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An Experimental Study on Clock Stabilization of IRNSS-GPS-SBAS (IGS) Receiver

Somnath Mahato, Atanu Santra, Sukabya Dan, P Banerjee and Anindya Bose
Department of Physics, The University of Burdwan, Golapbag, Burdwan, India

Abstract:*Indian Regional Navigation Satellite system (IRNSS) or Navigationwith Indian Constellation (NavIC) is a new regional system designed and developed by ISRO. Both L5 and S band navigation signals transmitted by the system can be utilized together by the ISRO developed IRNSS-GPS-SBAS (IGS) receiver. This paper presents the initial experiment and the results for understanding the receiver's performances while external 10 MHz signal is provided during operation. Clock stability of the GNSS receiver being an important aspect for good performance of the receiver, the complete effort in this regard may be useful for performance improvement of the receiver.*

Keywords:IRNSS/NavIC, GPS, Clock, Frequency, Synchronization.

Introduction:

Global Navigation Satellite System (GNSS) is a generic term representing all satellite based navigation systems. Global Positioning System (GPS), developed by USA, is a fully active member of the GNSS family. IRNSS, also known NavIC, developed by Indian Space Research Organization (ISRO)has beendeveloped and initiated over the recent few yearsand isin operation currently. The GPS satellites work on L1bandwhereas IRNSS satellites work on L5(1176.45 MHz) and S(2492.028 MHz) bands[1].
The GPS and IRNSS satellitesmay be tracked together using an IGS receiver that is capable to track GPS on L1 band and IRNSS satellites on L5 and S bandsindividually or in tandem.Every GNSS receiver has a crystal oscillator which provides time that should be synchronized with the onboard satelliteprecise and stable atomic (Rubidium or Cesium) clocks [2]. But in most of the cases, receiver clock is not exactly synchronized with satellite onboard clock. And hence a variable clock offset is observed between receiver and satellite clocks. Accuracy in time is an important factor in accuracy in solution of satellite based navigation technique because 1ns error in time leads to 30 cm error in distance calculation from satellite to receiver. The offset is treated as a nuisance parameter for estimating the receiver's position which continuously changes without any significant constraints[3]. By analogy, the receiver clock drift (time derivative of the clock offset) is often also estimated as a nuisance parameter along with the receiver velocity [4]. Some GNSS receiver manufacturers steer the receiver clock to make the clock drift zero, so thatthe clock offset will become constant.More discussions on GNSS receiver clocksmay be found in [3-5]. The Indian Space Research Organization (ISRO) announced that IRNSS-1A has failed due to deficiencies in three atomic clocks that are crucial in providing positional information to users on earth [6].In this paper, the initial results of the efforts to harmonize the IGS receiver using an external stable frequency source have been presented. This discussion would be helpful in studies of the improvingthe performance of IGS receivers and towards finding out a method for validating the synchronized condition of the GNSS receivers.

Experimental setup:

IGS receiver is a high performance Global Navigation satellite System (GNSS) receiver capable of acquiring and tracking IRNSS (dual frequency L5 and S band), GPS (L1 C/A) and SBAS (GAGAN) signals. IGS receiver's unique feature is the capability of using both L5 and S band signal, which is not present for any other commercial GNSS receiver currently available in market. IGS receiver can estimate user PVT solution using any combination of IRNSS and GPS ranging signals. The ports of the IGS receiver include a TCP/IP Ethernet port, RS232 NMEA output port, External 10 MHz reference input port, Reference output (1 PPS or

10 MHz), and Antenna input. Ethernet TCP/IP is the main port for controlling the receiver from a list of supported receiver input commands present in IGS receiver GUI [6]. Using the same port data from the receiver is logged at a predefined rate of 1Hz/5Hz, and is stored as 'Raw Data Log Files' in a computer. In this work, the '10 MHz In' port of IGS receiver is connected toa signal generator (Agilent, ESG vector signal generator). The signal from the generator is splitted using a passive signal splitter; one part is fed to the IGS receiverand the other signal is connected to channel #1 ofa Digital Storage Oscilloscope (DSO; Aplab 36000 series). The externally supplied 10 MHz signal is a sine wave with signal strength of +/- 3dB and is valid only if within +/-30 Hz of 10 MHz [6]. 'Reference output' port of the IGS receiver is connected to channel #2 of the DSO. The corresponding raw data is logged in a laptop. The usable data is extracted from the raw data by using the vendor-provided IRNSS user interface software; different .csv files are generated after the extraction. These files directly provides navigation solution and other parameters like receiver clock offset data, computed position, dilution of precision etc.,few of these are used for the results presented in this paper. On the availability of a valid external signal, the internal oscillator is synchronized to the external 10 MHz signal. The status of the internal clock with respect to the externally supplied frequencyis displayed by the clock information fields in the GUI of the receiver.The schematic and real experimental set up is shown in Fig. 1(a) and Fig. 1(b) respectively.

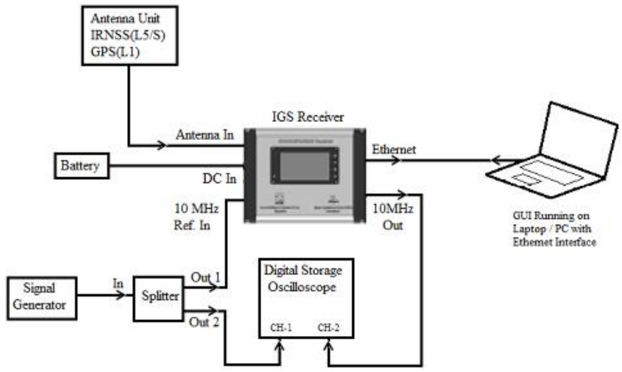

Fig. 1(a): Schematicof the experimental set up

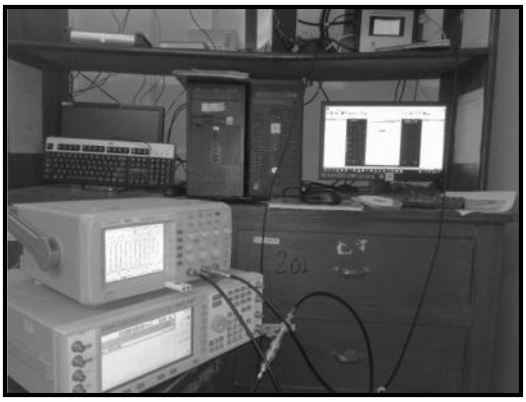

Fig. 1(b): The experimental set up

Results:

When 10MHz reference input is fed to the '10 MHz In' port of the IGS receiver, receiver's clock gets synchronized with the reference input signal and the status displayed as "Synced" on receiver's display screen, as shown in Fig. 2(a).

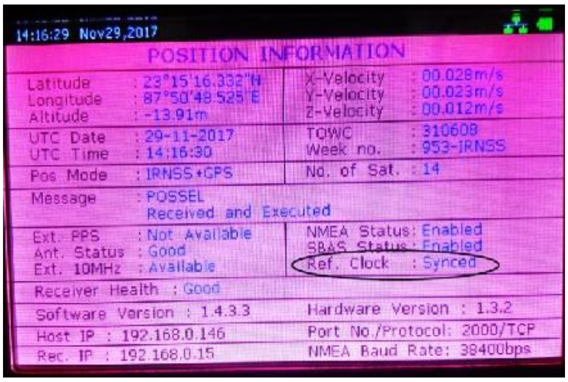

Fig. 2(a): Screenshot of the IGS receiver display panel after synchronization

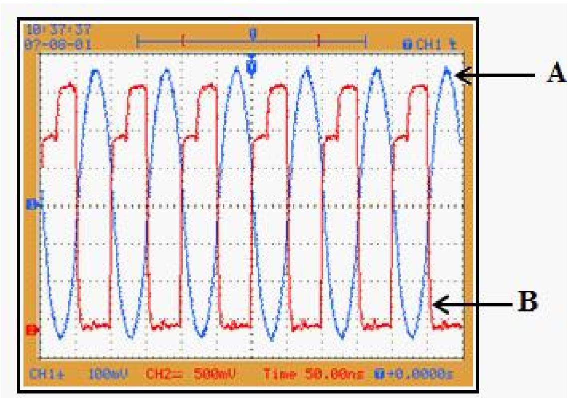

Fig. 2(b): Screenshot from DSO showing the input (trace A) and output (trace B) 10 MHz signal to the IGS receiver after synchronization

IGS receiver hasa '1PPS/10 MHZ out port' which can be set to provide 1 pulse per second (PPS) or 10 MHz output as per the user setting. The output 10 MHz signal from the IGS receiver is a measure of the statusof the internal crystal oscillator of the receiver. Now the signals from channel 1 and 2 after the synchronization are displayed simultaneously on the DSO as shown in Fig. 2(b). The smooth sinusoidal curve marked by 'A' indicates the 10 MHz pure input signal from the signal generator and the curve marked by 'B' shows output from the IGS receiver which is a distorted form of 10 MHz square wave.

The receiver offset or bias represents the difference between the receiver's time and the true time, with the latter determined by underlying GNSS atomic time scale [3,4]. The receiver clock drift is time derivative of the clock offset [4].Now it has to be observed how the clock bias and clock drift of the receiver is changed before and after synchronization due to application of the external 10 MHz signal. For this purpose, data of two consecutive seconds are taken into consideration in GPS standalone, IRNSS pure dual and GPS+IRNSS pure dual modes of operation of the IGS receiver and are shown in Table 1.It is observed from the table, that receiver clock bias is changed for each epoch. The clock drift is significantly decreased after synchronization. The clock drift should ideallybe minimum to obtain constant receiver clock bias for precise positioning. It should be noted that, data presented before and after synchronization although shown in the same table, are for different observation instants, so are uncorrelated.

Table 1: IGS Receiver's clock bias and clock driftsbefore (a)and after (b) synchronization

Operating Mode	Before synchronization **(a)**		After synchronization **(b)**	
	Clock bias (ns)	Clock drift (ns/s)	Clock bias (ns)	Clock drift (ns/s)
GPS	-4.5607	-540.8005	-6.4806	-42.4137
	-4.1361	-540.3608	-13.0574	-42.3459
IRNSS(pure dual)	-17.0129	-540.2917	-10.3510	-42.1904
	-4.9365	-539.9371	-17.6378	-41.8414
GPS+ IRNSS (pure dual)	-7.7063	-539.0210	-9.3665	-42.2074
	-11.5424	-538.8244	-21.4777	-42.1324

To obtain very high oscillator stability, quartz crystal oscillators are generally used as local oscillator in the GNSS receivers. Even when it is initially set accurately in synchronization with atomic clock, the clock bias differ every instant due to clock drift at slightly different rates. This experiment shows external stable 10 MHz signal helps in decreasing the clock drift; but this effort needs future exploration.

Final comments and future scope of work:

This paper presents the results of preliminary experiments on IGS receiver clock stabilization. The distortion of the 10 MHz out signal needs to be characterized. Similar experiments using GNSS receiver from other manufacturer capable of IRNSS+GPS operation would be taken up shortly, that would help to characterize the current observations. Effects of such synchronization on position solution accuracy would be taken up next. Finally, efforts would be made to develop cost-effectivemethods for the IGS receiver clock stabilization.

Acknowledgments

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