FFT Averaging Ratio Algorithm for IRNSS

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Abstract. Navigation with Indian Constellation (NavIC) or Indian Regional Navigational Satellite System (IRNSS) is an independent satellite based navigation system developed by Indian Space Research Organization (ISRO). Due to solar activity the Total Electron Content (TEC) of atmosphere will have fluctuations, which causes fluctuations in the satellite signal. IRNSS based on Internet of Things (IoT) platform positioning system signals also experience delays as it propagates through the atmosphere irregularities, the majority of which is contributed by the ionosphere. Hence, to make IRNSS based application free of ionodelay prior detection technique is essential. In this paper analysis is done using Fast Fourier Transform (FFT) Averaging Ratio (FAR) to classify the satellites which are more affected by the ionospheric irregularities. The detection threshold is found by using an inverse chi-squared distribution. The data received at the IRNSS receiver located at Communication Research Lab, SVNIT Surat (21.16^0 N, 72.78^0 E), Gujarat is considered for analysis.

Keywords: Indian Regional Navigation Satellite System (IRNSS)
Ionodelay · Total Electron Content (TEC)
Fast Fourier Transform (FFT) · FFT Averaging Ratio (FAR)

1 Introduction

IRNSS is a satellite based regional navigational system consisting of 3 geosynchronous and 4 geo-stationary satellites developed by ISRO, India. The applications of such a system includes, but is not limited to: Intelligent navigation system based on Internet of Things (IoT). The accuracy of such a positioning system is depending on many factors. Since the positional accuracy of the system depends on the time delay of arrival of the signal from the satellite, even a small delay in the signal offsets the position of user (receiver) by a significant amount. There are different sources of error in pseudorange measurements [1]. The major source of error in pseudorange measurement is caused by the ionosphere [2].

The ionosphere, due to sun's energy, is having a large portion of free electron and charged ions. Since the radio waves are electromagnetic in nature, they are affected by the charged ionosphere in varying manner. Since the ionosphere is

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a dispersive medium (delay is different for different frequency), the ionospheric delay can be estimated proportional to the TEC by using [3,4].

$$\mathrm{TEC} = \frac{1}{40.3}\frac{F_1^2.F_2^2}{(F_1^2 - F_2^2)}(\mathrm{P1} - \mathrm{P2}) \tag{1}$$

where P1 and P2 are pseudoranges measured in two frequencies F1 and F2.

The ionospheric delay is directly proportional to the TEC over the region through which the signal propagates. The ionospheric irregularities are more prominent in the latitude range of $\pm 15^0$ to $\pm 20^0$ [5]. Indian territory in this area experiences TEC variations at a higher scale. Due to the relative location of the IRNSS satellite, signal from each satellite experiences a different amount of ionospheric delay. The solutions obtained by considering those satellites with higher ionospheric irregularities tend to be inaccurate. By avoiding these satellites, positioning accuracy can be improved.

In this paper classification of satellite, which are more affected, is done by using FAR Algorithm. The classified satellites can be removed or ignored during computation of Position Velocity Time (PVT) measurements, if sufficient number of satellites are available. The algorithm calculates a decision variable for each satellite and then is classified on the basis of a threshold, set using an inverse chi-squared distribution function [6]. The algorithm is usually used to detect traffic in radio channels used by Chen et al. [7], which is explained in next section, followed by the results and observations with the test data.

2 FAR Algorithm

IRNSS satellites that were affected by the ionospheric effects were evaluated using the FAR algorithm. For the analysis the TEC data from each satellite was taken and given as input to the algorithm. Let $a_n(t)$ be the variation in TEC, where the data is taken at 1 sample per second. Applying FFT to the input, the output is obtained as [6]

$$A_n(s) = \sum_{l=0}^{L-1} a_k\,(l)\,e^{-j2\pi sl/L} \tag{2}$$

where l = 0 to L−1 and n = 1 to N, the number of satellite.

Consider that the input data sequence is even numbered samples. Since the FFT output is symmetric, only the first half of the output $A_n(s)$ is considered. So s = 0 to L/2 +1 and n = 0 to N.

Next the Power Spectral Density (PSD) is found by squaring each of the terms.

$$PSD_n\,(s) = |A_n\,(s)|^2. \tag{3}$$

For every segment, the average of all values of PSD is calculated by using

$$PSD_{avg}(n) = \frac{1}{L}\sum_{s=1}^{L} PSD_n(s)\,. \tag{4}$$

The mean of PSD corresponding to each PRN is calculated by using

$$PSD_{mean} = \frac{1}{N}\sum_{n=1}^{N} PSD_{avg}(n)\,. \tag{5}$$

Now a decision criteria is defined by taking the ratio between P_{avg} and P_{mean}

$$D(n) = \frac{PSD_{avg}(n)}{PSD_{mean}}. \tag{6}$$

In order to classify the satellite, the decision criteria is compared with the threshold. The classification is done by the following rule

$$D(n) \underset{Quiet}{\overset{Disturbed}{\gtrless}} \alpha \tag{7}$$

where α is the threshold value. The threshold is calculated using the inverse chi-squared distribution [8].

The implementation of FAR algorithms on IRNSS system is covered in next section

3 Results and Observations

The simulation related to FAR algorithm on IRNSS data is done on MATLAB 2014 platform. Flow graph for this simulation is summarized in Fig. 1

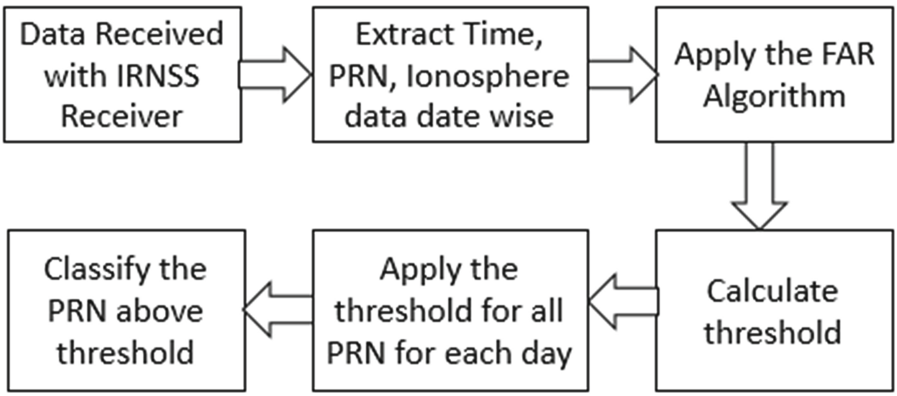

Fig. 1. Flowgraph of processing

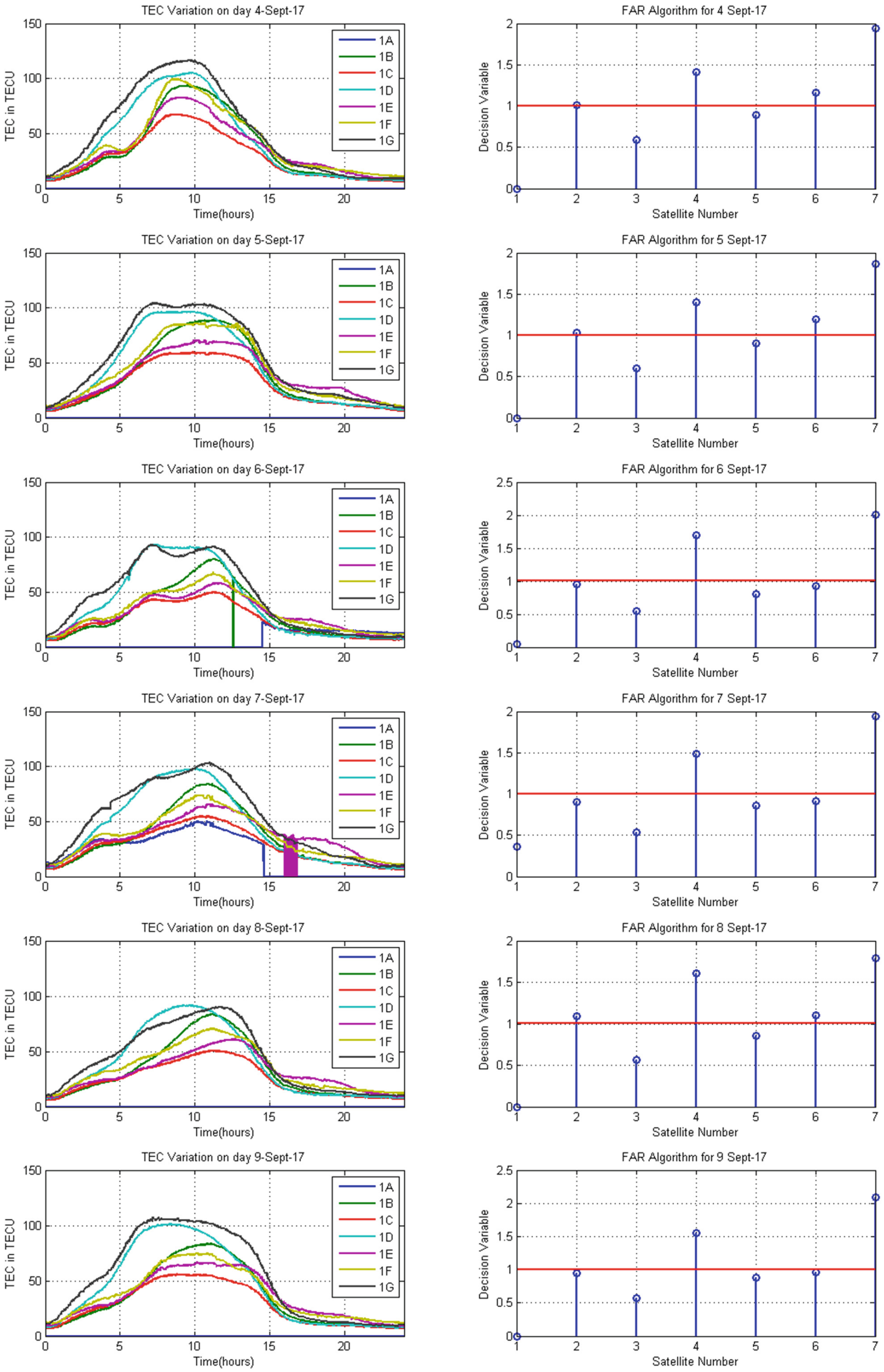

Fig. 2. FAR algorithm for 2nd week of September 2016

The necessary data was obtained from the IRNSS receiver. The data considered was for 2nd week of September 2016. The data was sorted day wise with each of the 7 satellite having their own corresponding TEC data. The TEC data was plotted for 6 days and the FAR algorithm applied on each satellite for 6 days and plotted. The TEC data and the result of the algorithm are plotted side by side as shown in Fig. 2.

In each day, the different satellites- IRNSS 1A, 1B, 1C, 1D, 1E, 1F and 1G provide different TEC values. The shape of the curves are similar- it all reaches a peak from a low value and then gradually decreases to that low value. But the peak of each satellite is different. It is noticed that in all days, the highest peak is that of 7th satellite (1G). The lowest peak is corresponding to 3rd satellite(1C). The data of 1A satellite should be neglected as the receiver was not tracking the satellite properly.

The decision variable obtained after applying the algorithm is in correlation with the TEC data. The highest value of decision variable is for the 1G satellite and the lowest one for 1C satellite.

Table 1. Mean, Minimum, Maximum values of TEC averaged for 6 days

Parameter	1A	1B	1C	1D	1E	1F	1G
Mean	4.4229	34.5293	**27.1646**	42.6009	34.3781	37.1597	**49.5688**
Minimum	0	0	6.1590	6.8767	0	9.0821	8.3974
Maximum	49.7571	93.6586	**67.1377**	105.1793	82.7566	99.1519	**116.4038**

From Table 1 it is observed that 1G satellite is experiencing much higher ionospheric effects compared with the others. The data is obtained by taking mean over the entire day and the averaging over the 6 observed days. The min value of some satellites are shown as zero. This is because of receiver losing track of the respective satellite. Neglecting the 1A satellite, the 1C satellite has the

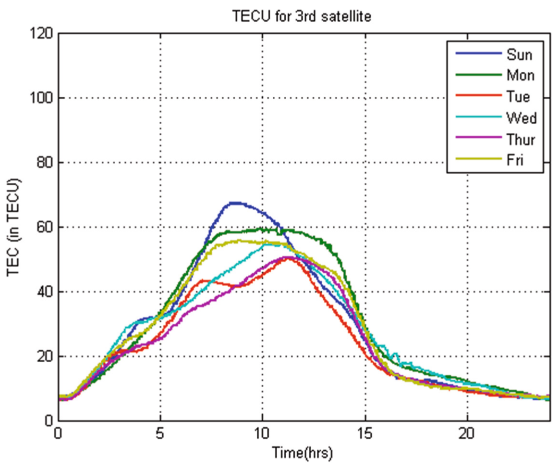

Fig. 3. TEC data observation for 3rd satellite on different days

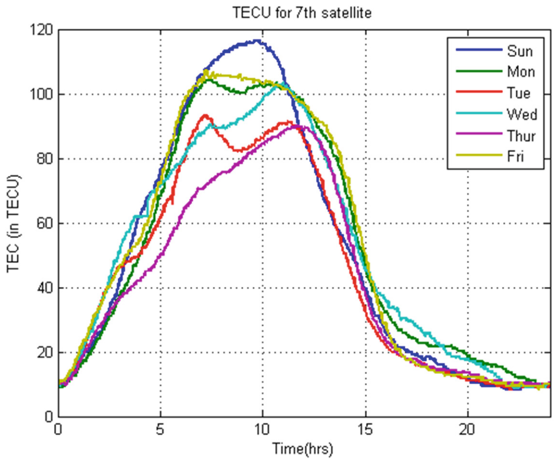

Fig. 4. TEC data observation for 7th satellite on different days

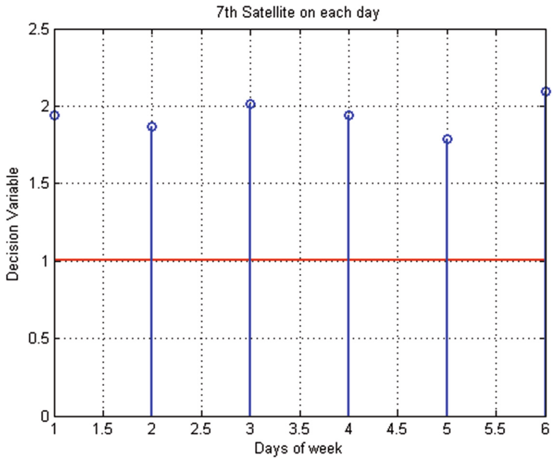

Fig. 5. Decision for 7th satellite

lowest of mean and maximum values for TEC and 1G is having the highest of mean and maximum. The TEC data of the 3rd and 7th satellites are shown in Figs. 3 and 4 respectively for clarity.

Comparing Figs. 3 and 4 it can be seen that the ionospheric irregularities experienced by the 7th satellite is much higher than that of the 3rd.

It can be seen from Fig. 5, the 7th satellite is always classified as experiencing a stormy ionosphere, whereas the 3rd satellite (Fig. 6) is always classified as a quiet ionosphere. This is agreeing with the TEC data obtained for the corresponding satellite.

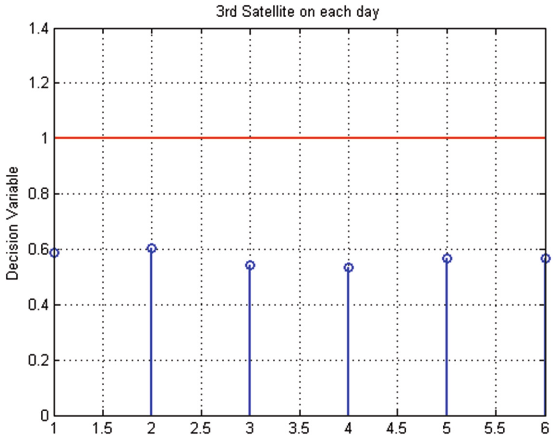

Fig. 6. Decision for 3rd satellite

From the Fig. 2 the 7th satellite is affected more due to the ionospheric variations throughout the analysed days and that the 3rd satellite is least affected. This can be justified by checking the arrangement of the satellite from the skyplot [9] as shown in Fig. 7. It describes the relative arrangement of the satellite constellation with respect to the receiver location. The signal from satellite 7 has to traverse a longer distance through the ionsophere whereas it is shorter for the 3rd satellite.

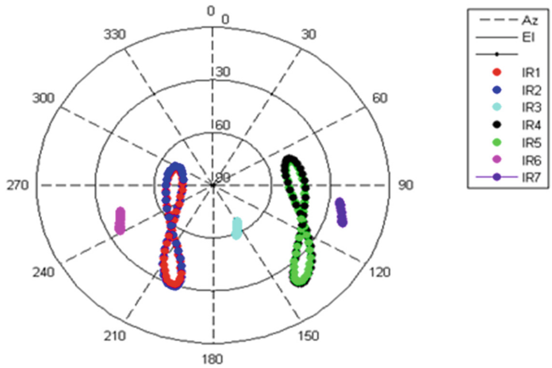

Fig. 7. Skyplot of IRNSS seven satellites [9]

4 Conclusions

Data was observed for the 2nd week of September 2016 using IRNSS receiver. The data was compiled for each satellite PRN seperately and the FAR algorithm applied. The satellites are classified as per the threshold found using the inverse chi-squared technique. The results obtained after application of algorithm is in agreement with that of the TEC data associated with each satellite. The algorithm is able to distinguish the satellites that are affected by large variation in the ionosphere. When sufficient number of satellites are available, the satellites with higher value of decision variable can be avoided for PVT measurement. Thereby improving the accuracy in positioning.

Improved positioning system can help in various applications like navigation, disaster management, intelligent vehicle tracking and vehicle routing to avoid traffic jams using developing IoT implementations. The applications are innumerable.

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