Time Traceability to

Secondary Time Scale Labs at Regional Reference Secondary Laboratories (RRSL)

From NPL India, New Delhi

Location of the Secondary Time Scales

Common –View Time Transfer Method

The common view (CV) technique is a method for comparing the time difference between two geographically separated clocks. It works by having both clocks simultaneously observe the same satellite, typically a Global Positioning System (GPS), Navigation with Indian Constellation(NavIC) or another Global Navigation Satellite System (GNSS) satellite.

How It Works

Each ground station measures the time difference between its local clock and the satellite's clock. This measurement, known as Refsys, includes various delays and offsets. The key insight of the common view technique is that since both stations are observing the same satellite at the same time, the errors originating from the satellite's clock and the propagation path (like atmospheric delays) are nearly identical for both stations.
By taking the difference between the two Refsys measurements at each observation epoch, these common errors largely cancel out, leaving the relative time difference between the two ground station clocks.

All-in–View Time Transfer Method

The All-in-view (AIV) technique is an advanced method for time transfer that overcomes some of the limitations of the common-view (CV) method. Instead of relying on two stations simultaneously tracking the same single satellite, the AIV technique uses observations from all visible satellites at a given station. This provides a more robust and accurate estimate of the station's clock offset relative to a GNSS reference time.

How it works

Each GNSS receiver at a station simultaneously tracks multiple satellites. The receiver calculates its local clock offset from the GNSS time scale for each of these satellites. These individual measurements, which can be noisy due to factors like satellite clock errors, ephemeris errors, and atmospheric delays, are then combined.

The core of the AIV technique is the statistical averaging of all these observations. By combining data from a larger number of satellites, the random errors associated with each individual measurement are significantly reduced. The weighted average method is a common way to achieve this.

REFSYS Calculation for Common View

Average of difference between Refsys values at each epoch

$$Common - View\ at\ each\ epoch = \sum_{SAT(i=1)}^{n} \frac{(Refsys_{(1,i)} - Refsys_{(2,i)})}{n}$$

Example for calculation: Common-view Performance at each epoch

GPS Receiver 1 data
(CGGTTS V2E)

SAT	MJD	STTIME	ELV	REFSYS	FRC
		hhmmss	.1dg	.1ns	
G10	60269	1400	392	-94	L1C
G10	60269	1400	392	-86	L1P
G10	60269	1400	392	247	L2C
G10	60269	1400	392	-69	L2P
G10	60269	1400	392	159	L5C
G15	60269	1400	351	-25	L1C
G15	60269	1400	351	-8	L1P
G15	60269	1400	351	308	L2C
G15	60269	1400	351	-26	L2P
G18	60269	1400	697	-17	L1C
G18	60269	1400	697	1	L1P
G18	60269	1400	697	339	L2C
G18	60269	1400	697	4	L2P

GPS Receiver 2 data
(CGGTTS V2)

SAT	MJD	STTIME	ELV	REFSYS	FRC
		hhmmss	.1dg	.1ns	
8	60269	1400	188	-80	L1C
32	60269	1400	289	-63	L1C
27	60269	1400	595	-47	L1C
16	60269	1400	451	-23	L1C
23	60269	1400	458	-70	L1P
18	60269	1400	267	-85	L1P
10	60269	1400	835	-122	L1P
26	60269	1400	291	-40	L1P
8	60269	1400	188	-104	L2P
32	60269	1400	289	-88	L2P
27	60269	1400	595	-68	L2P
27	60269	1400	595	-23	L3P
16	60269	1400	451	-4	L3P

Choice of signal Frequency (L1P)

Common Satellites

Refsys values for CV (units: 0.1 ns)

$$\text{CommonView difference} = \sum_{\substack{SAT\ (i=1),\\ frequency\ (f)\\ Receiver\ (1,2)}}^{n} \frac{\left(Refsys_{(1,i,f)} - Refsys_{(2,i,f)}\right)}{n} = \frac{[(-8.6) - (-12.2)] + [0.1\ - (-85)]}{2}$$

$$= 6.1 \text{ ns}$$

Weighted REFSYS Calculation for All-in-View

➢ Weighted Refsys of each receiver

Sum of the weighted REFSYS values of all satellites available, with respect to their elevation angles

$$weighted\ Refsys_1 = \sum_{SAT(i=1)}^{n} \frac{Refsys_i\ *\ sin^2(ELV_i)}{\sum_{i=1}^{n} sin^2(ELV_i)} \qquad weighted\ Refsys_2 = \sum_{SAT(j=1)}^{n} \frac{Refsys_j\ *\ sin^2(ELV_j)}{\sum_{j=1}^{n} sin^2(ELV_j)}$$

➢ All - in– View method

All-in-view at each epoch = $weighted\ Refsys_1$ - $weighted\ Refsys_2$

Example for calculation of Weighted Refsys: Receiver clock - GNSS(time)

CGGTTS data snippet

SAT	MJD	STTIME	ELV	REFSYS	FRC
		hhmmss	.1dg	.1ns	
G10	60269	1400	392	-94	L1C
G10	60269	1400	392	-86	L1P
G10	60269	1400	392	247	L2C
G10	60269	1400	392	-69	L2P
G10	60269	1400	392	159	L5C
G15	60269	1400	351	-25	L1C
G15	60269	1400	351	-8	L1P
G15	60269	1400	351	308	L2C
G15	60269	1400	351	-26	L2P
G18	60269	1400	697	-17	L1C
G18	60269	1400	697	1	L1P
G18	60269	1400	697	339	L2C
G18	60269	1400	697	4	L2P

At each epoch

Sum of the weighted REFSYS values of all satellites available, with respect to their elevation angles

$$sum\ of\ weighted\ Refsys = \sum_{i=1}^{n} \frac{Refsys_i\ *\ sin^2(ELV_i)}{\sum_{i=1}^{n} sin^2(ELV_i)}$$

$$sum\ of\ weighted\ Refsys = \frac{-8.6 *\ sin^2(39.2) - 0.8 *\ sin^2(35.1) + 0.1 *\ sin^2(69.7)}{sin^2(39.2) + sin^2(35.1) + sin^2(69.7)}$$

= -2.24 ns

Example for calculating: All-in-view Performance at an epoch

GPS Receiver 1 data
(CGGTTS V2E)

At each epoch

SAT	MJD	STTIME	ELV	REFSYS	FRC
		hhmmss	.1dg	.1ns	
G10	60269	1400	392	-94	L1C
G10	60269	1400	392	-86	L1P
G10	60269	1400	392	247	L2C
G10	60269	1400	392	-69	L2P
G10	60269	1400	392	159	L5C
G15	60269	1400	351	-25	L1C
G15	60269	1400	351	-8	L1P
G15	60269	1400	351	308	L2C
G15	60269	1400	351	-26	L2P
G18	60269	1400	697	-17	L1C
G18	60269	1400	697	1	L1P
G18	60269	1400	697	339	L2C
G18	60269	1400	697	4	L2P

GPS Receiver 2 data
(CGGTTS V2)

SAT	MJD	STTIME	ELV	REFSYS	FRC
		hhmmss	.1dg	.1ns	
8	60269	1400	188	-80	L1C
32	60269	1400	289	-63	L1C
27	60269	1400	595	-47	L1C
16	60269	1400	451	-23	L1C
23	60269	1400	458	-70	L1P
18	60269	1400	267	-85	L1P
10	60269	1400	835	-122	L1P
26	60269	1400	291	-40	L1P
8	60269	1400	188	-104	L2P
32	60269	1400	289	-88	L2P
27	60269	1400	595	-68	L2P
27	60269	1400	595	-23	L3P
16	60269	1400	451	-4	L3P

- Choice of signal Frequency (L1P)
- Elevation Angle (unit 0.1 degrees)
- All available Satellites
- Refsys values for AV (units: 0.1 ns)

$$\text{sum of weighted Refsys for receiver 1} = \frac{-8.6 * sin^2(39.2) - 0.8 * sin^2(35.1) + 0.1 * sin^2(69.7)}{sin^2(39.2) + sin^2(35.1) + sin^2(69.7)} = -2.24 \text{ ns}$$

$$\text{sum of weighted Refsys for receiver 2} = \frac{-7.0 * sin^2(45.8) - 8.5 * sin^2(26.7) - 12.2 * sin^2(83.5) - 4.0 * sin^2(29.1)}{sin^2(45.8) + sin^2(26.7) + sin^2(83.5) + sin^2(29.1)} = -9.43 \text{ ns}$$

All-in-view performance = (-2.24) – (-9.43) = 7.19 ns

Details of the Current Files

GPS CGGTTS files exchanged:	Version 2E
GNSS observation code for CV and AV:	L3P
NavIC CGGTTS files exchanged:	Version 2E
GNSS observation code for CV and AV:	LSC
Fiel exchange rate	Daily Once

Files Mapping

NAVIC - Common View

'IRNPLI': 'NPLI_Nav_CV',
'IRLMB1': 'Blr_Nav1_CV',
'IRLMB2': 'Blr_Nav2_CV',
'IRLMA1': 'Ahm_Nav1_CV',
'IRLMA2': 'Ahm_Nav2_CV',
'IRLMF1': 'Frd_Nav1_CV',
'IRLMF2': 'Frd_Nav2_CV',
'IRLMO1': 'Bhu_Nav1_CV',
'IRLMO2': 'Bhu_Nav2_CV',
'IRLMG1': 'Gwh_Nav1_CV',
'IRLMG2': 'Gwh_Nav2_CV',
'IRDRC1': 'DRC_Nav1_CV',
'IRDRC2': 'DRC_Nav2_CV',

NAVIC - All-in-View

'IRNPLI_AV': 'NPLI_Nav-AV',
'IRLMB1_AV': 'Blr_Nav1-AV',
'IRLMB2_AV': 'Blr_Nav2-AV',
'IRLMA1_AV': 'Ahm_Nav1-AV',
'IRLMA2_AV': 'Ahm_Nav2-AV',
'IRLMF1_AV': 'Frd_Nav1-AV',
'IRLMF2_AV': 'Frd_Nav2-AV',
'IRLMO1_AV': 'Bhu_Nav1-AV',
'IRLMO2_AV': 'Bhu_Nav2-AV',
'IRLMG1_AV': 'Gwh_Nav1-AV',
'IRLMG2_AV': 'Gwh_Nav2-AV',
'IRDRC1_AV': 'DRC_Nav1-AV',
'IRDRC2_AV': 'DRC_Nav2-AV'

GPS - Common View

'GZLI2P': 'NPLI_GPS_CV',
'GZLMB1': 'Blr_GPS1_CV',
'GZLMB2': 'Blr_GPS2_CV',
'GZLMA1': 'Ahm_GPS1_CV',
'GZLMA2': 'Ahm_GPS2_CV',
'GZLMF1': 'Frd_GPS1_CV',
'GZLMF2': 'Frd_GPS2_CV',
'GZLMO1': 'Bhu_GPS1_CV',
'GZLMO2': 'Bhu_GPS2_CV',
'GZLMG1': 'Gwh_GPS1_CV',
'GZLMG2': 'Gwh_GPS2_CV',
'GZDRC1': 'DRC_GPS1_CV',
'GZDRC2': 'DRC_GPS2_CV',

GPS - All-in-View

'GZLI2P_AV': 'NPLI_GPS-AV',
'GZLMB1_AV': 'Blr_GPS1-AV',
'GZLMB2_AV': 'Blr_GPS2-AV',
'GZLMA1_AV': 'Ahm_GPS1-AV',
'GZLMA2_AV': 'Ahm_GPS2-AV',
'GZLMF1_AV': 'Frd_GPS1-AV',
'GZLMF2_AV': 'Frd_GPS2-AV',
'GZLMO1_AV': 'Bhu_GPS1-AV',
'GZLMO2_AV': 'Bhu_GPS2-AV',
'GZLMG1_AV': 'Gwh_GPS1-AV',
'GZLMG2_AV': 'Gwh_GPS2-AV',
'GZDRC1_AV': 'DRC_GPS1-AV',
'GZDRC2_AV': 'DRC_GPS2-AV',

All-in-View (AV)
Common View (CV)