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Real time estimation of IRNSS for positioning error and ionospheric delay measurement using klobuchar model for TEC calculation

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***Abstract*- Indian Regional Navigation Satellite System (IRNSS) is fully established and operational, independent and indigenous satellite based navigation system to provide the services in and around India. The real time analysis of the system in field of ionospheric is carried in which the effect of the ionospheric is shown. This ionospheric effects are most varied at the equatorial region of the earth due to its magnetic field, as India is situated in equatorial region its effect are to be considered for position measurement. The method used for measuring the iono delay and calculating the total electron content (TEC) is the method that used for GPS. There's no particular method or model used for measuring the ionospheric delay for Indian region navigation satellite, here we use Klobuchar model for measuring the TEC and ionospheric delay. Also the grid based model can be used for measuring the iono delay. The effect of iono delay on the position is observed, this give inaccurate location with ionospheric error in measuring the position. The ionospheric is layer build with ions and which is highly influenced by the solar activity. The comparison of IRNSS with GPS satellites is observed, which are tracked at a moment by IRNSS receiver shows the interoperability.**

***Index Term*- IRNSS, Ionospheric delay, TEC, Klobuchar model.**

I. INTRODUCTION

Indian Regional Navigation Satellite System (IRNSS) is a regional, independent satellite navigation system, established and controlled by the Indian Space Research Organization (ISRO) reason for developing such a navigation system is to be independent from existing GNSS system during Hostile situation. The constellation consists of seven satellites and is fully functional now. They are named as "IRNSS-1" series. It is designed to provide the service for positioning in and surrounding India up to 1500km, with two services, encrypted service and open access services that are Standard Positioning Service (SPS) and Restricted Service (RS). As the Indian is situated in near equatorial region its ionosphere is characterized by large gradients, intense irregularities and equatorial anomaly conditions, a suitable regional ionospheric model is necessary. For cm level positioning accuracy the ionospheric delay becomes more stringent. As different models are developed for measuring the iono delay but any of these models are not perfectly suitable to the equatorial region. Many researches and models are being study, out of which here we are using Klobuchar model used to correct the iono delay for positioning error up to 50%. The value of TEC will give the total number of electron in the line of sight. This is the basic approach to analysis the ionospheric effect and delay on IRNSS and to design the model based on further research carried in upcoming years using RT data of more than one or two years from IRNSS receiver over all India.

II. IONOSPHERIC DELAY AND KLOBUCHAR MODEL

Ionosphere is the layer above the earth surface from 50km to thousands of km. It has four layers and consists of free electrons and ions, solar radiation highly drives the ionospheric effect and they are describe in terms of electron density. Due to earth's equatorial magnetic effect there is highest variation in the density of electrons in equatorial region. The electron density varies with the day time and observed to be highest in noon time and low in the midnight this electron density is measured in term of total electron content (TEC) which means that number of electron in a cross-sectional area of 1 square meter. The altitude above 350km in F2 region has maximum variation in electron density during day time so the ionospheric delay is measured at the layer 350km above the earth surface. The signal delay caused is directly proportional to the number of free electron along the ray path. Total electron content (TEC) along the ray path of the signal from satellite to the receiver is given by equation (1)

$$\text{TEC} = \int_S^R Ne(l)\,dl \qquad \text{.... (1)}$$

Where, Ne is number of free electrons and l is distance between satellites to receiver.

First the point where the signal cut the ionospheric layer at 350km altitude is need to identify this point is known as Ionosphere Pierce Point (IPP) from this point the slant delay and latitude and longitude of this point is calculated. From this calculation the Iono time delay is calculated as given by equation (2)

$$\text{Iono delay} = I * C \qquad \text{.... (2)}$$

Where, I is the time delay measured using the slant factor obtain from the IPP and the C is speed of the light.

From this the value of total number of electron can be calculated as given in equation (3)

$$\text{TEC} = \text{Iono delay} * (F)^2 / 40.3 \qquad \text{.... (3)}$$

Where, F is the frequency of the signal. For IRNSS uses L5 and S band frequency whose centred frequency is 1176.45 MHz and 2492.028 MHz respectively.

Thus the Iono delay calculation is carried. The effects due to ionosphere are the time delay of all the codes of the signal are change, also change in carrier phase occurs and modulation changes, which it possess at the time of transmission. The signal travelling from the satellite to the receiver come across the ionosphere region if it spend more time in the ionosphere region it will have more delay. For higher frequency the time delay is less compare to lower frequency. This means the higher frequency carrier are lesser affected by the ionosphere than the lesser frequency carrier. The navigation message also changes due to the ionosphere effect. Group delay and the phase delay are occurs due to which the carrier may get phase advancement in ionosphere region. The pseudorange value will be change due to the ionospheric effect it can be short or long according to the observed code. These cause the error in manipulation of position of the receiver or the user.

III. SIMULATION AND RESULTS

Calculation for TEC on the basis of the calculated Iono delay is as shown in following table 1 and table 2, for one particular day and two different time slots. This calculation is based on the equation 2 and 3 mention in above section. For the same day the Sky plot shows the number of satellite track by the IRNSS receiver for which the TEC is calculated for only IRNSS satellites.

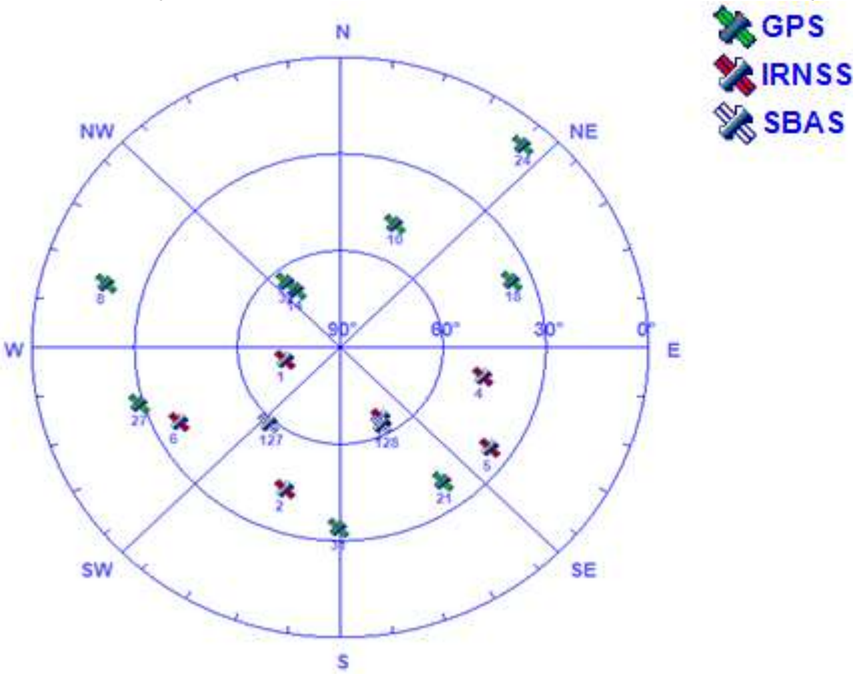

Figure 1

Sky plot shows the position of satellite and number of satellites track over that time and day by IRNSS receiver. This receiver can take the signal of IRNSS along with the GPS and SBAS. So the GPS as well as SBAS signal can also be manipulated for comparison. So at a time three different GNSS satellites are tracked by IRNSS receiver.

The value of TEC calculated by Matlab programming using single frequency Klobuchar algorithm and they are as shown in table 2 and table 3 on an average for two different time slots, one at the midnight and other at noon is being shown, at the midnight time the value of TEC is low and where as in the noon time the observed value of the TEC increase to a greater value this shows that the electron density is highly influenced by the solar activity. For the same day and the time the graph is plotted for Iono delay which clearly can be seen that the Iono delay increases with the time of day and becomes highest in the noon time this value are not certain but can be approximate using more data.

This data is collected from the Surat station at an Latitude of 21°8'23.63" N, Longitude of 72° 47'39.62" E and altitude of -25.44 and RT data is manipulated in Matlab programming. This tabular data and graph of figure 2 and figure 3 are both using the data provided from the IRNSS receiver from Surat.

Table 1

21 April 2016, 12-3 AM	Ionospheric Delay	TEC
PRN 1	3.8875	4.0052e+25
PRN 2	2.5571	2.6345e+25
PRN 3	2.6231	2.7025e+25
PRN 4	3.8482	3.9647e+25
PRN 5	5.3299	5.4913e+25
PRN 6	3.7481	3.8616e+25

Table 2

21 April 2016, 12-3 PM	Ionospheric Delay	TEC
PRN 1	10.1706	1.0478e+26
PRN 2	6.7394	6.9435e+25
PRN 3	8.5535	8.8126e+25
PRN 4	14.2304	1.4661e+26
PRN 5	7.7637	7.9989e+25
PRN 6	10.7757	1.1102e+26

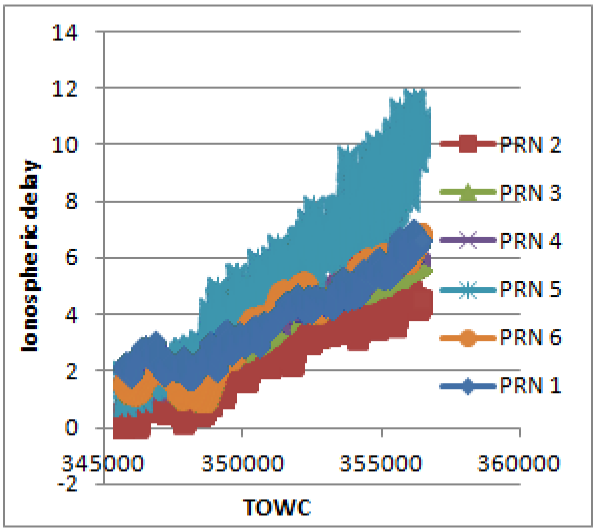

Figure 2

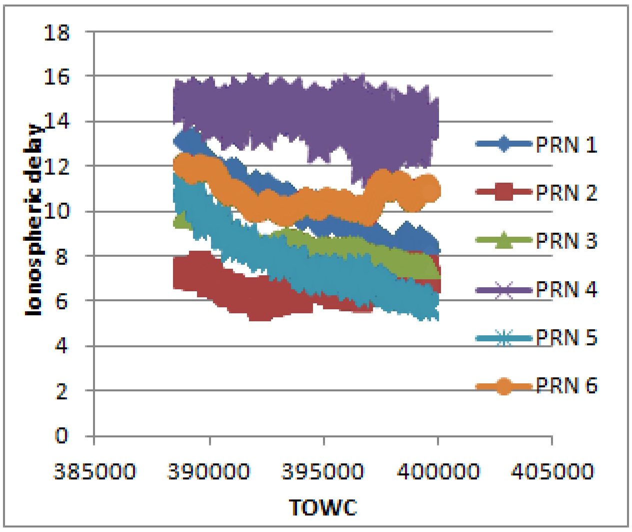

Figure 3

Position error is the error in measuring the location of the receiver from the satellite, it is the difference in the actual calculated position by satellite and the once shown in the satellite receiver data. This position error in meters is shown for IRNSS as well as for GPS in figure 4 and figure 5 respectively.

In figure 4 and figure 5, along with the position error due to ionospheric effect the number of satellites and the GDOP is shows. GDOP is the geometric dilution of precision, which means the effect of the position of satellite in measurement of the receiver position. The value of the GDOP should be less, lesser the value more accurate the position of the receiver is calculated. This data is collected from the Ahmedabad receiver.

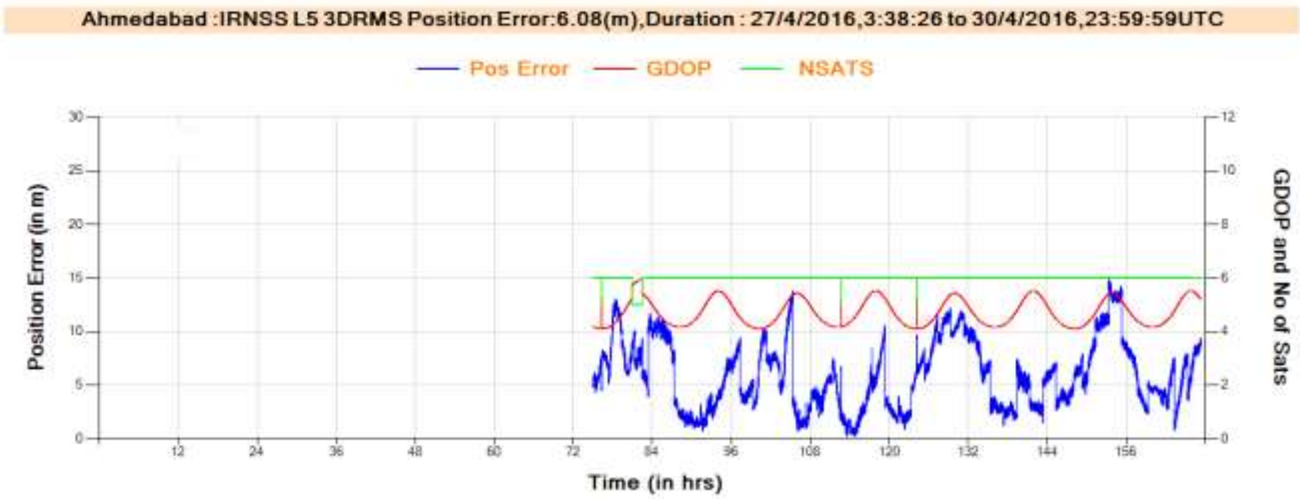

Figure 2

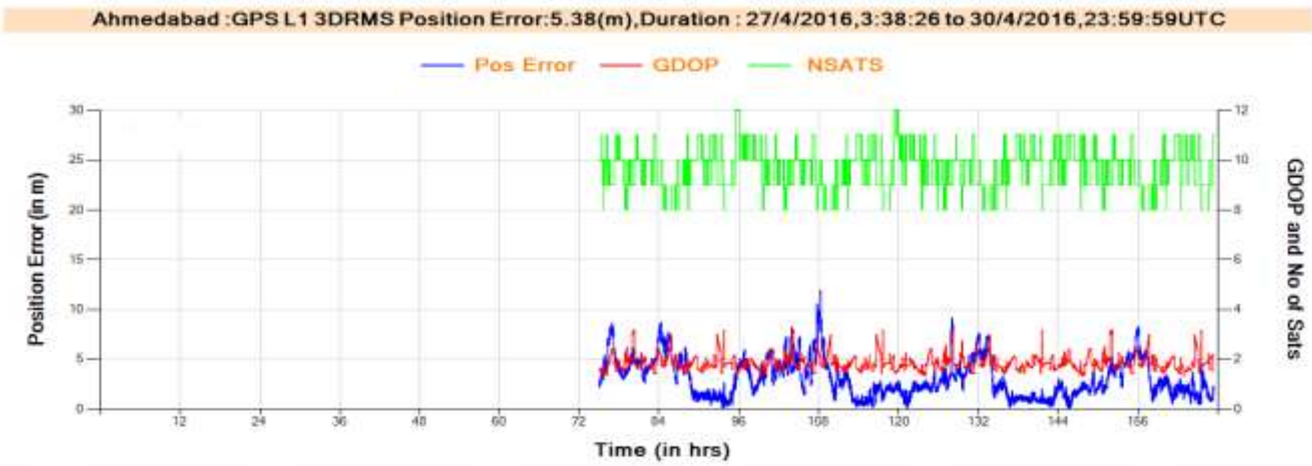

Figure 3

IV. ACKNOWLEDGMENT

We would like to thank Anil K Sisodia sir who is Professor in LJ institute of technology at Ahmadabad and also retired from SAC, for providing RT data of IRNSS receiver of the Ahmedabad region.

V. CONCLUSION

As India is near the equatorial region of the earth it has large gradient in the ionospheric region highly irregularity in the region due to which a perfectly match model should be build specially for India so as to minimise the error in positioning due to the ionospheric effects. The TEC calculated for particular day using the real time data extracted from the receiver, the value is more interesting. The values for the day time are large, which clearly shows that the ions in the ionospheric region are highly active in the solar radiation are less active at the night time in absence of the solar activity. The perfect model required the data to be collected from all over the Indian region to predict at one particular result for developing the Indian own mathematical model for ionospheric measurement. We can say that the position error increases with the Iono delay and the TEC value. So the perfectly model should be made using more data from the IRNSS receiver which can mitigate this error to excellence.

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