REVIEW ON ESTIMATION OF IONOSPHERIC TEC

Monalika Pradhan[1], Krishnanand Jha[2], Nidhi Poojari

[1]Student, Monalika Pradhan, EXTC Engineering, SIES College, Maharashtra, India
[2]Student, Krishnanand Jha, EXTC Engineering, SIES College, Maharashtra, India
[3]Student, Nidhi Poojari, EXTC Engineering, SIES College, Maharashtra, India
[4]Prof, Sumitra Iyer, EXTC Engineering, SIES College, Maharashtra, India

---***---

Abstract - *GPS is an important aspect for navigation but there are many errors that needs to be corrected. There are various errors like satellite clock, upper atmosphere, lower atmosphere and multipath errors. However, one of the largest errors in GPS positioning is attributable to the atmosphere. The magnitude of these delays is determined by the state of the ionosphere at the moment the signal passes through, so it's important to note that its density and stratification varies. The sun plays a key role in the creation and variation of these aspects. Also, the daytime ionosphere is rather different from the ionosphere at night. The project is carried out in four stages: Data abstraction, Converting the data, Studying the necessary parameters to estimate the impact of ionosphere in positional accuracy and Developing a software to calculate the parameters. We are developing a software which will take the input (raw data) and give us the necessary parameters of ionosphere as output which will help in estimating the errors.*

1. INTRODUCTION

GPS is an important aspect for navigation but there are many errors that impacts the accuracy of the system which needs to be corrected. Some of major errors are due to satellite clock, upper atmosphere, lower atmosphere and multipath. GNSS is used which is the constellation of GPS. Equivalent of GPS is GLONASS(Russia), IRNSS an Indian satellite. As the GPS satellite data is available in real time, the improved correction is implemented on GNSS system instead of IRNSS. Further, IRNSS is located at 30000km above the earth's surface and we don't have a receiver available that is compatible with IRNSS to study the correction. In the late 90's, space-based geodetic techniques such as the Global Positioning System (GPS) reached a level where millimeter-level positioning became achievable globally. In geophysics, GPS measurements have been widely used over the past decade to monitor crustal displacements, with precision levels on the order of a few mm/yr. now routinely achieved. In addition to science applications, GPS has become an essential part of the infrastructure of today's society and represents a significant commercial and job market. Application range from surveying, navigation, transportation, GIS, geophysics. GPS is now one of several positioning systems grouped under the" Global Navigation Satellite System" (GNSS).

1.1 Literature Survey

The GPS project was started by the U.S Department of Defense (DoD) in 1973, with the first prototype spacecraft launched in 1978 and the full constellation of 24 satellites operational in 1993. The Global Positioning System may be free for the whole 1 world to use, but it wasn't always that way. Originally the satellite-based system was for U.S. military only because they developed and launched the satellites, but also feared that giving the public access could potentially harm the U.S. in combat. After all, this was a system used to help missiles find targets. The military originally had no intentions on opening the system to the public. But then in 1983, a Soviet SU-15 shot down a Korean passenger jet as it strayed from its intended route into Soviet prohibited airspace. Realizing world-wide GPS could have prevented the tragedy and could prevent more in the future President Ronald Reagan opened this system to the public on September 16, 1983. There was a catch, however. The public version would have its accuracy fuzzed to a radius of about100 meters to ensure that only the U.S. military had the best data available. Now the GPS system has been developed a lot. The U.S. has long been the world leader in satellite-based positioning with its Global Positioning System. China launched 18 satellites for the system in 2018 alone. As of the end of June, there were 35 BeiDou satellites in operation, compared with 31 for GPS. The EU, meanwhile, has 22 positioning satellites and Russia 24. Japan operates four "quasi-zenith" satellites, which are limited to regional use, while India has six. The frequency used by GPS for following purpose is as shown in table.

Band	Frequency	Description
L1	1575.42mHZ	Used by civilian and military.
L2	1227.6Mhz	Used by civilian and military
L3	1381.05Mhz	Used for nuclear detonation detection.
L4	1379.913Mhz	Being studied for additional ionospheric correction
L5	1176.45Mhz	Proposed for civilian safety of life (SOL) signal.

Table 1.1: GPS frequency overview

Indian Regional Navigation Satellite System (IRNSS) its operational name is NavIC. It covers Indian region extending 1,500 km. The system currently consists of a constellation of 7 satellites, with 2 additional satellites on ground as standby. NavIC will provide two levels of service the" Standard positioning service" which will be open for civilian use and a" Restricted service" which is an encrypted service for authorised users only. Both will be carried on L5 (1176.45 MHz) and S band (2492.028 MHz). The SPS signal will be modulated by a 1 MHz BPSK signal. The Precision Service will use BOC (5,2). The navigation signals themselves would be transmitted in the S-band frequency (2–4 GHz) and broadcast through a phased array antenna to maintain required coverage and signal strength.

L5 BAND

service	Center Frequency	Allocated Bandwidth
Standard positioning system	1176.45MhZ	24Mhz (1164.45-1188.45Mhz)
Restricted positioning system (data)	1176.45MhZ	24Mhz (1164.45-1188.45Mhz)
Restricted positioning system (pilot)	1176.45MhZ	24Mhz (1164.45-1188.45Mhz)

Table 1.2: IRNSS frequency overview

S BAND

service	Center Frequency	Allocated Bandwidth
Standard positioning system	2492.028MhZ	16.5Mhz (2483.778-2500.278Mhz).
Restricted positioning system (data)	2492.028MhZ	16.5Mhz (2483.778-2500.278Mhz).
Restricted positioning system (pilot)	2492.028MhZ	16.5Mhz (2483.778-2500.278Mhz).

Table 1.3: IRNSS frequency overview.

To understand in depth about GPS following literature review has been undertaken.

Title	Reference	Objective.
Elements of Geodesy	http://www.geologie.ens.fr/ ecalais/teaching/gps-geodesy/	studied the various coordinate systems and ellipsoidal coordinate which is important for calculating distance.
Earth centric Earth fixed (ECEF) co-ordinate system	http://what-when-how.com/gps/geocentric-earth-fixed-coordinate-systems-gps	Conversion of ECEF to Ellipsoidal coordinate and vice versa
Total electron content (TEC's)	https://www.swpc.noaa.gov/phenomena/total-electron-content	Understanding the need of TEC's in GPS system. 1 TEC Unit TECU=1016 electrons/m2
RINEX data	https://cddis.nasa.gov/GNSS/RINEX.html	Understanding the Rinex format, types of files it contains and the description of interested files.
Ionosphere	http://solar-center.stanford.edu/ionosphere.html	Layers of ionosphere, effect of ionosphere on GPS precision.
Working of GPS	https://spaceplace.nasa.gov/gps/en/	How GPS works, what are the process involved in GPS, what are the GPS errors .

Table 1.4: Literature Review

1.2 Objective

The main objective of this project is to reduce errors caused due to ionospheric layer factors on GPS. The collected satellite data is available online. The data available is in a format called 'Rinex'. Our aim is to convert this data to extract necessary parameters and study the parameters affecting the accuracy of GPS signals. This data is further processed by our software program in MATLAB and Python to estimate and reduce the maximum errors.

1.3 Significance

Global positioning system utilizes frequency between 1.1 Ghz to 1.6 Ghz(microwave). The receivers are mainly of three types: 1. Single Frequency Receiver. 2. Dual Frequency Receiver. 3. Fixed Position Receiver. There are 3 main different bands with following frequency range: 1.GPS L1 Band: 1575.42 MHz with a bandwidth of 15.345 MHz 2.GPS L2 Band: 1227.6 MHz with a bandwidth of 11 MHz 3.GPS L5 Band: 1176.45 MHz with a bandwidth of 12.5 MHz 1.Dual frequency- The dual-GPS frequency reduces the GPS error rate by bringing more information and giving out a more accurate positioning reading. The devices using L1+L2 or L1+L5 bands are called dual-frequency GPS receivers. The L5 band makes it easier to distinguish real signals from the ones reflected by buildings, reducing the multipath effect caused by tall buildings in urban environments. However, it is difficult to use dual frequency in smartphones. 2.Fixed frequency- These receivers are fixed. This is the biggest drawback of fixed receivers as it is fixed for particular location. So, the operation is limited to that location only.
3. Single frequency- It is most commonly used receiver due to the fact that single-frequency GPS receiver can be used in our smartphones. Further , the reason why it is used the most is cost and the computational requirements are less

.Hence the correction is made in single frequency receiver though dual frequency and fixed position receivers have better accuracy as compared to single frequency , the correction has to be incorporated in single frequency because they are the ones used the most. But they are more prone to errors. Hence this study is very significant and for improving the accuracy in single frequency receiver there is a need to eliminate all the possible errors in the incoming signal.

2. ELEMENTS OF GEODESY

2.1 Parameterization of the ellipsoidal Earth

The shape of the Earth is mathematically represented as an ellipsoid defined by:

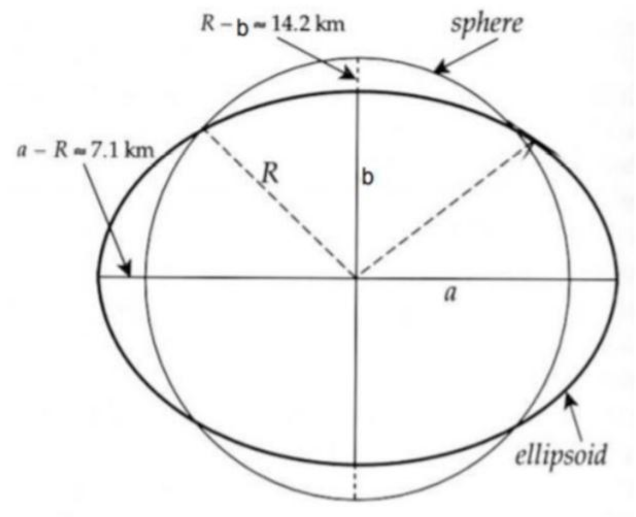

FIG 2.1: Parameters of ellipsoid
Source: www.geologie.ens.fr/ecalais/teaching/gps-geodesy

Semi-major axis = equatorial radius = a
Semi-minor axis = polar radius = b
Flattening (the relationship between equatorial and polar radius): 8 f=(a-b)/a
Eccentricity e=sqrt((sq.(a)-sq(b))/a OR sq(e)=2f-sq(f)

2.2 Co- ordinates on the ellipsoidal Earth

Given that the shape of the Earth is close to an ellipsoid, it is convenient to define a position by its latitude, longitude, and height = ellipsoidal (or geodetic) coordinates: 1. The Prime Meridian is the origin for longitudes. The Equator is the origin for latitudes. 2. Geodetic latitude phi = angle from the equatorial plane to the vertical direction of a line normal to the reference ellipsoid. 3. Geodetic longitude Lambda = angle between a reference plane and a plane passing through the point, both planes being perpendicular to the equatorial plane. 4. Geodetic height h = distance from the reference ellipsoid to the point in a direction normal to the ellipsoid. 5. Other quantities: Geocentric latitude phi

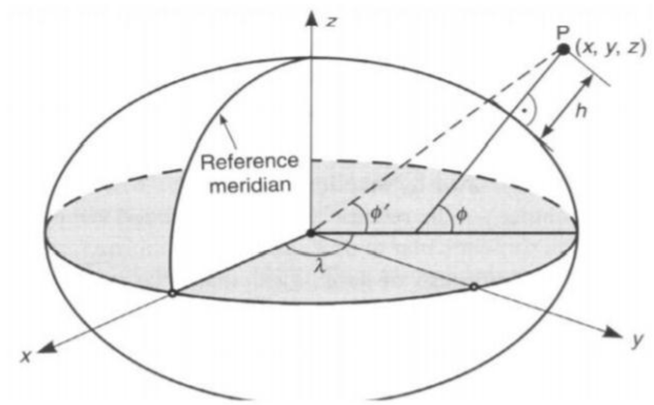

FIG 2.2: Co-ordinates of ellipsoidal
Source: www.geologie.ens.fr/ecalais/teaching/gps-geodesy

2.3 Total Electron Content (TEC's)

The total number of electrons present along a path between a radio transmitter and receiver is called as Total Electron Content. The presence of electrons affects the Radio wave. The more the radio signal will be affected, if there are more electrons in the path of radio wave. For ground to satellite communication and satellite navigation, TEC is a good parameter to monitor for possible space weather impacts. TEC is measured in electrons per square meter. By convention, 1 TEC Unit TECU = 10raiseto16 electrons/sq(m). Vertical TEC values in Earth's ionosphere can range from a few to several hundred TEC. The TEC in the ionosphere is modified by changing solar Extreme Ultra- Violet radiation, geomagnetic storms, and the atmospheric waves that propagate up from the lower atmosphere. The TEC will therefore depend on local time, latitude, longitude, season, geomagnetic conditions, solar cycle and activity, and troposphere conditions. The propagation of radio waves is affected by the ionosphere. The velocity of radio waves changes when the signal passes through the electrons in the ionosphere. The total delay suffered by a radio wave propagating through the ionosphere depends both on the frequency of the radio wave and the TEC between the transmitter and the receiver. The radio waves passes through the ionosphere for some frequencies and for other frequencies, the waves are reflected by the ionosphere. The change in the path and velocity of radio waves in the ionosphere has a big impact on the accuracy of satellite navigation systems such as GPS/GNSS. Neglecting TEC can introduce tens of meters of error in the position calculations. The GPS, the US part of GNSS, uses an empirical model of the ionosphere, the Klobuchar model, to calculate and remove part of the positioning error caused by the ionosphere when single frequency GPS receivers are used

3. WORKING AND ERRORS OF GPS

3.1 Working of current GPS system

GPS unit receives signal from satellite through GPS receiver. The Global Positioning System (GPS) is a network consisting of 30 satellites orbiting the Earth at an altitude of 20,000 km.

Currently, anyone with a GPS device, be it a SatNav or cellphones can receive the radio signals broadcasted by the satellite, but earlier this was developed only for the military navigation by the US government. There are at least 4 GPS satellites covering every part of the Earth. Each one transmits information about its position and the current time at regular intervals. These signals, travelling at the speed of light, are intercepted by your GPS receiver, it calculates how far away each satellite is based on how long it took for the messages to arrive. Once it has information the distance between the 3 satellites, your GPS receiver can pinpoint your location using a process called trilateration. Trilateration Process Imagine you are present on a particular location on Earth with 3 satellites in the sky above you. If you know how far away you are from satellite A, then you know you must be located somewhere on the red circle. If the same is done for satellites B and C, you can work out your location by seeing where the three circles intersect. Basically, intersection of all the 3 circles made by the 3 satellites will give you your exact location. This is just what your GPS receiver does, although it uses overlapping spheres rather than circles. GPS satellites have atomic clocks on board to keep accurate time the clocks on board the satellites will therefore seem to run faster than a clock on Earth. 38usec is the difference between these clocks.

3.2 Errors of GPS System

Some of the factors responsible for errors in GPS are as follows: 1. Satellite clock: Calculation of GPS positioning depends on measuring signal transmission time from satellite to receiver, this depends on knowing the current time on both sides. NAVSTAR satellites use atomic clocks, they are very accurate but can vary up to a millisecond. The errors can be minimized by calculating clock corrections and transmitting the corrections along with the GPS signal to appropriately GPS receivers. 2. Upper atmosphere (ionosphere): As GPS signals pass through the upper atmosphere, signals are delayed and deflected. Thus, signals are delayed more in some places than others due to vari15 action in ionosphere density. How close the satellite is to being overhead also determines delay. By modelling ionosphere characteristics, GPS monitoring stations can calculate and transmit corrections to the satellites, which in turn pass these corrections along to receivers. 3. Receiver clock: GPS uses quartz crystal clocks which are less stable than the atomic clocks used in NAVSTAR satellites. By comparing the times of arrival of signals from two satellites (whose transmission times are known exactly), elimination of receiver clock is done. 4. Lower atmosphere: Troposphere, tropopause, and stratosphere are the 3-lower layer of atmosphere extend from the Earth's surface to an altitude of about 50 km. The lower atmosphere delays GPS signals, adding slightly to the calculated distances between satellites and receivers. 5. Satellite orbit: GPS receivers calculate coordinates relative to the known locations of satellites in space, a complex task that involves knowing the shapes of satellite orbits as well as their velocities, neither of which is constant. The GPS Control Segment monitors satellite locations at all times, calculates orbit eccentricities, and compiles these deviations in documents called ephemerides. An ephemeris is compiled for each satellite and broadcast with the satellite signal. 6. Multipath errors: Multipath occurs when a GNSS signal is reflected off an object, such as the wall of a building, to the GNSS antenna. Because the reflected signal travels farther to reach the antenna, the reflected signal arrives at the receiver slightly delayed. This delayed signal can cause the receiver to calculate an incorrect position. The simplest way to reduce multipath errors is to place the GNSS antenna in a location that is away from the reflective surface. When this is not possible, the GNSS receiver and antenna must deal with the multipath signals. Long delay multipath errors are typically handled by the GNSS receiver, 16 while short delay multipath errors are handled by the GNSS antenna. Due to the additional technology required to deal with multipath signals, high end GNSS receivers and antennas tend to be better at rejecting multipath errors.

3.3 Factors Giving Rise to Ionospheric Error

The ionosphere is ionized plasma composed of negatively charged electrons which remain free for long periods before being captured by positive ions. It is the first part of the atmosphere that the signal encounters as it leaves the satellite and extends from about 50 km to 1000 km above the earth's surface. The magnitude of these delays is determined by the state of the ionosphere at the moment the signal passes through, so it's important to note that its density and stratification varies. The sun plays an important role in the creation and variation of these 19 aspects. Also, the daytime ionosphere is different from the ionosphere at night. When the sun's ultraviolet radiation ionizes gas molecules, free electrons are released. As their number and dispersion varies, the electron density varies in the ionosphere. This density is often described as total electron content (TEC), a measure of the number of free electrons in a column through the ionosphere with a cross-sectional area of 1 square meter: 1 TEC unit=1016. The higher the electron density, the larger the delay of the signal, but the delay is by no means constant. Changes in the ionosphere happen slowly through a daily cycle. During midnight and early morning, its value is least whereas most during local noon. During the daylight hours in the midlatitudes, the ionospheric delay may grow to be as much as five times greater than it was at night, but the rate of that growth is seldom more than 8 cm/minute. The delay is 4 times greater in November, when the earth is nearing its perihelion, its closest approach to the sun, than it is in July near the earth's aphelion, its farthest point from the sun. The effect of the ionosphere on the GPS signal usually reaches its peak in March, during the time of the vernal equinox. The ionosphere has layers, the mesosphere and thermosphere that are themselves composed of D, E, and F regions. Neither the boundaries between these regions, nor the upper layer of the ionosphere can be defined precisely. Here are some general ideas on the subject. The lowest layer, the D region, extends from about 50 km-90 km. It disappears at night and has no effect on GPS signals. The E region (a daytime phenomenon), is between 90 km and 120 km. It can cause the signal to scintillate, but its effect on the signal is slight. The F region is the layer that affects the propagation of electromagnetic signals the most. It extends from about 120km-1000km The F region contains the most concentrated ionization in the atmosphere. In the daytime, the F layer can be further divided 20 into F1 and F2. F2 is the most variable and F1, the lower of the two, is most apparent in the summer. These two layers combine at night. Above the F layer is fully ionized.

4. METHODOLOGY

4.1 Understanding the coordinate system and converting it from one system to another

We have studies about the various co-ordinate system and conversion between them. Understanding the Coordinate system is very necessary in estimating the parameters of ionosphere and calculating the position. various types of co-ordinate system studied are: 1.Cartesian Co-ordinate system 2.Spherical Co-ordinate System 3.Cylindrical Co-ordinate system 4.Polar Co-ordinate system 5.Ellipsoidal Co-ordinate system 6.Earth Centered Earth Fixed Co-ordinate system(ECEF) The significance of using ECEF co-ordinate system is since the entire ECEF reference frame rotates with the earth, this coordinate system is useful for positioning geo-stationary objects such as satellites. Earth has different reference of coordinate and the Reference of satellite is also different we needed a new coordinate system that could connect both of these which is called ECEF.

4.2 Data abstraction

The data is taken from the GPS receiver which is freely available online. The data is in RINEX format. Receiver Independent Exchange Format (RINEX Data): Easy exchange of collected, raw GNSS/SNS data. GPS receiver's output data: its position, velocity, heading determined in real time. It is useful necessary to store the measurements for postprocessing. RINEX is a standard format which allows the usage of measurements generated in the receiver, and their further 22 analysis (e.g. disturbances and position degradation, identification, development of better ionospheric models, etc). The format consists of several file types: 1. Observation Data File 2. Navigation Message File 3. Meteorological Data File 4. GLONASS Navigation Message File 5. Galileo Navigation Message File 6. GEO Navigation Message File 7. Satellite and Receiver Clock Date File 8. SBAS Broadcast Data File. "We are interested only in observation and navigation file. We have an example of RINEX observation file given below."

```
     3.01           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
BLANK OR G = GPS,  R = GLONASS,  E = GALILEO,  M = MIXED    COMMENT
gLAB                gAGE                20100317 121400 UTC PGM / RUN BY / DATE
EXAMPLE OF A MIXED RINEX FILE                               COMMENT
MRKR                                                        MARKER NAME
9080.1.34                                                   MARKER NUMBER
GEODETIC                                                    MARKER TYPE
gAGE                UPC: Technical University of Catalonia  OBSERVER / AGENCY
THIS FILE IS PART OF THE gLAB TOOL SUITE                    COMMENT
FILE PREPARED BY: ADRIA ROVIRA GARCIA                       COMMENT
PLEASE EMAIL ANY COMMENT OR REQUEST TO: glab.gage @ upc.edu COMMENT
IR2200716006        ASHTECH UZ-12       CQ00                REC # / TYPE / VERS
482                 AOAD/M_T        NONE                    ANT # / TYPE
   4789028.4701   176610.0133  4195017.0310                 APPROX POSITION XYZ
        0.9030        0.0000        0.0000                  ANTENNA: DELTA H/E/N
        0.0000        0.0000        0.0000                  ANTENNA: DELTA X/Y/Z
G C1C   0.9030        0.0000        0.0000                  ANTENNA: PHASECENTER
        0.0000        0.0000        0.0000                  ANTENNA: B.SIGHT XYZ
        0.0000                                              ANTENNA: ZERODIR AZI
        0.0000        0.0000        0.0000                  ANTENNA: ZERODIR XYZ
        0.0000        0.0000        0.0000                  CENTER OF MASS: XYZ
G    7 L1C L2P C1P C2P C1C S1P S2P                          SYS / # / OBS TYPES
R    3 L1C C1C S1C                                          SYS / # / OBS TYPES
S    3 L1C C1C S1C                                          SYS / # / OBS TYPES
DBHZ                                                        SIGNAL STRENGTH UNIT
    30.000                                                  INTERVAL
  2010     3     5     0     0    0.0000000     GPS         TIME OF FIRST OBS
  2010     3     5    23    59   30.0000000     GPS         TIME OF LAST OBS
     1                                                      RCV CLOCK OFFS APPL
G CC2NONCC          p1c1bias.hist @ goby.nrl.navy.mil       SYS / DCBS APPLIED
G PAGES             igs05.atx @ igscb.jpl.nasa.gov          SYS / PCVS APPLIED
G 0001  12 L1C S1C L2P S2D C1P S1P C2P S2P C1C S1C D1C D2P  SYS / SCALE FACTOR
```

FIG 4.1: Screenshot of Observation File

Source: gage.upc.edu

```
G 0001  12 L1C S1C L2P S2D C1P S1P C2P S2P C1C S1C D1C D2P  SYS / SCALE FACTOR
R 0001   4 L1C S1C C1C S1C                                  SYS / SCALE FACTOR
S 0001   4 L1C S1C C1C S1C                                  SYS / SCALE FACTOR
G L1C  0.00000   9 G07 G09 G12 G13 G15 G20 G21 G26 G31 G32  SYS / PHASE SHIFTS
G L2P  0.00000   9 G07 G09 G12 G13 G15 G20 G21 G26 G31 G32  SYS / PHASE SHIFTS
R L1C  0.00000   3 R11 R19 R23                              SYS / PHASE SHIFTS
S L1C  0.00000   1 S24                                      SYS / PHASE SHIFTS
  3 R11 -5R19 +3R23 -6                                      GLONASS SLOT / FRQ
    15    15  1573    64                                    LEAP SECONDS
    14                                                      # OF SATELLITES
   G07   815   815   815   815   815   815   815   815   815PRN / # OF OBS
         815   815   815                                    PRN / # OF OBS
   G09   246   246   246   246   246   246   246   246   246PRN / # OF OBS
         246   246   246                                    PRN / # OF OBS
   G12   687   687   687   687   687   687   687   687   687PRN / # OF OBS
         687   687   687                                    PRN / # OF OBS
   G13   762   762   762   762   762   762   762   762   762PRN / # OF OBS
         762   762   762                                    PRN / # OF OBS
   G15   454   454   454   454   454   454   454   454   454PRN / # OF OBS
         454   454   454                                    PRN / # OF OBS
   G20   599   599   599   599   599   599   599   599   599PRN / # OF OBS
         599   599   599                                    PRN / # OF OBS
   G21   636   636   636   636   636   636   636   636   636PRN / # OF OBS
         636   636   636                                    PRN / # OF OBS
   G26   210   210   210   210   210   210   210   210   210PRN / # OF OBS
         210   210   210                                    PRN / # OF OBS
   G31   874   874   874   874   874   874   874   874   874PRN / # OF OBS
         874   874   874                                    PRN / # OF OBS
   G32   457   457   457   457   457   457   457   457   457PRN / # OF OBS
         457   457   457                                    PRN / # OF OBS
   R11   907   907   907   907                              PRN / # OF OBS
   R19   348   348   348   348                              PRN / # OF OBS
   R23   936   936   936   936                              PRN / # OF OBS
   S24   198   198   198   198                              PRN / # OF OBS
                                                            END OF HEADER
```

FIG 4.2: Screenshot of Observation File showing the data of satellite with PRN 26

Source: gage.upc.edu

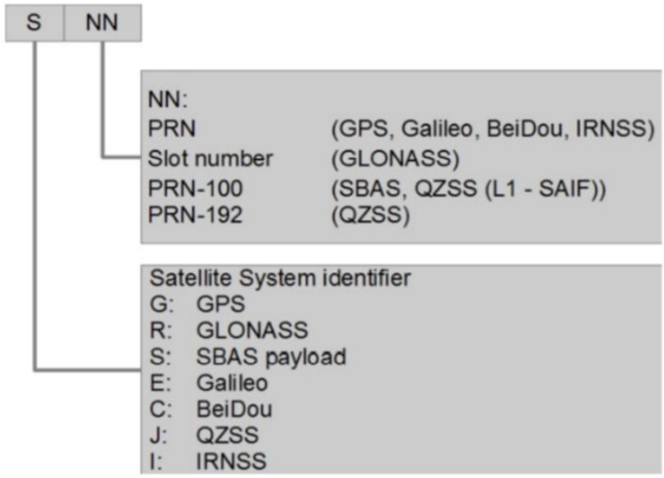

FIG 4.3: Screenshot of Satellite numbers
Source: gage.upc.edu

Description: The following Fig shows the former two-digit satellite PRN numbers 'NN' preceded by a one-character system identifier 'S' which represents the satellite for e.g. 'G' stands for GPS and '26' is PRN of GPS.

t :observation type	C = pseudorange,	L = carrier phase,	D = doppler,	S = signal strength)
n :band / frequency	1, 2, . . . , 8			
a : attribute	tracking mode or channel, e.g., I, Q, etc			

FIG 4.4: Screenshot of Observation codes
Source: gage.upc.edu

Description: The following screenshot shows three parts of observation table i.e. t, n, a where t stands for observation type, n stands for band or frequency and a stand 26 for attribute.

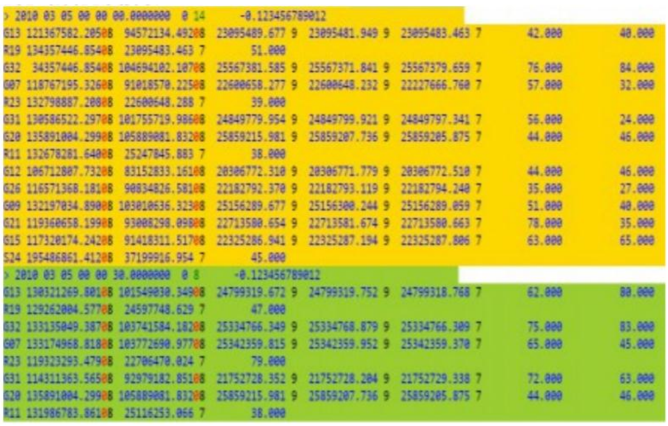

FIG 4.5: Screenshot of Observation File
Source: gage.upc.edu

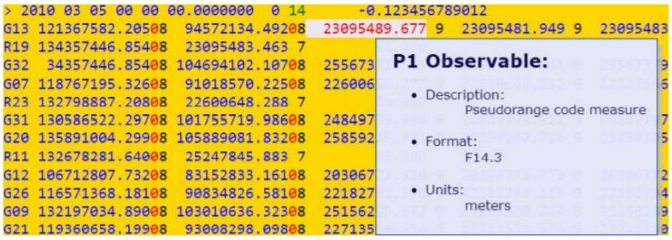

FIG 4.6: P1 observable (Pseudo range for L1)
Source: gage.upc.edu

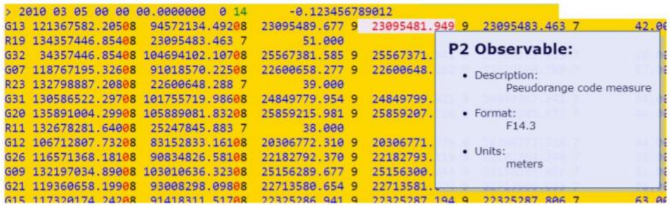

FIG 4.7: P2 observable (Pseudo range for L2)
Source: gage.upc.edu

4.3 Calculation of TEC

We are working on observation table from this we will get the value of p1 and p2(pseudo range for L1 and L2 respectively) which is required for calculation of Total electron count (TEC'S). If there is any missing of data in p1 and p2 we can use c1 data. As we are not making a real time software, we don't need l1 and l2 values (phase value of L1 and L2 band). There are many satellites above us, a minimum of 8-9 satellites are always above us of which three satellites will give us position depending upon a criteria that the satellite should be at an angle of 30 degree with respect to user. This parameter is obtained using Navigation file. The parameter of Ionosphere that affects the radio signals are Total Electron Count (TEC's). The path between the GPS satellite and GPS receiver the integral of electron density is TEC. TEC is measured in TECU where 1TECU= 1x1016electrons/m2.

5. RESULTS

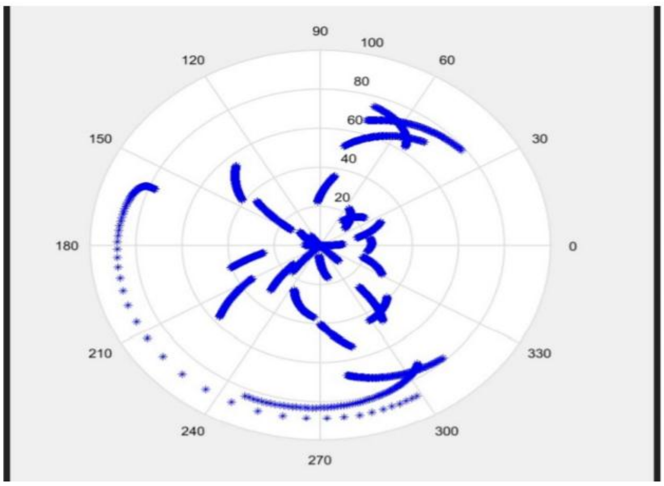

FIG 5.1: Graph of Satellite positioning.

This figure shows the different satellite views from which we can identify how many satellites are available to us. This graph is obtained using MATLAB. There are certain factors to be taken care of while selecting the satellite like the angle should be less than 30 degree.

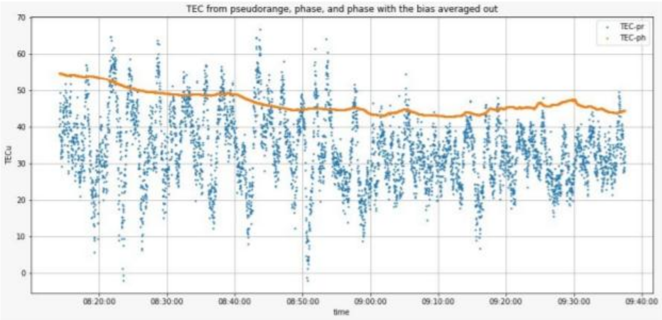

FIG 5.3: Graph of TEC VS Time

The above graph shows the output predicted using the software developed by us. The graph is obtained using Python programming. It shows total electron content (TEC's) from 8:20AM to 9:40AM. This TEC is obtained from pseudo range and phase with biased average output. TEC = (1/40.3) *(f1*f2/f1-f2) *(p2-p1) where p2 and p1 are pseudo range.

6. CONCLUSIONS

In this project we have estimated the TEC's. There are two methods for processing the TEC first is using TEC dual frequency and second is TEC Map. We used the first method i.e. TEC dual frequency method. There are some meters of errors in GPS, the factor which gives the highest error is due to ionosphere known as ionospheric delay. Ionosphere is a plasma of electrons which behave were abruptly and the sun plays a major role in change of Total electron content. As India lies near the equator it's even more difficult to predict the error by ionosphere. For this first the required data was abstracted from the RINEX observation file. Then using the data TEC was calculated. The resulting TEC contains noise effect so it was removed by Levelling Process.

REFERENCES

[1] Mitra, Monojit. Satellite Communication. PHI Learning Pvt. Ltd., 2005.
[2] Noll, Carey. "CDDIS Data Center Summary for the IVS 2015–2016 Biennial Report." (2017).
[3]DeMets, Charles, et al." GPS geodetic constraints on CaribbeanNorth America plate motion." Geophysical Research Letters 27.3 (2000): 437-440.
[4]Hernandez-Pajares, M., et al." The ESA/UPC GNSS-lab tool (glab)." Proc. of the 5th ESA Workshop on Satellite Navigation Technologies (NAVITEC'2010), ESTEC, Noordwijk, The Netherlands. 2010.
[5]Arikan, F., et al." Space weather activities of IONOLAB group: IONOLAB-TEC." EGU General Assembly Conference Abstracts. Vol. 11. 2009.
[6]Scherrer, Philip, Deborah Scherrer, and Stanford Solar Center. " Solstice and Equinox ("Sun track") Season Model." (2014): 1-17.