

# IMPROVEMENT OF THE TIME SCALE OF NPLI

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## Abstract

The National Physical Laboratory, India (NPLI), is responsible for maintenance and development of the Indian Standard Time (IST) and also contributes through the GPS network to the generation of UTC coordinated by BIPM. The objective of the Time Unit is to implement a smoother timescale at NPLI. Recently, NPLI has made some special efforts to improve the uncertainty between UTC and UTC (NPLI). One basic clock ensemble algorithm is implemented to make the timescale of UTC (NPLI) by combining the intercomparison data of five cesium clocks. Some initial tests have been carried out to check the validity of this algorithm, and they observed a significant improvement in the UTC – UTC (NPLI) Circular T values and frequency offset with respect to UTC. This is necessary to judge the efficacy of the algorithm. A few iteration processes and/or some sort of modification may be anticipated to optimize the algorithm further. The output of the optimized process is normally fed to a micro-phase stepper to steer the timescale.

Data from only one cesium is currently submitted to BIPM, but the aim is to submit data from all five cesium atomic clocks to BIPM in the near future.

NPLI also plans to take intercomparison data from the eight Indian Space Research Organisation (ISRO) cesium clocks. By optimally ensembling of these clocks and the addition of data from these clocks, NPLI may generate an improved timescale.

The uncertainty for the NPLI – PTB time link in Section 6 of BIPM Circular T is 2.5 ns for Type A and 7.0 ns for Type B, giving a total uncertainty of 7.4 ns. If the NPLI TTS2 receiver is calibrated on-site at NPLI by a travelling calibration BIPM receiver, then the Type B uncertainty may be reduced further to 5.0 ns. Various efforts are underway to improve the uncertainty  $U_A$  and  $U_B$ .

TWSTFT has the capability of achieving 0.1 ns jitter. NPLI is planning to procure a TWSTFT system to initiate such a link.

This paper describes these studies and presents the analysis of these observations.



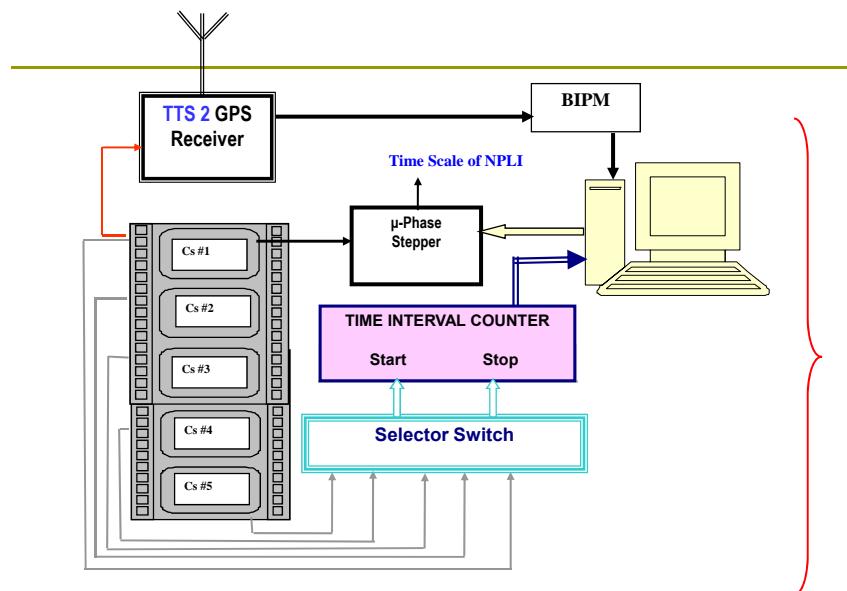
## Main Instruments

Cesium Clock (HP5071A)	5 units	(94-06)
GPS receiver (TTS2-A)	2 units	2005
Freq. & Phase Offset Generator (HROG-5 Spectra Dynamics)	1 unit	2006
Universal Counter(HP53131/32) 300/500ps	2units	1997
Universal Counter (SRS) 50ps	1unit	2007

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## Schematic Diagram of Time Scale at NPLI



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## EFFORTS TO IMPROVE



## Cause of Multipath Effect



## Change in Environment

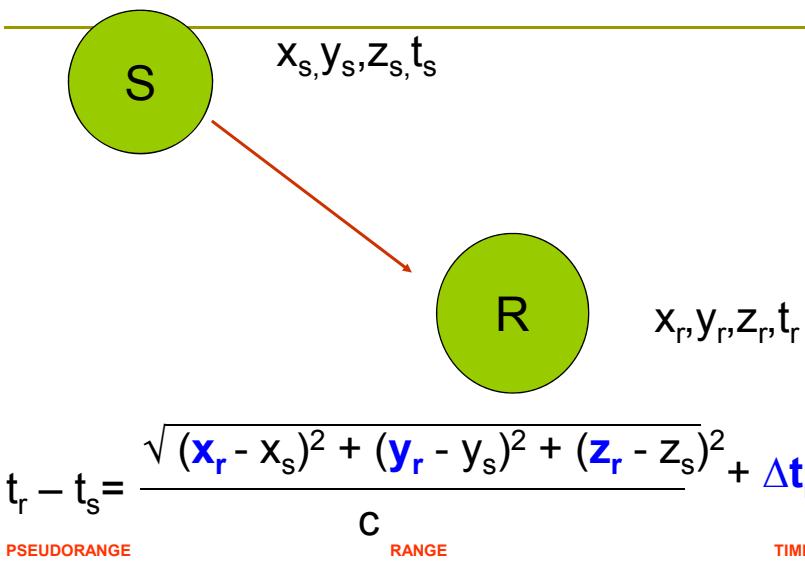
1. Temperature (23 1) ° C
  2. Relative Humidity (45 5) %
  3. Stabilized Power Supply

## Coordination of UTC through GPS Network



## Reduction of Multipath Effect

# Code-based Time transfer





## Typical Error Budget for GPS

Source	Error( $1\sigma$ )
Sat Clock	1.5m
Orbit	2.5m
Ionosphere	7m
Troposphere	0.7m
Rx Noise	1.5m
Multipath	1.2m
Total	8.0m (UERE) (26.6 ns)

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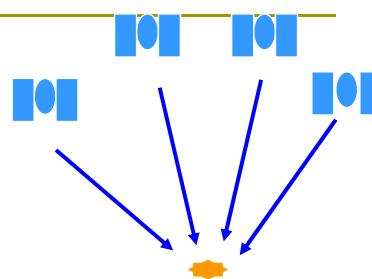


## GPS RECEIVER FOR TIMING

### MULTI CHANNEL (sat) RECEIVER

Unknown: 4 parameters  
(3 coordinates and time)

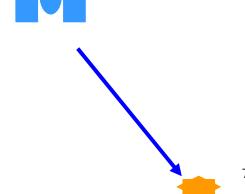
4 satellites to be tracked (Method I)



### SINGLE CHANNEL(SAT) RECEIVER

Known: 3 coordinates of Receiver  
Unknown: (One parameter) TIME

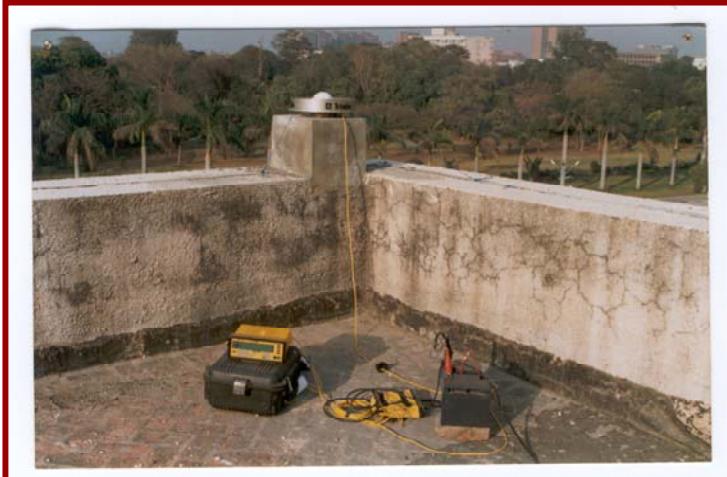
1 satellites to be tracked (Method II)



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## Determination of Precise Coordinates of NPLI

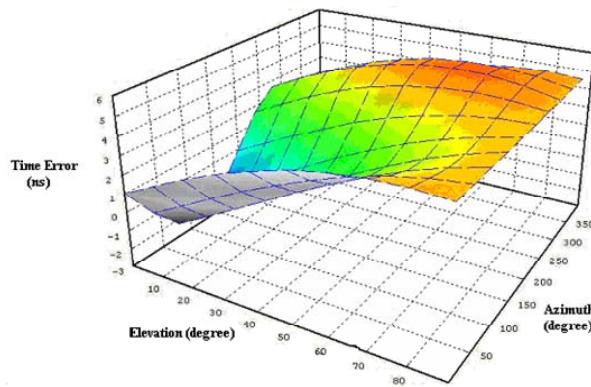


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## Effect of Incorrect Coordinates of GPS Antenna on Time Accuracy

$$\Delta T = \frac{\Delta R}{c} = \frac{1}{30} [E_x . \text{Cos}(e) . \text{Cos}(a) + E_y . \text{Cos}(e) . \text{Sin}(a) + E_z . \text{Sin}(e)]$$

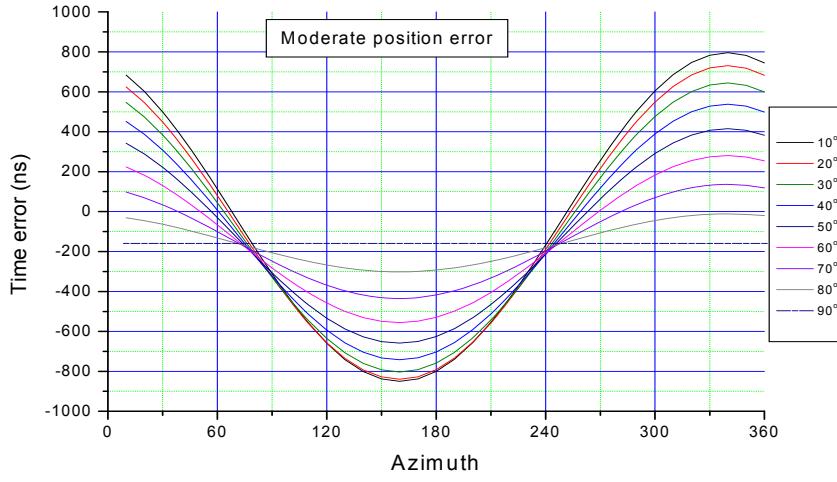


Effect of Position Error on GPS Time depends on Satellite Elevation & Azimuth with position error within a box of 100cms at NPLI

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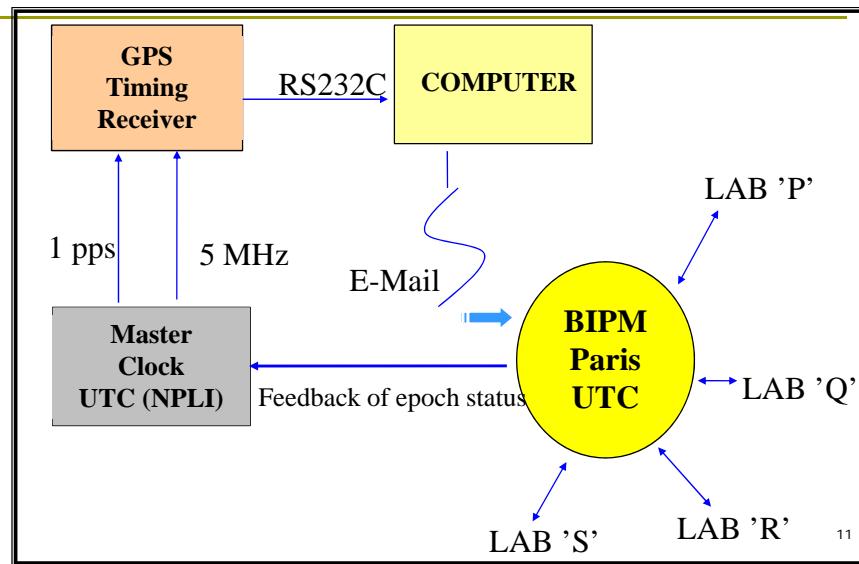
## Moderate Position Error



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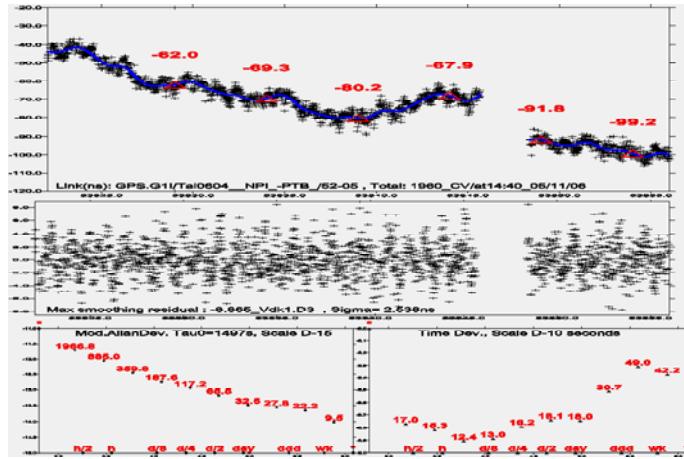
## Time Keeping Using GPS



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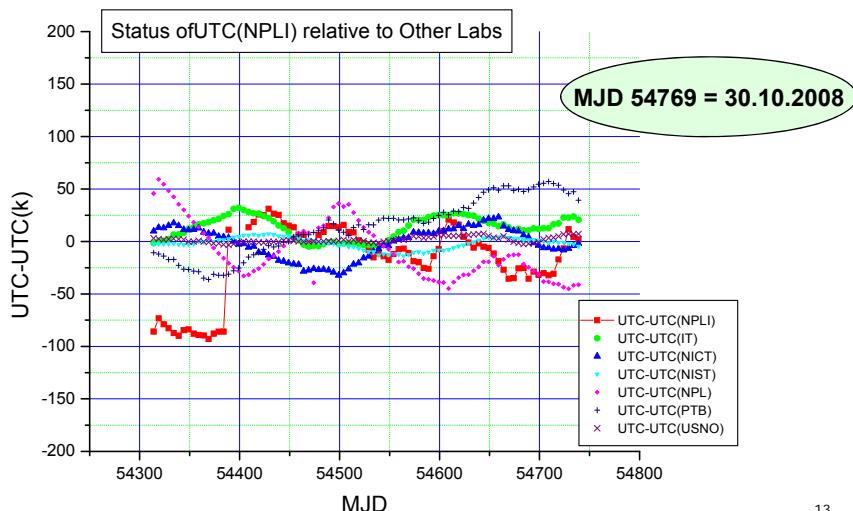
## [UTC(NPL) – UTC(PTB)] by multi-channel GPS Common-View



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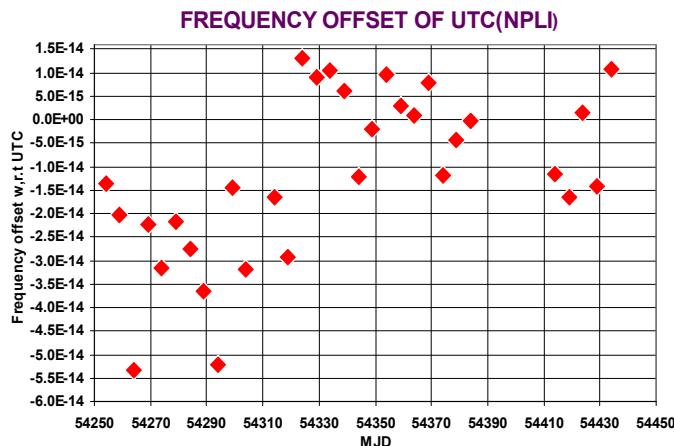
## Status of UTC(NPL)



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### Status of frequency of UTC(NPLI) with respect to UTC: Frequency offset fluctuate around zero within a range of $1.5 \times 10^{-14}$



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### Uncertainty of IST

By taking some remedial measures based on observations of special campaign experiment and the study of circular T data, the uncertainty of Type A ( $U_A$ ) of UTC(NPLI) has been reduced to 2.5 ns.

It is a practice, now-a-days, to use IGS products like ephemeris and ionospheric data to improve the uncertainty of time link. Efficacies of IGS products for GPS timing in Indian subcontinent need to be studied.

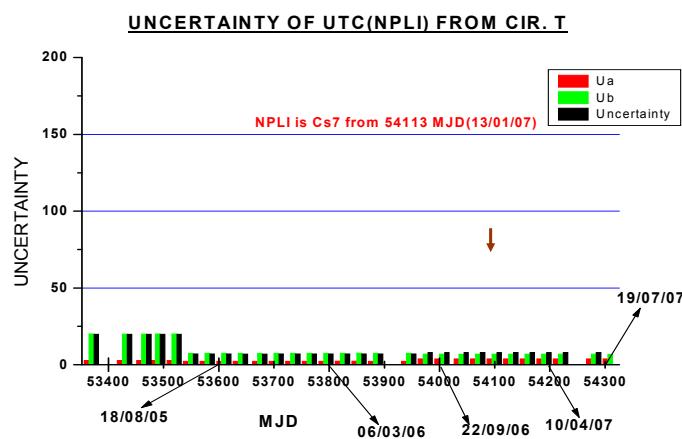
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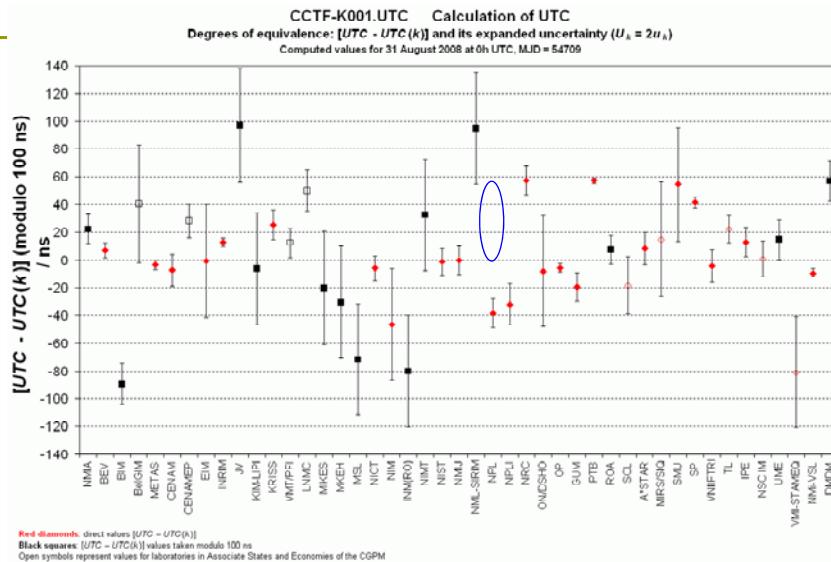
## Uncertainty UTC(NPLI)

<b>UA</b>	<b>2.5 ns ( clock noise + Link Noise)</b>
<b>UB</b>	<b>7 ns ( value fixed for GPS Rx calibrated before supply)</b>
<b>Efforts to Improve UA</b>	
<b>Clock Noise</b>	<b>Time Scale by a single clock</b>
<b>Working on Time Scale by combination of Clocks</b>	
<b>Link Noise</b>	<b>Antenna Position Error</b>
<b>Ionosphere Delay Error</b>	
<b>To improve UB</b>	
<b>5 ns ( fixed for Calibration of GPS Rx by BIPM)</b>	
<b>less than 5 ns ( TWSTFT link)</b>	

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## DEVELOPMENT OF CESIUM FOUNTAIN AT NPL

Development of Laser cooled Cs Fountain clock has been undertaken by NPL. The overall design of the optical setup and the physics package have been finalized. The system is in process of integration.