TIME DISSEMINATION AT SHANGHAI OBSERVATORY

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ABSTRACT

After a brief review of the historic status of HF standard frequency and time signal transmission (call signs are BPV and XSG respectively) at Shanghai Observatory(SO),this paper describes recent progress in time comparison and synchronization at SO, including Loran C,TV synchronization,portable clock,laser pulses and geostationary satellite methods. Finally,the planned international T/F links between SO and other T/F laboratories will also be presented,such as the utilization of the ranging signals of the Japenese Geostationary Meteorological Satellite,the Global Positioning System (GPS) and the VLBI technology.

1. Historic Review

Radio time signal transmission in HF band has been carried out by Shanghai Observatory (SO) for more than sixty years. For a long period of time before 1981, SO was in charge of the national radio time service in China which provided the users with precise time of UT1 and UTC. The historic status of the radio time signal service at SO are given in Table 1.

Table 1. Radio time signal service at SO

call sign	type of time signal	carried frequency(MHz)	service period(year)	accuracy level
----	Morse code	HF	1914 - 1940	500 ms
----	rythmic	HF	1940 - 1954	30 ms
XSG	UT1	0.5225,6.454, 8.487,12.954, 16.938	1954 -	10 ms
BPV1	UT1	5.430,9.351	1955 - 1981	10 ms
civil	UT1	MF	1955 -	100 ms
(via radio broadcast station at Shanghai)				
BPV3	UT1	5,10,15	1958 - 1981	10 ms
BPV2	UTC	5,10,15	1970 - 1981	10 μs

The service of BPV standard frequency and time signal transmission lasted 23 years. Till 1978, it reached the 1*10E-10 transmission

precision of frequency and time interval, i.e. the control accuracy of time signal emission was 10 microseconds. The emission characteristics were described in Table 2.

Table 2. The characteristics of BPV emission

frequency (MHz)	antenna type	antenna elevation	received field strenth at one hop distance Er(μv/m)
5	biconical	27°02′	16.8
10	biconical	13°52′	37.5
15	biconical	8°43′	5.7

In July 1981, BPV station ended its service, and another new station BPM managed by Shaanxi Observatory, was put into service. Now, the XSG UT1 time signal transmissions, still maintained by Shanghai Observatory, provides standard time for nautical ships. It works two times per day at UT 03h and 09h and has a special program for time signal.

2. Recent Progress

2.1 LF navigation signal

SO started to receive continuously the Y and M stations of the Northwest Pacific Loran C chain for time comparison in 1976 and 1985 respectively. Since 1981,the BPL LF time signal transmitted by Shaanxi Observatory also has been received by SO,as a monitor station for BPL transmission. The time delay, fields trength, Er and the normal measurement precision S(hour) for each station received at Shanghai Observatory are given in Table 3.

Table 3. Performances of the received LF time signal at SO

station	distance (km)	receiver delay(μs)	total delay(μs)	Er(db)	S(hour) (*10E-12)
9970-Y	828.841	25.9	62286.15	74.4	8.3
9970-M	2077.737	26.2	6991.59	75.6	50.0
BPL	1184.763	16.2	4005.19	57.0	33.1

At present, LC/9970 still is the important link between SO and the BIH and other T/F Labs. Through it,the UTC time scale and TA time scale of Shanghai Observatory have been issued in BIH Circular D since 1983 and 1984 respectively.

2.2 Passive TV comparison

Using the line 6 of the odd frame TV signal broadcasted by the Chinese Central TV station as a common reference,the passive TV time comparison has been used by various T/F Labs in China at a routine bases. The adopted values of propagation delay and measurement precision for some stations are given in Table 4,among these,BAO is Beijing Obs.,CSAO is Shaanxi Obs.,WTO is Wuhan Obs.

Table 4. TV signal propagation delay and measurement precision

station	delay CCTV-Obs.(μs)	single measurement precision(ns)	two Obs.syn. precision(μs)
BAO	75.3	25	0.1
CSAO	3611.0	45	0.1
SO	6830.4	25	0.1
WTO	4086.6	25	0.2

In order to check the accuracy of TV method,several portable clock time measurements were done between Shanghai and Shaanxi Observatories. Table 5 shows the systematic deviation between TV and Portable clock.

Table 5. Systematic deviation between TV and portable clock

time	October 1982	March 1984	June 1984	April 1985
TV-PC(μs)	-1.82	0.73	1.24	0.34

The early measurement in October 1982 showed the large deviation, while recent measurements showed somewhat of an improvement. These deviations could be considered to come from the variance of propagation delay which can be checked by taking more extended TV measurement data from more than three T/F Labs. Now we could distribute these delay variances to the random changes of the equipment and cable at the TV studio. While it is difficult to estimate the accuracy of the passive TV method, it is thought to be one or two microseconds.

2.3 portable clock

Since 1981,portable clocks from the U.S.Naval Observatory have been taken to some of the Chinese T/F Labs four times. The time differences of atomic time scales between USNO and each laboratory were determined precisely with an accuracy of 0.1 microsecond,and the time delay of Loran C signal of Northwest Pacific chain has been checked.

Table 6. Timing results and systematic deviations via LC and PC (in μs)

date	SO - USNO			BAO - USNO			CSAO - USNO		
	LC	PC	L-P	LC	PC	L-P	LC	PC	L-P
Aug.1981	1.8	5.9	-4.1	-2.6	2.9	-5.5	-2.8	3.2	-6.0
Oct.1982	5.1	8.3	-3.2	-2.9	1.8	-4.7	-4.8	-0.5	-4.3
Aug.1984	7.5	10.7	-3.2	1.0	5.3	-4.3	-16.2	-9.1	-7.1
Apr.1985	7.3	9.9	-2.6	-	-	-	-6.8	-2.0	-4.8
mean			-3.3			-4.8			-5.6
r.m.s.			0.62			0.61			1.2
adopted delay	62286.15			65708.35			66224.79		

From Table 6,we can see that the systematic deviations for various labs have a common trend,the average value is about -4.5 μs. The inconsistency of mean values between different Labs shows that there still are some systematic deviations in the prediction of groundwave delay and measurement of receiver delay for various Labs. The magnitudes of r.m.s. reflect not only the uncertainty of USNO correction, but also the uncertainties of each measurement of portable clock and Loran C for various Labs.

2.4 Laser pulses

Time comparison experiment via laser pulses has been made between the two sections of Shanghai Observatory, Zi-Ka-Wei and Zo-Se,separated by 25.2 km in 1982. In the experiment, a Q-switch ruby laser, photo-receiving system, retro-reflectors, 0.1 nsec resolution counters as well as rubidium clocks were used. Fig.1 shows the block diagram for laser time comparison system. During the experiment, a portable cesium clock comparison between Zi-Ka-Wei and Zo-Se sections also was made successfully with a uncertainty only about 4 nsecs.Due to the difficulty in measurement of photo-detector delay at that time,we did not get accuracy estimate for laser time comparison. But the result of time fluctuations of about 1.3 nsec(r.m.s.) for two-minute measurements still was encouraging. It was the first experiment in China to get such high precision for time transfer.

Furthermore, a practical calculation method for the relativistic correction due to earth rotation effect was proposed. For time transfer via satellite,a correction value d can be calculated as follow:

$d=(V*T/2c)*\cos H*\sin A$

here,c is the speed of light,

V is the linear speed of Earth rotation at the observing station B with latilude ϕ,

T is the measurement value of flight time of laser or microwave signal that goes back and forth between two stations of B and C,

H and A are the elevation and the azimuth of satellite respectively,which are observed at station B.

2.5 Time comparison between China and France via Symphonie Satellite

This was the first time transfer via geostationary satellite in which the Chinese T/F Labs took part. It was made between Shanghai and Paris in June 1979,Fig.2 shows the block diagram of the experiment system and Table 7 describes the parameters for both ground stations.

Table 7. Parameters of ground station

parameter	Hong-Qiao station	Pleumeur-Bodou station
longitude	121°20′ E	3°52′ W
latitude	31°14′ N	48°47′ N
antenna	10 meter	16 meter
elevation	6°.4	15°.4
azimuth	260°.6	120°
EIRP(dbw)	84	85
emission	6130 MHz	6340 MHz
frequency	(B transponder)	(D transponder)
receiving	4115 MHz	3905 MHz
frequency	(D transponder)	(B transponder)
I.F.band	30 MHz	30 MHz
frequency offset	15KHz:51MHz/V	15KHz:5.1MHz/V
type of sig.	TV type 1pps	TV type 1pps
modulation	FM	FM

Precision of 10 ns was obtained. The multi-loop delay measurement was used for determining instrument delay at Hong-Qiao station. Because both delays for the up and down frequency transformers as well as modulator and demodulator can not be separated, the accuracy estimate was about 100 nsecs.

2.6 Time comparison between China and Italy via Sirio-1 satellite

The experiment was proposed and studied by Istituto Electrotecnico Nazionale (IEN) and Politecnico di Torino,Italy. In China, Shaanxi,Shanghai and Beijing Observatories took part in the time comparison. Two periods of experiment were performed.

The sequential mode of the two-way technique was tested in the first period in May and June 1984, i.e., signal transmission on the same communication channel in time sharing. Fig.3 shows the block diagram of the experimental system. Table 8 describes the parameters for both ground stations. Time comparison via Sirio-1 lasted 9 days, each day has 5-9 groups of measurement with an interval about 20 minutes, and each group lasted 100 seconds with 100 measurement data. Due to the fact that the Italian portable ground station in Beijing was only a 3m antenna, the precision of time comparison was limited to 30 ns. The delay of high frequency part in the Beijing ground station equipment was not measured,it can be estimated with an uncertainty of about 50 ns. A portable clock trip between IEN,Torino and Beijing was failed during the return to Torino, thus the portable clock check was not obtained.

Table 8. Parameters of both ground stations

parameter	Beijing station	Lario station
longitude	116°18′43" E	9°24′33" E
latitude	39°56′43" N	46°09′30" N
antenna	3m	16m
elevation	19°	13°
azimuth	240°	-
e.frequency	17.1028 GHz	17.1028 GHz
r.frequency	11.5268 GHz	11.5268 GHz
I.F.band	2.5 MHz	2.5 MHz
	1.25 MHz(narrow)	1.25 MHz(narrow)
sig.type	TV syn. pulse	TV syn. pulse
modulation	FM	FM

The microwave time and ranging equipment with pseudorandom noise code technique called MITREX Modem was used in the second period of experiment in February and March 1985. This Modem was developed by Prof.Ph.Hartl, Stuttgart University,West Germany. Prof.S.Leschiutta and Prof.Pisani, Politecnico di Torino,Italy, brought it to Beijing station and performed timing and ranging experiments. Shanghai and Shaanxi Observatories brought their respective portable cesium clock to Beijing station and joined the timing experiment. Fig. 4 shows the MITREX Moden at Beijing station. Table 9 gives the preliminary results. PC(IEN) was an IEN portable clock brought to Lario station as a working clock.

Table 9. Preliminary results

date	time (UT)	satellite link PC(SO)-PC(IEN) (μs)	r.m.s.(ns)	PC link UTC(SO,MC)-PC(SO) (μs)
Feb.27	12h			2.888
Feb.28	12h			2.894
March.1	10h20m	10.037	0.75	
March.1	12h			2.902
March.2	10h06m	10.040	0.83	
March.2	12h			2.914
March.3	12h			2.927
March.4	12h			2.939

Unfortunately,the Sirio-1 satellite was at the end of its life-time, it can no longer be used for experiments.

3. The Planned International T/F Links

3.1 Geostationary Meteorological satellite (GMS-3)

The proposed time transfer using ranging signal of the Japanese Geostationary Meteorological Satellite is an available method of high

potential precision and routine capability in the region of the Northwest Pacific. Research work for this project has been carried out at Shanghai Observatory. The receiving system for reception of GMS's ranging signal at 1684 MHz,which is phase-modulated by a 200 KHz side tone and the 200 KHz tone is AM-modulated by a series of lower frequency tones, is being developed at SO under the technical cooperations of Radio Research Laboratories (RRL), Japan. At the beginning of 1985, a 6 meter diameter antenna, the front-terminal and high frequency part of the receiving system were completed. The 70 MHz IF from ranging signal has been received successfully.
According to technical parameters of GMS's ranging signal and the receiving ground station at SO, estimation for the performance of the receiving system and error of time transfer between RRL,Tokyo and SO,Shanghai were made. The main figures are as follows :

receiver input power	-102.0 dbm
overall carrier to noise density ratio	71.8 db.Hz
signal to noise ratio in the PLL	38.6 db
precision of time transfer	10 - 20 ns
accuracy of time transfer	50 - 100 ns

3.2 VLBI time transfer

A Mark-II VLBI system with 6 meter antenna has been developed at Zi-Ka-Wei section of Shanghai Observatory. By this system, we performed the first VLBI experiment with remote baseline between Europe and Asia, in collaboration with the 100 meter radio telescope of Max-Plank-Institute fur Radioastronomie, Bonn, West Germany in Nov. 1981. The first China-Japan VLBI observation also was conducted between SO and RRL in September 1985. For development, a new Mark-III VLBI system with 25 meter antenna is going to built at Zo-Se section of SO, and is expected to be completed in 1987.
This background opens up broad prospects for the clock synchronization experiments via VLBI at SO. We expect to set up international T/F transfer links between SO with USNO,RRL and other T/F laboratories with accuracy of a nanosecond level by making the daily T/F transfer links such as GMS and GPS with periodical calibration with the accurate VLBI link. It would lead to the possibility that the Chinese atomic clocks make a greater contribution to International Atomic Time (TAI).

3.3 GPS Timing

With the decrease in receiver cost, a rapid expansion of civilian applications of the GPS technique is expected not only in navigation and location but also in timing. More and more T/F laboratories will equiped with GPS receiver, it could become the primary means for the international time link between the various T/F laboratories, thus replacing the Loran C time link which still plays an important role for clock synchronization at present. Shanghai Observatory also wants to carry out this work, both for timing and location and expects to establish a GPS time link at daily bases both for national and

international time coordination.

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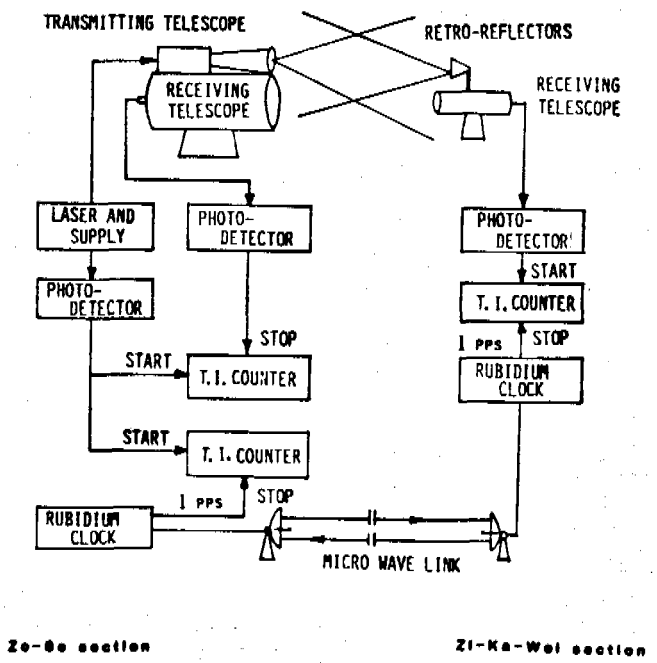

Fig.1 The block diagram for laser time comparison system

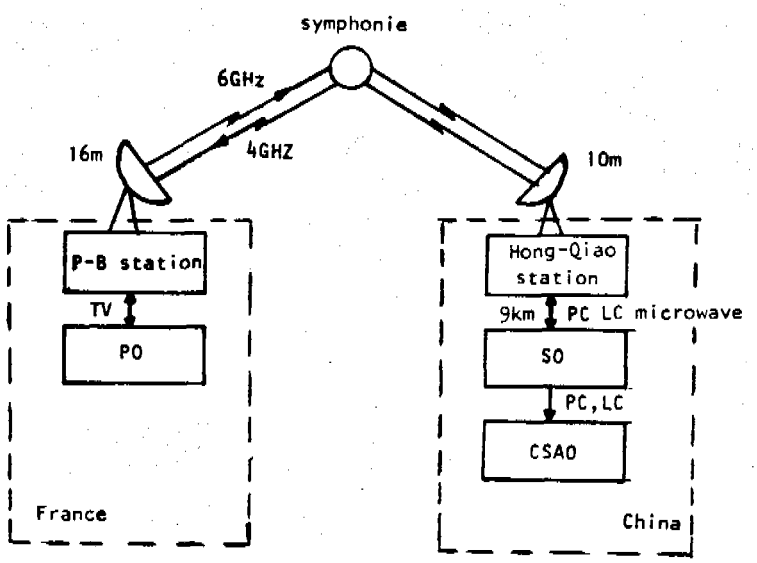

Fig.2 The block diagram of experiment system for time comperison via Symphonie

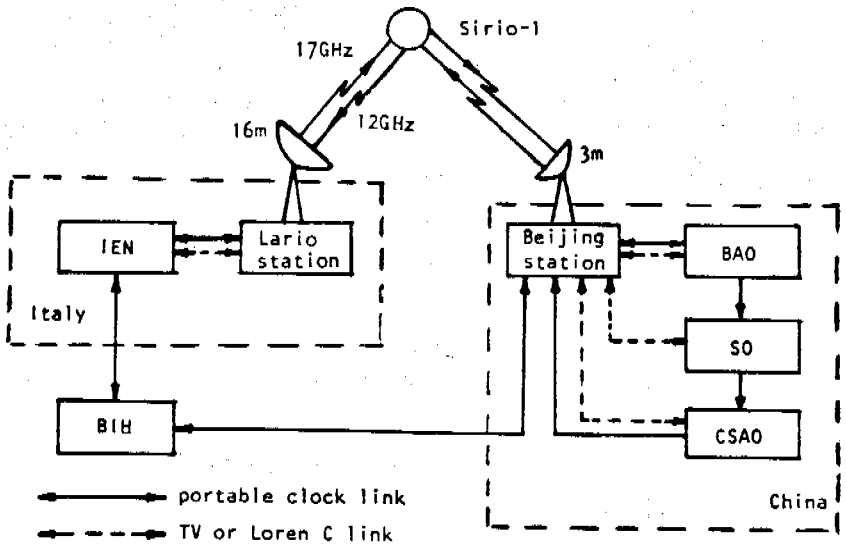

Fig.3 The block diagram of experiment system for time comparison via Sirio-1

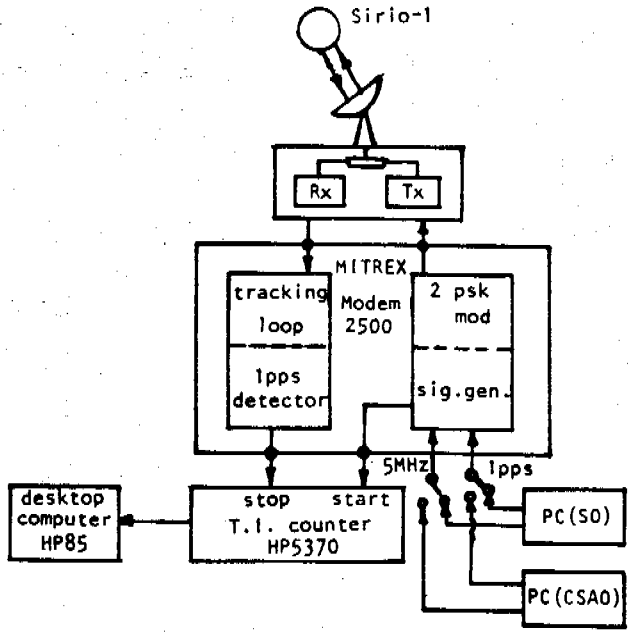

Fig.4 Beijing ground station with MITREX-Modem 2500