Design of Atomic Time Scale Release System for Multiple Laboratories

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Abstract: The atomic time scale release system for multiple laboratories is completed by modular design according to the atomic clock data provided by eight domestic punctual laboratories. The system includes the three modules, the processing of atomic clock data, the calculation of atomic time scale and the release of atomic time scale data, using MATLAB for data processing and time scale calculation, and using GUI for data visualization design. The system has clear process of the algorithm, simple function modules and friendly human-machine interface. The operation results of actual data show that the time difference between the integrated atomic time scale of the system and UTC is better than ±10ns, and the content of data release can meet the needs of the scientific research in related fields in China.

Key words: Atomic Clock, Weight Distribution, Atomic Time Scale, Data Release

1 Introduction

With the rapid development of technology, high stability and high accuracy of time and frequency standards have become indispensable key technologies in navigation, positioning, measurement, astronomy and time benchmarks. To this end, countries around the world have established their own punctual laboratories. The International Bureau of Metrology (BIPM) integrates the clock data of the punctual laboratories in the world, and calculates and publishes the UTC of the world coordination time. Because the number of atomic clocks directly affects the stability of the atomic time scale, the stability of UTC is very high, which provides a time benchmark for punctuality laboratories of countries around the world.

BIPM generates the international atomic time scale UTC from the punctual atomic clocks of countries around the world through the ALGOS algorithm. It uses the Allan variance to calculate the weight of the clock in order to eliminate the influence of space, climate and other factors on the atomic clock, and maintain the long-term stability of the time scale. BIPM publishes an international time bulletin once a month (one value every five days) to provide a time benchmark for atomic time scale of countries around the world. In order to improve the stability of China's atomic time scale, the "Atomic Time Scale Publishing System of Multiple Laboratories" designed in this paper adopts a weighting algorithm different from BIPM. It replaces the Allen variance with Hadma variance to reduce the influence of frequency drift of atomic clock on stability, and constructs China's comprehensive atomic time scale. The time bulletin is issued once a month, but it provides a value every day, which provides a timelier time benchmark for punctual laboratories in our country.

The NIM punctuality laboratory of the National Institute of Metrology (China)[1] and the NTSC punctual laboratory of the National Time Service

Center of the Chinese Academy of Sciences[2] are both involved in the BIPM international comparison. However, there are still many laboratories in the country that do not participate in the international comparison, and there is no domestic coordination time UTC(CN). Combining the domestic punctual laboratories, making full use of China's atomic clock resources, and generating China's coordination, it is expected to raise the stability of China's time and frequency standards to a higher level, which is conducive to the comparison between China's punctual laboratories and UTC to improve the level of its atomic clock time scale and meet the needs of domestic research.

2 General Design of the System

The atomic time scale release system for multiple laboratories adopts all hydrogen clocks and cesium clock data from the National Institute of Metrology (China) and seven other time-frequency laboratories in China (as shown in Table 1, note: 4 laboratories currently provide relevant data, the rest of the laboratory data is being reported). The processing of clock difference data, the weight distribution, calculation and calibration of the atomic time scale and the data comparison are performed.

Table 1 Laboratory involved in atomic time-scale research projects

Laboratory Abbreviation	Full Name of the Laboratory
NIM	National Institute of Metrology (China)
SIMT	Shanghai Institute of Measurement and Testing Technology
NTSC	National Time Service Center Chinese Academy of Sciences (China)
BIRM	Beijing Institute of Radio Metrology
CMTC	People's Liberation Army 61081 troops
BACC	Beijing Aerospace Control Center
UNDT	National University of Defense Technology (China)
FKZX	Beijing Institute of Metrology

The flow chart of system design is shown in Fig.1.

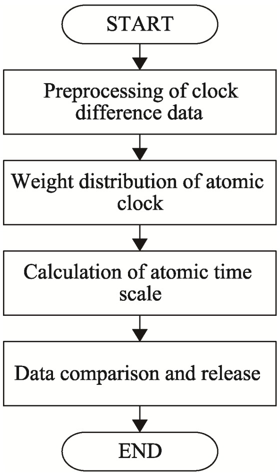


Fig.1 The flow chart of system design

3 Preprocessing of Clock Difference Data

The atomic time-scale calculation relies mainly on the clock data of the atomic clock. The data provided by the eight time-frequency labs is not exactly the same in the original data format. Therefore, the original clock data must be preprocessed (format check, main clock selection, clock difference normalization). Then processing of gross errors and missing values are performed on the frequency difference data obtained after the preprocessing.

3.1 Unification of Data Format

The data of clock difference is mainly composed of clock difference data (Clock data) [3] and GPS common view data (GPSP3 data)[4] between laboratories, which are generally given in the form of data files.

The Clock data file of the clock difference data[5] is shown in Fig.2, including the date of the reduced Julian Day date MJD (column 1), the laboratory number (column 2), and the atomic clock number (columns 3, 5, 7, 9, 11).), time difference data of atomic clock (columns 4, 6, 8, 10, 12).

The GPSP3 data [6] file for common view data is shown in Fig.3, including header files and common view data files.

Header files include data format version number

(GGTTS GPS/GLONASS DATA FORMAT VERSION), modification date (REV DATE), receiver model number (RCVR), channel number (CH), laboratory (LAB), GPS antenna coordinate parameters (X , Y, Z, FRAME), COMMENTS, Receiver Internal Delay (INT DLY), Antenna Cable Delay (CAB DLY), Reference Delay (REF DLY), Reference Time (REF), Checksum (CKSUM), etc. As is shown in the top half of Fig.3.

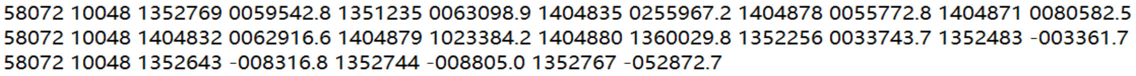
Common view data files include satellite pseudo-random coding (PRN), common-view category (CL), reduced Julian date (MJD), tracking satellite start time (STTIME), actual tracking period (TRKL), the satellite elevation angle corresponding to the midpoint of the actual tracking period (ELV), the satellite azimuth corresponding to the midpoint of the actual tracking period (AZTH), the local second pulse at the midpoint of the actual tracking period and the tracked satellite time difference (REFSV), the linear fitting slope of the REFSV (SRSV), the difference between the local second pulse and the GPS second pulse at the midpoint of the actual tracking period (REFGPS), the REFGPS linear fit slope (SRGPS), the root mean square of the difference between the true value of the REFGPS and the fitted value (DSG), ephemeris identification number (IOE), tropospheric delay (MDTR), MDTR linear fit slope (SMDT), ionospheric model delay (MDIO), MDIO linear fit slope (SMDI), ionospheric delay measured value (MSIO), MSIO linear fit slope (SMSI), root mean square (ISG) of the difference between the MSIO true value and the fitted value, parameter calibration data (CK), etc. As is shown in the lower part of Fig.3.

The principle of main clock selection is to adopt atomic clock with good stability and high accuracy. According to the performance comparison of atomic clock in domestic laboratories, the hydrogen clock (1404832) in NIM laboratory is better. In order to avoid problems with the main clock, two standby main clocks, hydrogen clock (1404871) and cesium clock (1352767), are added. The main clock is recorded as clock_m in the system.

In the Clock file shown in Fig.2, the Julian Day, the lab number, and the atomic clock number are fixed and can be arranged in order of date. The time difference of atomic clock refers to the difference between a laboratory atomic clock (clock_i) and the laboratory atomic time scale (UTC (lab_i)),

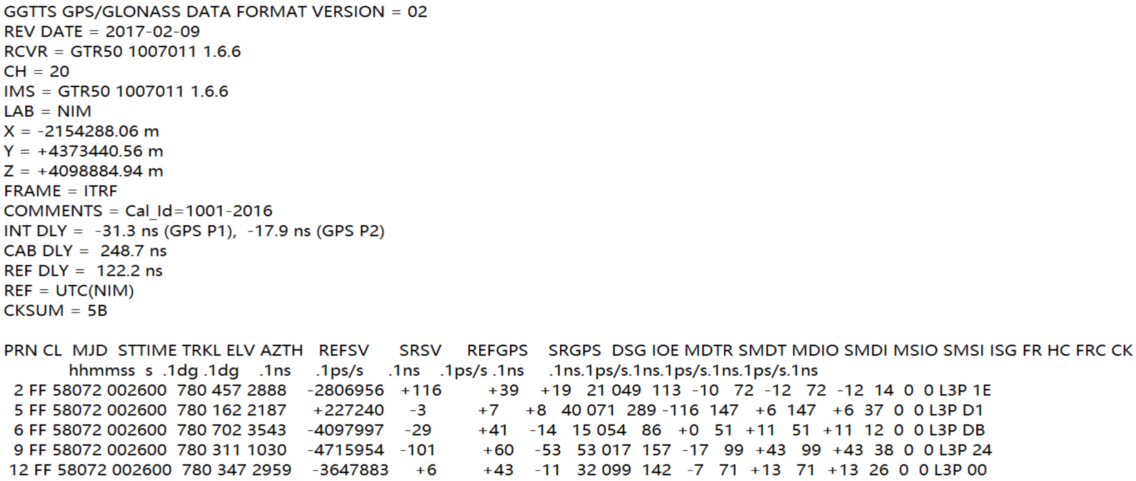
$$clock\_i - UTC\left(lab\_i\right) \tag{1}$$

In the calculation of comprehensive atomic time



```
58072 10048 1352769 0059542.8 1351235 0063098.9 1404835 0255967.2 1404878 0055772.8 1404871 0080582.5
58072 10048 1404832 0062916.6 1404879 1023384.2 1404880 1360029.8 1352256 0033743.7 1352483 -003361.7
58072 10048 1352643 -008316.8 1352744 -008805.0 1352767 -052872.7
```

Fig.2 Data file of Clock



```
GGTTS GPS/GLONASS DATA FORMAT VERSION = 02
REV DATE = 2017-02-09
RCVR = GTR50 1007011 1.6.6
CH = 20
IMS = GTR50 1007011 1.6.6
LAB = NIM
X = -2154288.06 m
Y = +4373440.56 m
Z = +4098884.94 m
FRAME = ITRF
COMMENTS = Cal_Id=1001-2016
INT DLY =  -31.3 ns (GPS P1),  -17.9 ns (GPS P2)
CAB DLY =  248.7 ns
REF DLY =  122.2 ns
REF = UTC(NIM)
CKSUM = 5B

PRN CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFGPS    SRGPS  DSG IOE MDTR SMDT MDIO SMDI MSIO SMSI ISG FR HC FRC CK
             hhmmss  s  .1dg .1dg    .1ns     .1ps/s    .1ns   .1ps/s .1ns   .1ns.1ps/s.1ns.1ps/s.1ns.1ps/s.1ns
  2 FF 58072 002600  780 457 2888   -2806956  +116        +39    +19  21 049  113  -10   72  -12   72  -12  14  0  0 L3P 1E
  5 FF 58072 002600  780 162 2187    +227240    -3        +7     +8  40 071  289 -116  147   +6  147   +6  37  0  0 L3P D1
  6 FF 58072 002600  780 702 3543   -4097997   -29       +41    -14  15 054   86   +0   51  +11   51  +11  12  0  0 L3P DB
  9 FF 58072 002600  780 311 1030   -4715954  -101        +60    -53  53 017  157  -17   99  +43   99  +43  38  0  0 L3P 24
 12 FF 58072 002600  780 347 2959   -3647883    +6        +43    -11  32 099  142   -7   71  +13   71  +13  26  0  0 L3P 00
```

Fig.3 Data file of GPSP3

scale, it is necessary to calculate the time difference between each atomic clock and the main clock. According to whether the atomic clock is in the same laboratory as the main clock, the time difference will be calculated separately. The specific methods are as follows:

(1) The calculation method of the time difference data between the local atomic clock and the main clock of the main clock laboratory (NIM):

The difference between the local atomic clock of the main clock laboratory and the NIM atomic time scale:

$$clock\_i - UTC(NIM) \tag{2}$$

The difference between the main clock and the NIM laboratory atomic time scale:

$$clock\_m - UTC(NIM) \tag{3}$$

Therefore, the time difference between the local atomic clock and the main clock:

$$\begin{aligned} clock\_i - clock\_m = & (clock\_i - UTC(NIM)) \\ & -(clock\_m - UTC(NIM)) \end{aligned} \tag{4}$$

(2) Calculation method for the time difference data of the alien atomic clock and the main clock in the non-main clock laboratory:

The data of clock difference between atomic clock and main clock in non-main clock laboratory also need to be calculated by GPSP3 data file. In the GPSP3 data file shown in Fig.3, the data that do not meet the common-view condition are eliminated. According to the principle of GPS common view, the condition for judging the common view is: TRKL=780s, ELV>=15°, and the errors such as when delay and ionosphere delay occur in the common-view process are corrected. According to the REFGPS in GPSP3 data file of the remote laboratory, the time difference between the UTC of the laboratory and a certain satellite clock (GPS_j):

$$UTC(\mathrm{lab}\_a) - GPS\_j \tag{5}$$

The time difference between a NIM laboratory and a satellite clock (GPS_j):

$$UTC(NIM) - GPS\_j \tag{6}$$

The difference between the atomic time scale (UTC (lab_i)) of each laboratory and the atomic time scale (UTC (NIM)) of the NIM laboratory is regarded as the average value of the sum of the clock differences between the two laboratories relative to the same time of the same satellite. That is the difference of the atomic time scale between the two laboratories on the same day:

$$\begin{aligned} & UTC(lab\_i) - UTC(NIM) = \\ & \frac{1}{n}\sum_{j=1}^{n} \begin{matrix} (UTC(lab\_i) - GPS\_j) \\ -(UTC(NIM) - GPS\_j) \end{matrix} \end{aligned} \tag{7}$$

j is 1, 2, 3 ... n, n is the number of values that both labs and the same satellite have at the same time. Thus, the time difference between the alien atomic clock and the main clock is obtained:

$$\begin{aligned} & clock\_i - clock\_m \\ & = (clock\_i - UTC(lab\_i)) \\ & + (UTC(lab\_i) - UTC(NIM)) \\ & - (clock\_m - UTC(NIM)) \end{aligned} \tag{8}$$

The clock difference data includes time difference and frequency difference. The original clock difference obtained in this paper is time difference data, but the subsequent algorithm research is performed on the frequency difference data. In order to facilitate the calculation of the later algorithm, the time difference data is converted into frequency difference. That is the difference between the time difference data of the atomic clock and the main clock for two days divided by the time interval (86400s).

3.2 Elimination of Gross Error and Compensation of Missing Values

If the atomic clock is affected by its own performance or the external environment during operation, the clock data may have gross errors or missing data, which reduces the frequency stability and accuracy of the atomic clock. Therefore, the abnormal data monitoring and elimination of clock error data and the compensation of missing data are usually carried out in order to reduce the influence of noise on clock error data.

Commonly used methods for judging gross errors are the Wright criterion, the Dixon criterion, and the Grubbs criterion. Because the amount of data that the system needs to process is large, the Wright criterion is chosen. Based on the characteristics of the frequency drift of hydrogen clock, in order to avoid eliminating the effective value at both ends or missing the intermediate error value, the frequency difference data is subjected to least squares linear fitting, and the residual of the frequency difference data and the fitted value is eliminated by the Wright criterion. Assume that the residual value set of the frequency difference data and the fitted value is $\{x_1, x_2, \cdots, x_i \cdots, x_{n-1}, x_n\}$, $x_i \in R$.

The sample mean is

$$\bar{x} = \sum_{i=1}^{n} x_i \Big/ n \tag{9}$$

The standard deviation σ is

$$\sigma = \sqrt{\frac{\sum_{n=1}^{n} (x_i - \bar{x})^2}{n-1}} \tag{10}$$

The Wright criterion rejects the outliers as $|x_i - \bar{x}| > 3\sigma$.

Since the data itself is missing or the data is missing due to the elimination of large error values, the system uses a commonly used linear fit for compensation of missing value.

4 Weight Distribution of Atomic Clock

Any of the continuously operating atomic clocks can produce a simple atomic time scale, but the time scale generated by a single clock is very unstable and susceptible to its own or the environment, so multiple clocks are used to obtain a stable average atomic time scale. The performance of each clock is different. In the calculation of the integrated time scale, each clock should be reasonably given different weights, so that the stability of the integrated atomic time scale is optimal. Due to the non-stationarity of the atomic time scale, the classical variance cannot be used to characterize the data stability. The stability of the atomic clock is characterized by the Allen variance[7] internationally. When the atomic clock has a frequency drift, the Allen variance cannot be used to characterize its stability. Therefore, the Hadma variance is used to characterize the stability of the atomic clock[8].

4.1 Hadma Variance

The Hadma variance is a three-sample variance that is not sensitive to frequency drift and is suitable for analyzing hydrogen clock stability with frequency drift characteristics. For time difference data, the Hadma variance is defined as

$$\begin{aligned} \sigma^2(\tau) &= \frac{1}{6\tau^2} E(((t_{i+3} - t_{i+2}) - (t_{i+2} - t_{i+1})) \\ &\quad - ((t_{i+2} - t_{i+1}) - (t_{i+1} - t_i)))^2 \\ &= \frac{1}{6\tau^2 (N-1)} \sum_{i=1}^{N-1} (t_{i+3} - 3t_{i+2} + 3t_{i+1} - t_i)^2 \end{aligned} \tag{11}$$

i = 1, 2, 3 ... N, is the time interval. N is the number of calculations, and t is the time difference data.

Take $f_i = \frac{t_{i+1} - t_i}{\tau}$ into equation (11), the definition of the Hadma variance for obtaining the frequency difference data is

$$\begin{aligned} \sigma_f{}^2(\tau) &= \frac{1}{6} E((f_{i+2} - f_{i+1})\text{-}(f_{i+1} - f_i))^2 \\ &= \frac{1}{6(N-2)} \sum_{i=1}^{N-2} (f_{i+2} - 2f_{i+1} + f_i)^2 \end{aligned} \tag{12}$$

After the Hadma variance of the frequency difference between each atomic clock and the main clock is obtained, the Hadma variance of the main clock and any two clocks can be obtained by using the triangle hat method, and then the Hadma variance of all atomic clocks can be obtained according to the Hadma variance between the other clocks and the main clock.

σ_z^2, σ_a^2, σ_b^2 respectively denotes the Hadma variance of the main clock z, the atomic clock a and the atomic clock b in the time interval τ. σ_{za}^2, σ_{zb}^2, σ_{ab}^2 respectively represents the Hadma variance obtained by comparing the three atomic clocks in time interval τ. Since any two different atomic clocks are independent of each other, the frequency difference data of the two pairs is not related, then:

$$\begin{cases} \sigma_{za}^2 = \sigma_z^2 + \sigma_a^2 \\ \sigma_{zb}^2 = \sigma_z^2 + \sigma_b^2 \\ \sigma_{ab}^2 = \sigma_a^2 + \sigma_b^2 \end{cases} \tag{13}$$

The Hadma variance of the main clock z, the atomic clock a and the atomic clock b is obtained by solving the equations (13):

$$\begin{cases} \sigma_z^2 = \frac{1}{2}(\sigma_{za}^2 + \sigma_{zb}^2 - \sigma_{ab}^2) \\ \sigma_a^2 = \frac{1}{2}(\sigma_{ab}^2 + \sigma_{za}^2 - \sigma_{zb}^2) \\ \sigma_b^2 = \frac{1}{2}(\sigma_{ab}^2 + \sigma_{zb}^2 - \sigma_{za}^2) \end{cases} \tag{14}$$

If the Hadma variance of the main clock and the other single clocks are known, the Hadma variance of the main clock and the other single clock k can be obtained according to the formula (13).

$$\sigma_{zk}^2 = \sigma_z^2 + \sigma_k^2 \tag{15}$$

The Hadma variance of the other single clock k can be obtained from formula (15):

$$\sigma_k^2 = \sigma_{zk}^2 - \sigma_z^2 \tag{16}$$

4.2 Dynamic Weight Distribution

In order to obtain a stable atomic time scale, dynamic weight distribution is performed on all atomic clocks, and the weight of the atomic clock with good stability is large, and vice versa. Since the stability of the atomic clock is inversely proportional to the Hadma variance of the atomic clock, the reciprocal of Hadma variance is used to represent the weight of the atomic clock. The relationship between the weight and the Hadma variance is:

$$w = \frac{1}{\sigma^2} \tag{17}$$

In order to prevent a certain clock with very poor stability from having a great impact on the atomic time scale, an upper limit is set on the Hadma variance of the atomic clock according to the empirical value in order to eliminate the atomic clock with very poor stability. According to the proportion of 0 weighted laboratory data released by BIPM (about 20% [9]), combined with the current performance of the atomic clock of domestic punctual laboratory, the upper limit of the Hadma variance is set $7\times10e^{-14}$ in the system. To ensure that the sum of the weights of the atomic clocks is 1, normalize the weights with formula (18):

$$w_i(t) = \frac{1/\sigma_i^2(t)}{\sum_{i=1}^{N} 1/\sigma_i^2(t)} \tag{18}$$

It can also be known from equation (18) that if there is one or more very stable clocks, the weight must be much higher than other clocks, which will lead to the dependence of the stability of the atomic time scale on it. It will have a lot of influence on the atomic time scale, which will reduce the reliability of the atomic time scale. To avoid this phenomenon, the upper limit of the weight is limited, that is, the maximum weight is the upper limit, and the upper limit weight is set:

$$w_{\max} = \frac{A}{N} \tag{19}$$

$w_{\max}$ represents the upper limit weight, N is the number of atomic clocks involved in the calculation of the atomic time scale, and A is the empirical value [10] (according to BIPM, set A = 2.5). The empirical value A should be selected as many atomic clocks with good stability and good accuracy as possible, but avoid the selected atomic clocks as the upper limit weights to ensure the stability of the atomic time scale.

Due to the upper limit weight limit on the weight, the sum of the weights will be less than 1, and the weights of the remaining weights after the upper limit are again weighted:

$$w_i = \frac{1/\sigma_i^2(t)}{\sum_{i=1}^{N} 1/\sigma_i^2(t)} \times \left(1 - \frac{A}{N} \times M\right) \tag{20}$$

M is the number of atomic clocks reaching the upper limit weight.

5 Calculation of Atomic Time Scale

The frequency difference and weight between each atomic clock and the main clock are obtained by the algorithm described above, and the frequency difference between the integrated atomic time scale TA and the main clock can be obtained:

$$f_{TA} - f_{clock\_m} = \sum_{i=1}^{N} w_i(t)(f_{clock\_\mathrm{i}} - f_{clock\_m}) \tag{21}$$

Based on the time difference data of UTC and UTC (NIM) published by BIPM, the frequency difference between UTC and NIM atomic time scale can be obtained.

$$f_{UTC} - f_{UTC(\mathrm{NIM})} \tag{22}$$

According to the time difference data between the main clock and the NIM laboratory, the frequency difference between the main clock and the NIM atomic time scale can be found:

$$f_{clock\_m} - f_{UTC(\mathrm{NIM})} \tag{23}$$

In conjunction with the formula (21), (22), (23), the frequency difference between UTC and the uncalibrated integrated atomic time scales is available:

$$\begin{aligned} f_{UTC} - f_{TA} = &\ (f_{UTC} - f_{UTC(\mathrm{NIM})}) - \\ &(f_{clock\_m} - f_{UTC(\mathrm{NIM})}) - (f_{TA} - f_{clock\_m}) \end{aligned} \tag{24}$$

The frequency difference between the UTC and the uncalibrated integrated atomic time scale is linearly fitted to find the difference between the true value and the fitted value, which is the frequency difference between the UTC and the calibrated integrated atomic time scale:

$$f_{UTC} - f_{UTC(TA)} \tag{25}$$

Finally, the frequency difference between UTC and the calibrated integrated atomic time scale is converted to the time difference:

$$\begin{aligned} &UTC - UTC(TA) = \\ &(f_{UTC} - f_{UTC(TA)}) \times 86400 \times 10^9 \end{aligned} \tag{26}$$

6 Data Comparison and Release

After the generation of the comprehensive atomic time scale, it is necessary to issue time bulletins to the domestic punctual laboratories. The time bulletin issued by BIPM is based on international punctual laboratories. Therefore, Chinese domestic time bulletin can be based on BIPM as a reference. At the same time, in order to meet the needs of scientific research in related fields in China, the following three main contents are published.

1) The release of Clock difference data: as the basic data of the calculation of atomic time scale, the raw data of each punctual laboratory and the difference between the processed atomic clock and the main clock can be downloaded through the publishing system.

2) The release of Hadma variance and weight data: the Hadma variance of atomic clock and main clock and the weight of atomic clock are published.

3) The release of the atomic time scale: release UTC-UTC (TA), UTC-UTC (K) (K is the domestic punctual laboratory), TA-clock_i.

7 System Construction and Implementation

The system is completed with MATLAB, which has the functions of powerful numerical calculation, function drawing, algorithm realization and user interface creation. According to the algorithm principle of atomic time scale and the content published in time bulletin, the system background and interface are designed and programmed. A detailed flow chart of the overall framework is shown in Fig.4.

The system consists of an atomic clock data module, an atomic time scale calculation module and an atomic time scale release module. According to 67 atomic clocks of four punctual laboratories of National Institute of Metrology (NIM), National Time Service Center Chinese Academy of Sciences (NTSC), Shanghai Institute of Measurement and Testing Technology, Beijing Institute of Radio Metrology, from December 2017 to March 2018, the atomic time scale was calculated. The overall interface of the system is shown in Fig.5.

The line diagram of the UTC and the calibrated integrated atomic time scale is shown in Fig.6. The abscissa indicates the Julian day time, and the ordinate indicates the time difference between UTC and the calibrated integrated atomic time scale (unit: ns). It shows that the time difference between the integrated atomic time scale of the system and UTC is obviously better than ±10 ns.

8 Conclusion

The atomic time scale release system designed in this paper for multiple laboratories is the first to integrate the clock difference data of domestic punctual laboratories, realize the unified format processing of data, calculate the integrated calibrated atomic time scale and complete release of the domestic time bulletin. This has great reference value for the construction and implementation of the Chinese atomic time scale scheme being studied in China.

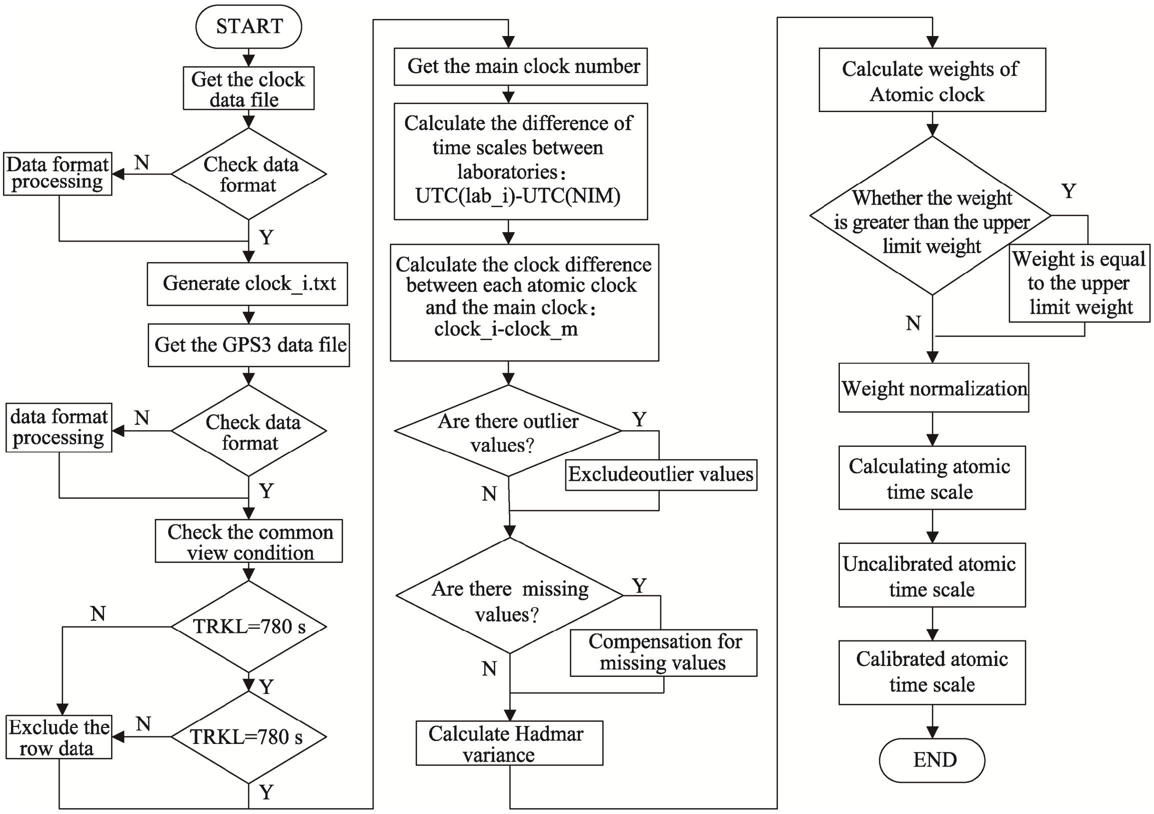
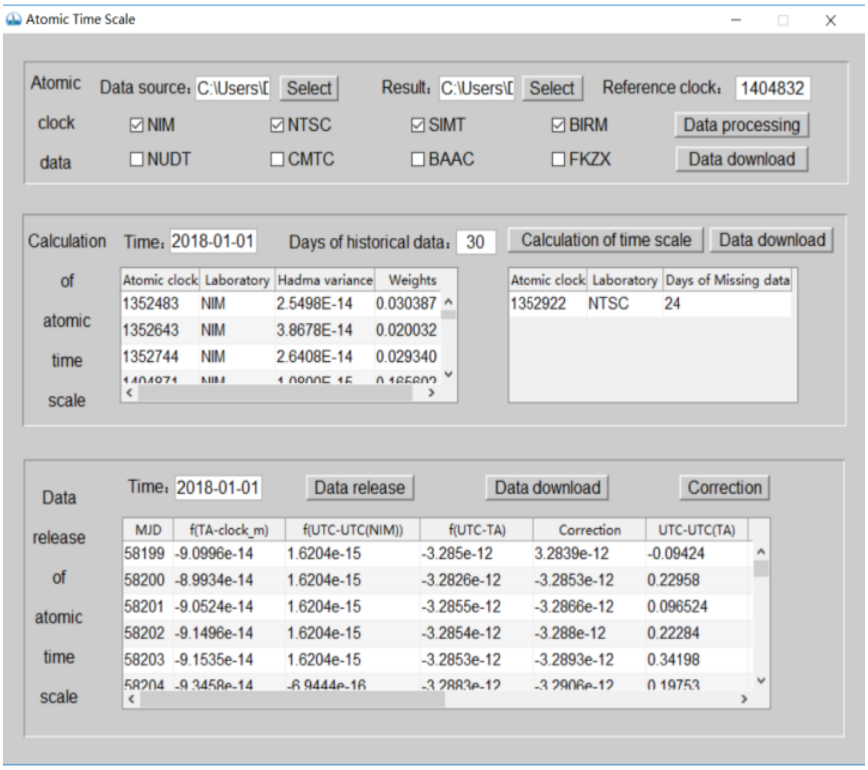


Fig.4 Detailed flow chart of the overall system framework



Atomic clock data

Data source: C:\Users\D

Result: C:\Users\D

Reference clock: 1404832

☑NIM ☑NTSC ☑SIMT ☑BIRM

☐NUDT ☐CMTC ☐BAAC ☐FKZX

Calculation of atomic time scale

Time: 2018-01-01

Days of historical data: 30

Atomic clock	Laboratory	Hadma variance	Weights
1352483	NIM	2.5498E-14	0.030387
1352643	NIM	3.8678E-14	0.020032
1352744	NIM	2.6408E-14	0.029340

Atomic clock	Laboratory	Days of Missing data
1352922	NTSC	24

Data release of atomic time scale

Time: 2018-01-01

MJD	f(TA-clock_m)	f(UTC-UTC(NIM))	f(UTC-TA)	Correction	UTC-UTC(TA)
58199	-9.0996e-14	1.6204e-15	-3.285e-12	3.2839e-12	-0.09424
58200	-8.9934e-14	1.6204e-15	-3.2826e-12	-3.2853e-12	0.22958
58201	-9.0524e-14	1.6204e-15	-3.2855e-12	-3.2866e-12	0.096524
58202	-9.1496e-14	1.6204e-15	-3.2854e-12	-3.288e-12	0.22284
58203	-9.1535e-14	1.6204e-15	-3.2853e-12	-3.2893e-12	0.34198
58204	-9.3458e-14	-6.9444e-16	-3.2883e-12	-3.2906e-12	0.19753

Fig.5 Atomic time scale system

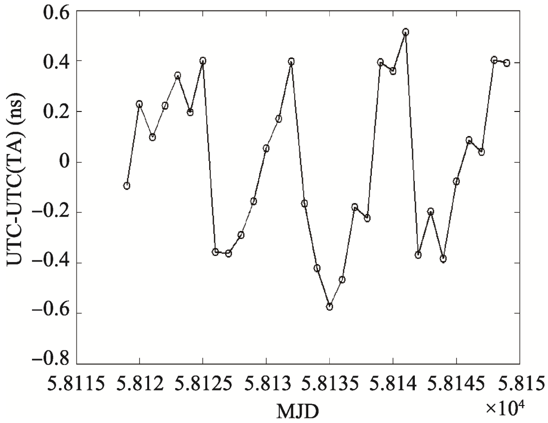


Fig.6 Line chart of UTC-UTC(TA)

References

[1] Zhang, GZH, et al. (2007). Research on AT1 atomic time algorithm, *Electronic Measurement Technology*, 2007(11), PP. 20-24.

[2] Dong, WW, et al. (2018). Progress of TAI and timekeeping work in NTSC, *Journal of Time and Frequency*,41(02), PP.73-79.

[3] Zhu, SG, et al. (2017). The denoise of the atomic clock frequency differences, *Acta Metrologica Sinica*,38(04), PP.499-503.

[4] Zhang, L. (2008). Two Way Satellite Time and Frequency Transfer Link, *Journal of Electronic Measurement and Instrument*, 22(S2), PP.93-95.

[5] Wang, WZH. (2016). Atomic Clocks' Data Exchange System for Time Keeping, *Computer Systems & Applications*, 25(09), PP.119-123.

[6] Zhang, G. (2004). Research on Timing Parameters for GPS Common-view Method, *Acta Metrologica Sinica*, 2004(02), PP.167-170.

[7] Wang, X. (2017). Exploration of time keeping system and atomic time algorithm in time and frequency measurement system, *Shanghai Measurement and Testing*, 44(05), PP.33-35.

[8] Gu, CHSH. (2010). Autonomous time synchronization algorithm on Hadamard variance among navigation satellites, *Chinese Space Science and Technology*, 30(01), PP.1-9.

[9] Qu, L. (2015). Research on the Relationship of Frequency Stability and Timekeeping Clock Allocation. *Journal of Astronautic Metrology and Measurement*, 35(01), PP.34-38.

[10] Li, Q G, et al. (2010). Local atomic time algorithm research. *Acta Astronomica Sinica*, 51 (04), PP.404-411.

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