

The Two-Way Time Synchronization System via a Satellite Voice Channel

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Abstract

A newly developed two-way time synchronization system is described in this paper. The system uses one voice channel at a SCPC satellite digital communication earth station, whose bandwidth is only 45 kHz, thus saving satellite resources greatly. The system is composed of one master station and one or several, up to sixty-two, secondary stations. The master and secondary stations are equipped with the same equipment, including a set of timing equipment, a synthetic data terminal for time synchronizing, and an interface unit between the data terminal and the satellite earth station. The synthetic data terminal for time synchronization also has an IRIG-B code generator and a translator. The data terminal of master station is the key part of whole system. The system synchronization process is full automatic, which is controlled by the master station. Employing an autoscanning technique and conversational mode, the system accomplishes the following tasks: linking up liaison with each secondary station in turn, establishing a coarse time synchronization, calibrating date (years, months, days) and time of day (hours, minutes, seconds), precisely measuring the time difference between local station and the opposite station, exchanging measurement data, statistically processing the data, rejecting error terms, printing the data, calculating the clock difference and correcting the phase, thus realizing real-time synchronization from one point to multiple points. We also designed an adaptive phase circuit to eliminate the phase ambiguity of the PSK demodulator. The experiments have shown that the time synchronization accuracy is better than 2 μ S. The system has been put into regular operation.

Introduction

Two-way time comparison via satellite is an important method for laboratories which require high precision time synchronization. Due to the wide frequency band and steep pulse edge, its precision is a few nanoseconds. If MITREX modems are used, the precision can be as good as subnanoseconds. In consideration of various delay corrections, the accuracy can achieve ten nanoseconds to one hundred nanoseconds. Because it necessary to use two satellite transponders, this method is not universally practical. There are quite a number of satellite earth stations of the CVSD/PSK/SCPC system in China. Generally, each station consists of several digital voice channels and several low rate data channels. Can the voice channel be used for a two-way time comparison? We analyzed carefully the composition and the principle of the earth station, and discovered that the CVSD circuit has the larger error and the PSK demodulator has a phase ambiguity. Thus we worked out a plan in which digital signal inputs to

the PSK modulator and outputs from the PSK demodulator, designed an adaptive phase circuit to eliminate the phase ambiguity, developed related equipment, and established a complete time synchronization network via the satellite.

System Configuration

The two-way time synchronization system via a satellite voice channel is composed of one master station and one or several, up to sixty-two, secondary stations. The equipment configurations of master and secondary stations are basically identical, including a set of timing equipment, a synthetic data terminal for time synchronization, and an interface unit between the data terminal and the satellite earth station, which are shown in Figure 1.

The master station terminal is the heart of whole system. The system synchronization process is full automatic, and is controlled by the master station. The master station controls scanning to all secondary stations, transmits standard time to secondary stations, controls the two-way comparison and monitors the secondary station status at any time, and determines what to do next according to secondary station status.

The data terminals of secondary stations are the same as the master except for work mode: one of the terminals is set up as master mode, the others are set up as secondary mode. They accomplish the different tasks. In fact, the interface unit is a signal format converter. It receives and demodulates the IRIG-B code from the terminal, converts it to the code data current for the PSK modulator, and generates a carry active signal for the voice channel. At the same time it receives and demodulates the code data current from the PSK demodulator, eliminates the phase ambiguity, and converts it to the IRIG-B code to be transmitted to the terminal.

Features

- **1. Narrow Frequency Band**—The two-way time transfer using earth stations generally requires two satellite transponders. However our system only requires one digital voice channel, its bandwidth is 45 kHz, thus saving satellite resources greatly.
- **2. Powerful Real-time**—The two-way time transfer using earth stations is not real-time. It is necessary to bring the data from the two stations together, then the data are processed and the clock difference is obtained. In our system, the master and each secondary station directly exchange the data using the same voice channel, and realize real-time synchronization.
- **3. High Automatization**—The procedure of real-time synchronization is fully automatic without manual intervention.
- **4. Multi-point Synchronization**—The system adopts the scanning method, thus realizing time synchronization from one point to multi-point. At present, the number of the secondary stations may be one up to sixty-two. If needed, the number can increase more.
- **5. Short Synchronization Time**—The period from the time when a secondary station runs free after tuning on to the time when it synchronizes accurately with the master

station is less than two minutes.

- **6. Multi-function**—Besides displaying the transmitting time and receiving time, having a phase shifter with a resolution of 0.1 microsecond, processing the data, printing the data, the data terminal also has a time interval counter with a resolution of 0.1 microsecond and the input and output interfaces for standard IRIG-B time code.

Synchronization Procedure

The system adopts a scanning method, each secondary station has a specially designated number. The voice channels of all secondary stations have the same receiving frequency which corresponds with the transmitting frequency of the master station and the same transmitting frequency which corresponds with the receiving frequency of the master station.

The data terminal of the master station first receives and demodulates IRIG-B code from the timing equipment, accomplishes the synchronization with it and calibrates the date and the time of day. Then it outputs the signal to the interface unit, the converted signal is input in the voice channel. Next the master channel transmits a selective calling code, the date and the time of day to all secondary stations.

All the secondary stations will go into receiving mode after turning on, demodulate the signal from the master station. When the demodulated selective calling code is same with the local station number, the secondary station activates the carry of the voice channel, accomplishes a coarse time synchronization, and calibrates the date and the time of day, then transmits a responding signal to the master station. After knowing that the secondary station had accomplished the coarse synchronization, the master station transmits a command to the secondary station. Then the two-way comparison starts. The time interval counter of the master station is started by the 1 PPS which is being transmitted by the master station and stopped by the 1 PPS which is received from the secondary station. The measured time difference and the time of the measurement are transmitted to the secondary station immediately. Similarly, the time interval counter of the secondary station is started by the 1 PPS which is being transmitted by the secondary station and stopped by the 1 PPS which is received from the master station. The measured time difference and the time of measurement are transmitted to the master station immediately. Both the stations print out the measured and received data. Besides, the data terminal of the secondary station processes the time difference data one by one, rejects error terms, calculates the clock difference between two stations on the basis of the two-way principle, and controls the phase shifter to shift the phase according to the calculated amount and sign. Then the secondary station transmits a synchronization success signal to the master station. After it has received the signal, the master station transmits a command to the secondary station to stop activating the carry. When it has detected that the secondary station really had stopped transmitting, the master station automatically calls the next secondary station, and so on. Thus it can be seen that the transmitting frequencies of the secondary stations are all the same, but only one of the secondary stations is transmitting the signal whenever so as to avoid confusion. The time need for above procedures is less than two minutes.

After the synchronization has been accomplished, the data terminal of the secondary station automatically outputs the 1 PPS and IRIG-B code signals to the timing equipment.

Experiments and Results

In order to test and verify the system accuracy, we have made experiments for two cases.

The first case refers to single station experiment. We put three data terminals in a timing room. One of them is assigned as the master station. Others are secondary stations. Three terminals use three voice channels of the same satellite earth station for comparison. The system configuration of a single station experiment is shown in Figure 2.

The input and output signals of the three terminals are connected with three interface units of the satellite earth station respectively by six paired cables with the same lengths. The voice channel of the master station transmits the messages at f_1 frequency to two secondary station channels, and receives the messages at f_2 frequency from two secondary station channels. Two secondary station channels transmit the messages at the same f_2 frequency to the master station channel by time division mode, and receive the messages at f_1 frequency from the master station channel. The time differences for the 1 PPS signals between the master station and two secondary stations are measured respectively by a time interval counter. The readings of the counters are the time synchronization accuracies.

The second case refers to two station experiment. We put three data terminals (one master station and two secondary stations) in a timing room. The master station terminal and one secondary station terminal are connected with two interface units of one satellite earth station with four paired cables. Another secondary station terminal is connected with an interface unit of another satellite earth station with two paired cables. The distance between the two earth stations is about five kilometers. The system configuration is shown in Figure 3. The experiment method is as same as described above.

For the above two cases, we changed different voice channels and tested many times. Table 1 lists the experiment results. The results have shown that the accuracy of the time synchronization system is better than one microsecond in most cases, and only for few cases the accuracy is worse than one microsecond, but better than two microseconds. This is caused by the voice channel delay.

Conclusions

The two-way time synchronization via a satellite voice channel has the features of narrow frequency band, powerful real-time, high automatization, short synchronization time, multi-function and so on. The system uses microprocessor control, adopts the scanning method and conversational model, automatically realizes real-time synchronization from one point to multi-point. The synchronization accuracy is better than two microseconds. The system has powerful practicality.

References

- P. Kartschoff, "Frequency and Time", 1978
- Miao Yong-rui et al., "International Comparison Test of Shaanxi Observatory's Clock", Publications of the Shaanxi Astronomical Observatory, No.1, 1981, pp1-16
- W. J. Klepczynski et al., "Preliminary Comparison Between GPS and Two-way Satellite Time Transfer", Proceedings of the 42nd Annual Symposium on Frequency Control, 1988, pp472-477

Table 1
The Experimental Results

No.	Average (μS)	Standard Deviation (μS)
1	10.4	0.03
2	20.6	0.03
3	30.2	0.02
4	40.8	0.04
5	50.2	0.03
6	61.4	0.04
7	70.6	0.05
8	81.6	0.04

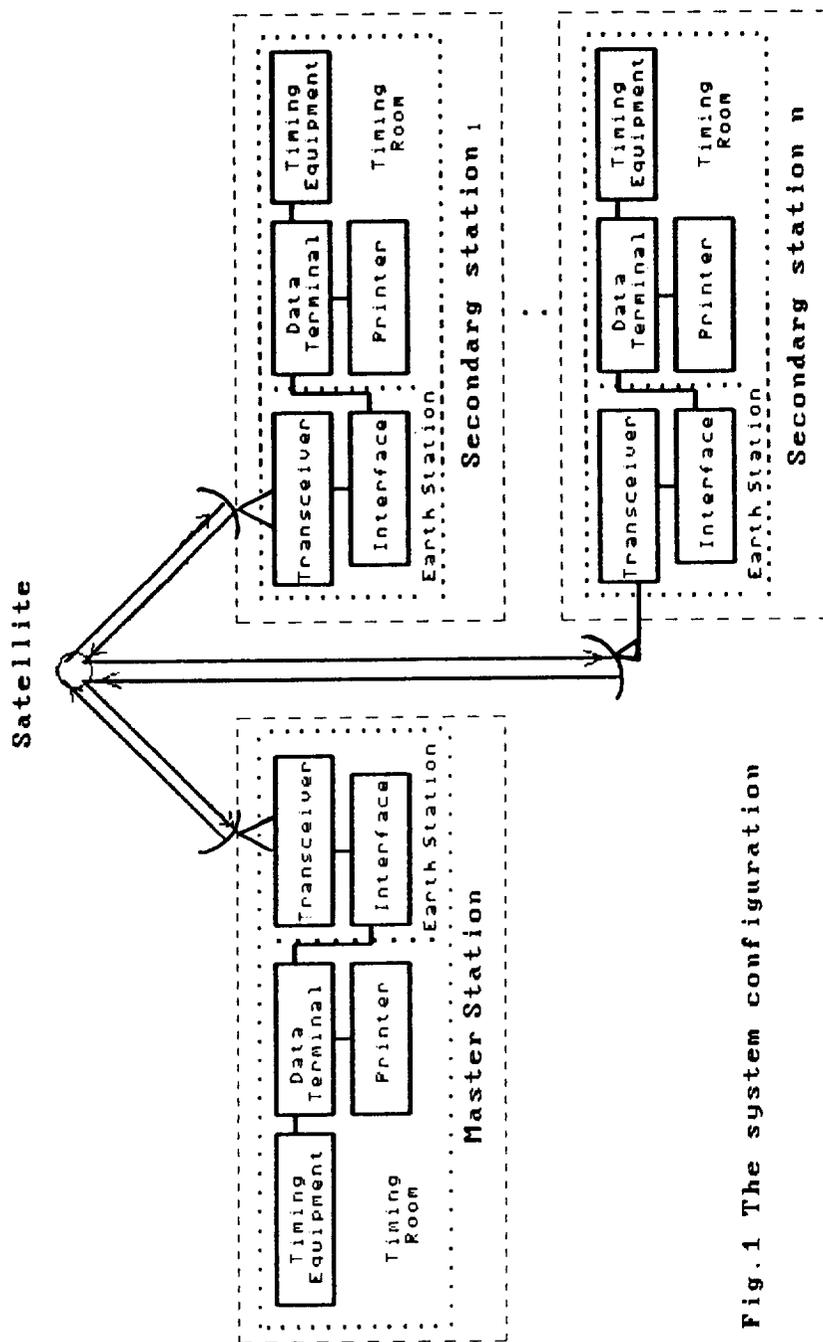


Fig.1 The system configuration

Fig. 2 Single Station Experiment

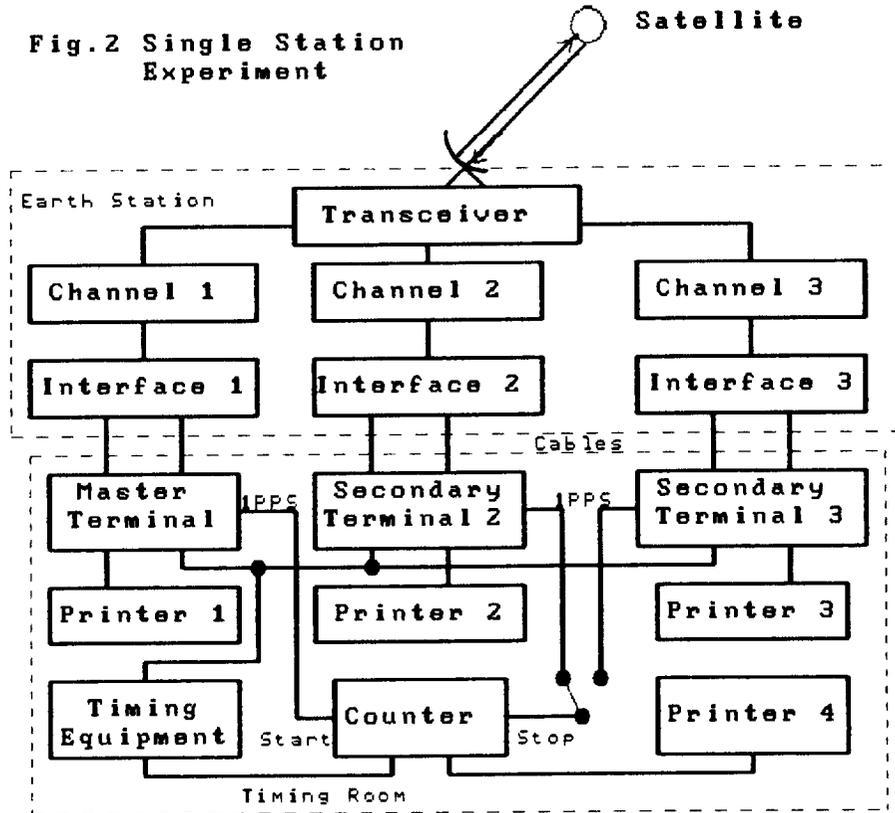


Fig. 3 Two Station Experiment

