Time and Frequency Research Activity in NIM

Gao Xiaoxun
National Institute of Metrology
Bei San Huan Dong Lu No.18 Beijing P.R.China

Abstract

This paper will introduce scientific research activities in the field of time and frequency in NIM China. All of projects in this field including atomic fountain, multi-channel GPS common view, telephone, television and NTP time transfer have been making successful progress and some results have been reported in this paper.

1. Introduction

It is well known that time and frequency plays important role in metrology science for it's high accuracy; very easy to transfer and broad use in industry and economy. That's why NIM has been paying great effort to this field. In the last two years, some projects have been making remarkable progress in NIM including primary frequency standard; multi-channel GPS common view; telephone and Internet time service. This paper will give you a brief introduction.

For different scientific research directions in T&F field, there are four groups responsible to different mission.

- **New primary frequency standard**
- **Time Keeping**
- **Time transfer**
- **Frequency and Phase noise calibration**

2. NIM4# Cesium fountain:

NIM had developed a time/frequency standard, NIM3# Cs clock, with uncertainty of $3x10^{-13}$ in 1986. From 1997 the National Institute of Metrology started to develop the NIM4# Cesium atomic cold fountain clock.

The Cs fountain uses six orthogonal laser beams combined with an anti-Helmholtz magnetic field to trap and cool a group of Cs atoms in a high vacuum chamber. The atom cloud, which is further cooled by laser post cooling to as low as ~5μK, is launched upwards and falls down in ballistic movement to interact twice with the 9.19 GHz microwave radiation. Two interactions, with the same microwave field, of the atoms stimulate the so-called Ramsay transition.

We trapped about 10^8 atoms with a joint action of optical and magnetic field in 1999. The atomic clouds were cooled to ~5μK and launched to the designed height of 56cm. Then the Ramsey transition was realized by twice interactions of the 9.19GHz microwave with the cooled atoms in their fountain movement at 2002. In the turn of 2003 we locked the 9.19GHz microwave frequency to the clock transition of the Cesium atoms.

The NIM4# atomic fountain clock has been operating stably and continually for 5 months since 8,2003 and a first run evaluation for its systematic frequency deviations was performed during 9-12,2003. NIM 4# clock has demonstrated a stability of $8\text{x}10^{-13}/\tau^{1/2}$, reproducibility of 5 $\text{x}10^{-15}$, and the evaluation with an uncertainty of 8.5 $\text{x}10^{-15}$ on NIM4#. As a collateral evidence the NIM4# has been compared with the NIM atomic time TA(NIM) for 120 days and the frequency difference was within the combined uncertainty of NIM4# and TA(NIM).

Fig 1 is physical part. Fig 2 shows optical system.

Fig 1 Fig 2

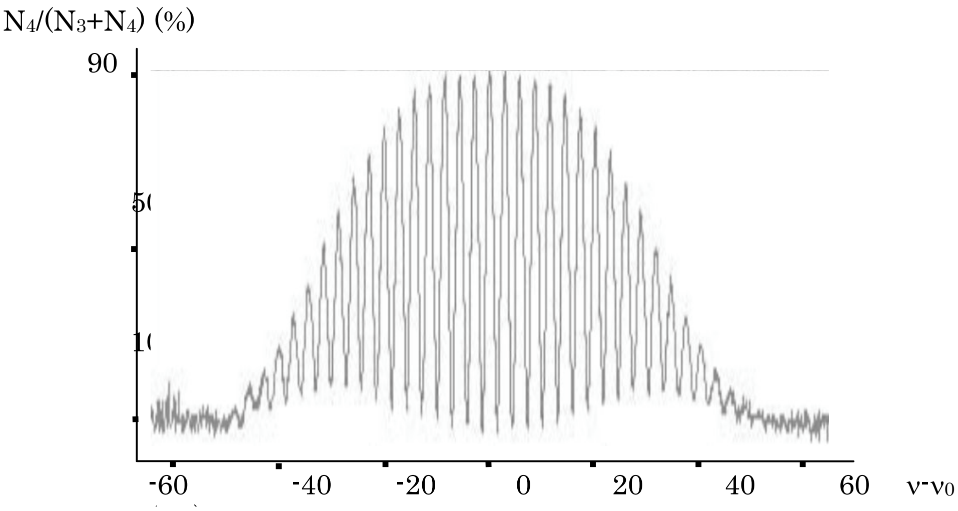


Fig 3 A Ramsey transition curve of NIM4# clock

Fig 3 shows Ramsay fringes obtained in the condition: Fountain height 56cm (16cm above cavity), microwave frequency step 0.1Hz, each point is an average of 6 fountain circle data, FWHM width of the central fringe ~1.35Hz

Table1 NIM4# clock evaluation of the main frequency biases and their associated uncertainties in 2003,9-12
(Fountain height h=56cm, width of Ramsey fringe W_R~1.35Hz)

	Physical Effect	Bias Value (10^{-15})	Uncertainty (10^{-15})	
1	Second order Zeeman:	1222	1.4	H_C=512.6nT
	H(L)≠H(l):	20	0.2	
2	Cold atom collision:	-3.1	5.5	
3	Microwave power:	0.0	0.2	
4	Blackbody:	-16	0.5	Cavity temperature 23°C
5	Gravitation:	3.8	0.1	Height above sea level 35m
6	Majorana Effect:	94	6.3	
7	Light Shift:	0.0	0.1	
8	Cavity Pulling:	0.0	0.1	Detuning 0.7MHz,Q_C=5400
9	Cavity Phase Difference:	0.0	0.1	Phase difference: 10^{-6} radian
	Combined:	1320.7	8.5	

3. Time Keeping

Time keeping group is in charge of UTC (NIM) and GPS common view. The atomic clock assembly consists of 5 clocks, 3 HP5071 Cs clocks, 1VCH1003 active Hydrogen clock and 1VCH1004 passive Hydrogen clock. Fractional frequency difference between UTC and UTC (NIM) has been kept in 5×10^{-14} in one and half year. Two commercial single channel GPS common view receivers (1TTR-6, 1Datum9390) and two multi-channel GPS common view receivers were used to link to UTC. Figure 4 shows one and half-year fractional frequency for UTC-to-UTC (NIM).

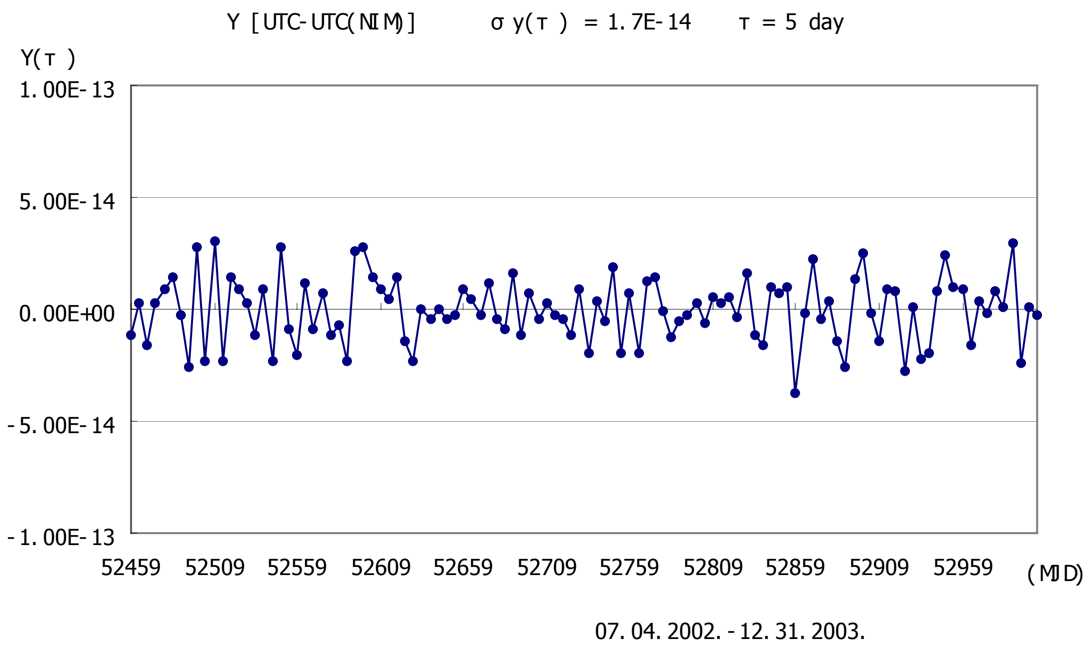


Fig 4 Fractional fluctuation between UTC and UTC(NIM)

In order to obtain good results for GPS common view and time measurement, two ways were taken. First one was a chock ring installed on the top of GPS antenna, which reduces the reflection of GPS signal from big object close to the antenna. Another way is new 1PPS distribution amplifiers was introduced in the system, which has long distance driving capacity, good isolation and keeps sharp rising edge of 1PPS signal from output of the clock.

4. Time Transfer

The mission of **time transfer group** is developing various time dissemination techniques to public service. Some progress has been made in this area.

NIM 'ACTS' was put into operation, which is a telephone time service. In domestic area, time delay error is within 10mS.

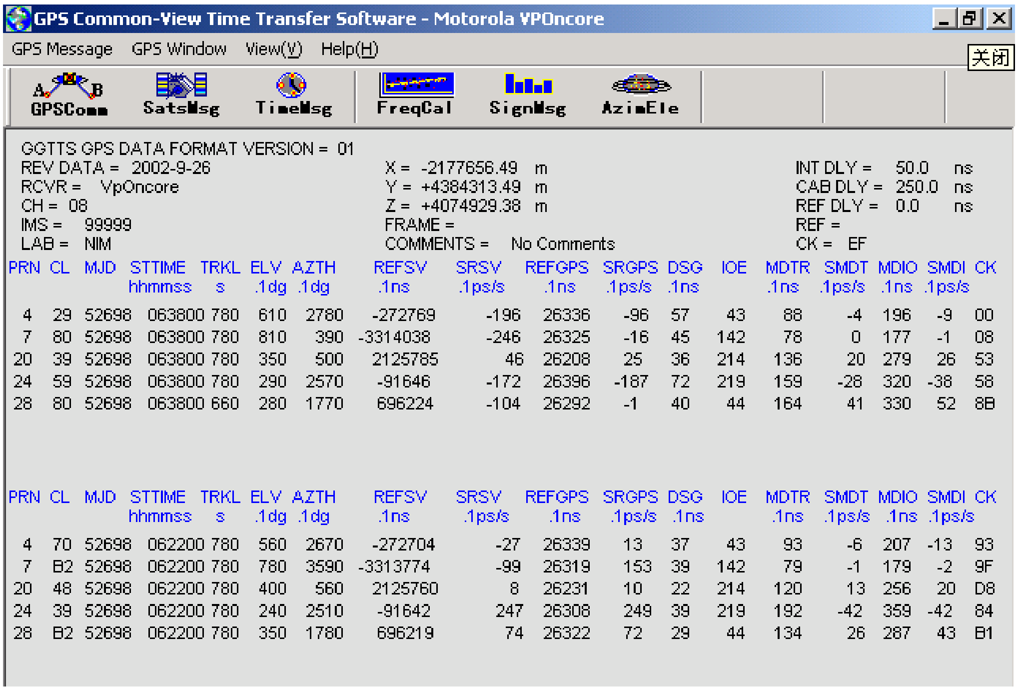
From Aug of 2002, NIMTIME has begun to open to public, which is Internet time service running NTP ver3.

NIM has insisted on TV time transfer for many years. In recent year, remote TV transfers has moved to satellite. In order to solve the problem of time delay change due to the movement of satellite, a compensated time code was added to TV signal line 329.By this means most of time delay-changing error can be eliminated.

In order to strengthen link to TAI and establish remote time and frequency calibration service system, GPS common view receiver has been developed in NIM. The receiver has following characteristics:

High-resolution time interval counter card integrated Motorola VpOncore GPS engine has been made by our staff. The TIC satisfies CCTF recommendation for hardware of GPS common view receiver. According to CCTF technical directives for GPS common view data processing, we have developed software based on windows 2000 system that means a GGTTS format file could be output at end of track. Fig 5 shows TIC card.

. Fig 5 TIC card integrated Vponcore engine



GGTTS GPS DATA FORMAT VERSION = 01
REV DATA = 2002-9-26
RCVR = VpOncore
CH = 08
IMS = 99999
LAB = NIM
X = -2177656.49 m
Y = +4384313.49 m
Z = +4074929.38 m
FRAME =
COMMENTS = No Comments
INT DLY = 50.0 ns
CAB DLY = 250.0 ns
REF DLY = 0.0 ns
REF =
CK = EF

PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFGPS .1ns	SRGPS .1ps/s	DSG .1ns	IOE	MDTR .1ns	SMDT .1ps/s	MDIO .1ns	SMDI .1ps/s	CK
4	29	52698	063800	780	610	2780	-272769	-196	26336	-96	57	43	88	-4	196	-9	00
7	80	52698	063800	780	810	390	-3314038	-246	26325	-16	45	142	78	0	177	-1	08
20	39	52698	063800	780	350	500	2125785	46	26208	25	36	214	136	20	279	26	53
24	59	52698	063800	780	290	2570	-91646	-172	26396	-187	72	219	159	-28	320	-38	58
28	80	52698	063800	660	280	1770	696224	-104	26292	-1	40	44	164	41	330	52	8B

PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFGPS .1ns	SRGPS .1ps/s	DSG .1ns	IOE	MDTR .1ns	SMDT .1ps/s	MDIO .1ns	SMDI .1ps/s	CK
4	70	52698	062200	780	560	2670	-272704	-27	26339	13	37	43	93	-6	207	-13	93
7	B2	52698	062200	780	780	3590	-3313774	-99	26319	153	39	142	79	-1	179	-2	9F
20	48	52698	062200	780	400	560	2125760	8	26231	10	22	214	120	13	256	20	D8
24	39	52698	062200	780	240	2510	-91642	247	26308	249	39	219	192	-42	359	-42	84
28	B2	52698	062200	780	350	1780	696219	74	26322	72	29	44	134	26	287	43	B1

Fig6 shows GGTTS format data displayed on screen every 16 minute updated.

5. Frequency and Phase noise Calibration

AS a NMI, NIM has been insisted on calibration service to science and industry for many years. The effort in this field was strengthened in recent years. As early as 1998,quality system was established according to ISO/IEC guidance 25. In 1999, quality system passed through accreditation by China National Accreditation Committee for Laboratories (CNACL). Since IT industry becomes most quickly increasing area in China, the demands of calibration are rising up.

Following are main technical characteristics of our measurement capability:

The frequency range of frequency and phase noise calibration is from 10Hz to 18GHz.

Phase noise bottom is –180dBc/10kHz.

The $\sigma_y(1s)$ of frequency measurement instrument is 1×10^{-13}.

H maser reference frequency stability is 2×10^{-15}/1day.

6. Future Development

We will continue scientific research on the atomic fountain. Develop GPS common view data process software based on Vondrak method or Kelman filter. Develop new Network time-server to give strong support to e-commerce. Update time scale UTC(NIM) measurement system and local atomic time algorism.