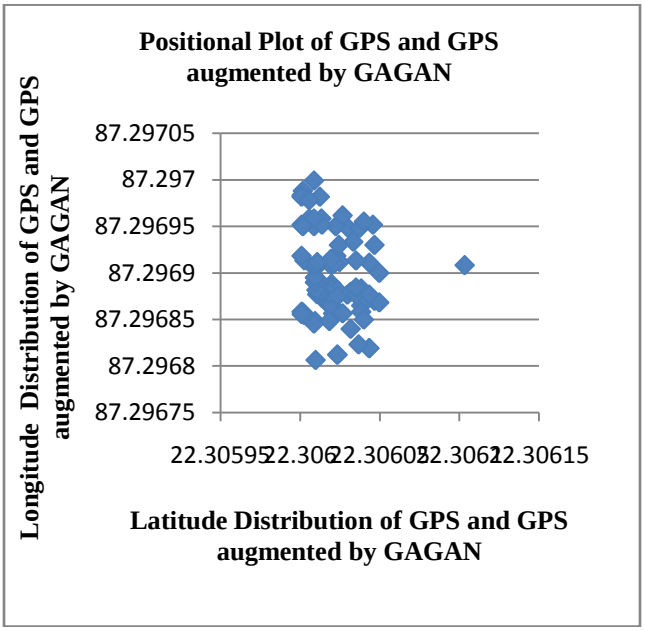

Fig. 15. Positional Plot of GPS and GPS Augmented By GAGAN

The analysis from the figure 14 shows that the coordinates both latitude and longitude spreads over a large area so that the positional accuracy and the integrity was not good in case of GPS, but the analysis from figure 15 shows that the coordinates both latitude and longitude of GPS augmented by GAGAN spreads over a very small area so that the positional accuracy and integrity of GPS augmented by GAGAN is good than the GPS alone.

Fig. 16. Positional Accuracy of GPS in Map View

The red dots from figure 16 indicate the various positions of the GPS receiver, but the receiver was kept in the static position. The black elliptical shape in figure 16 represents the range of position errors when the receiver uses the GPS signal alone.

Fig. 17. Positional Accuracy of GPS and GPS augmented by GAGAN in Map View

The red dots from figure 17 indicate the various positions of the GPS receiver, but the receiver was kept in the static position. The black elliptical shape in figure 17 represents the range of position errors when the receiver uses the GPS with GAGAN signal.

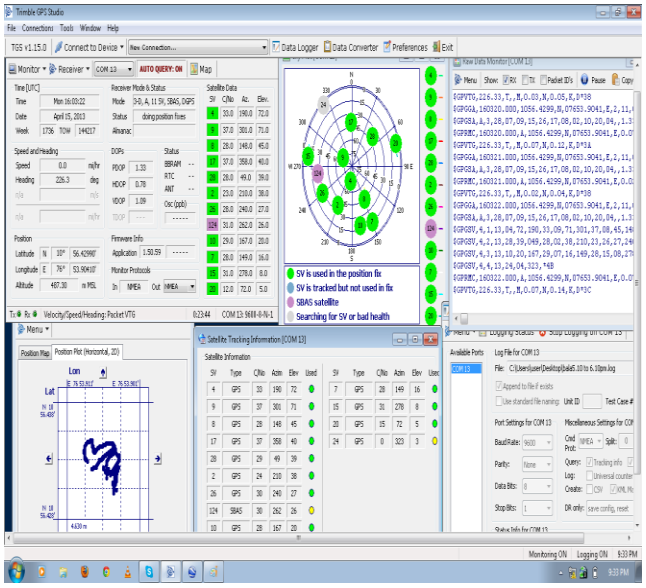

Fig. 18. Monitoring of GPS and GAGAN signal using Trimble Studio Software

4 Conclusion

The space based navigation system like GPS is providing Position, Navigation, and Time (PNT) signal to all over the globe, but the system is fully optimized to the geographical region of North America, and also they have an augmentation system called WAAS to improve the positional accuracy of GPS [8]. The positional accuracy of GPS was poor near the equatorial region. The India is currently in need of GPS for many applications, but India is located near the equatorial ionospheric belt so it is necessary to improve the accuracy of GPS over the Indian region [3]. In order to improve the positional accuracy of GPS, the ISRO along with Airport Authority of India has implemented the space based augmentation system called GAGAN [14]. The positional accuracy of GPS is continuously monitored and corrected by the Indian ground reference stations. The GAGAN ensures the good positional accuracy, continuity, availability of GPS signal over the Indian region. The receiver manufacturer's from India prefers the GAGAN augmentation system in order to provide the good positional accuracy to the civilians in India. The certification process of GAGAN is under progress and in future, the GAGAN enabled receiver will ensures a good positional accuracy over the Indian region [12].

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