# Design of GPS Remote Calibration System

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***Abstract*—A new design of GPS remote time and frequency calibration system is presented. Its hardware was composed with a time interval counter card, a GPS receiving modular and a controller. The counter card was manufactured with modeled number GT200 by Guide Technology, Inc. The Trimble ThunderBolt GPS disciplined clock was used as the GPS receiving modular. A personal computer with Redhat Linux operation system was utilized for the controller. The software is written by C language which controlled the GPS modular, the counter card, and data collecting.**

**The characteristic of the counter card and GPS receiving modular were performed. A series of test were executed to valuate this system. The short baseline common clock test with hydrogen maser was studied for the system noise level. The direct phase comparison in laboratory, GPS short baseline test in laboratory, and GPS field test within 10km between hydrogen maser and cesium clock were also experimented. Two methods were applied to evaluate the system performance and there were GPS all-in-view and phase difference comparison. The later one could illustrate the short-term frequency stability. The former method could demonstrate the longer term stability and time characteristic of the clock at remote site.**

**The accuracy and stability of the experimental result of the short baseline common clock with hydrogen maser reached to a few parts of $10^{-13}$ and the TDEV values were lower than the ITU-T G.811 requirements. The designed system with the capability could be applied for the remote time/frequency calibration and for the monitoring the performance of the primary reference clocks(PRC) of the digital telecommunication network, too.**

## I. Introduction

GPS has become the primary system for distributing time and frequency [1]. GPS receivers are utilized in many fields such as telecommunication networks, industries, calibration laboratories and testing laboratories. GPS makes it possible to synchronize clocks, to calibrate clocks and to control oscillators in facilities that can place an antenna outdoors for line-of-sight reception of the GPS satellites.

The common-view mode is also used to synchronize or to compare time standards or time scales at two or more sites [2]. Common-view GPS was the method used by BIPM to collect data from laboratories who contribute to the definition of UTC. However, it is a specialized technique that has many drawbacks. In recent years, many improvements occurred such as the number of GPS multi-channel receivers utilized for TAI increased, the ionosphere delay can be measured with the use of dual-frequency receivers, and the IGS provides precise ephemeredes and clock solutions for the GPS satellites. Consequently, the most important error sources of GPS time transfer are significantly reduced so that the common-view has lost most of its advantages. The BIPM colleague, Jiang and Petit, discussed the all-in-view method in 2004 [3] where the local reference was compared to a realization of GPS time using all the available measurements allowing to obtain the link between sites

In this paper, all-in-view GPS receivers are actually integrated systems that combine a standard GPS timing receiver with measurement hardware and software. This hardware and software enables the system to make measurements from individual satellites and to store the

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results so they can be processed later.

## II. GPS Model

The GPS code and phase models are described as follows.

$$C_k^i = \rho_k^i + I_k^i + T_k^i + c\delta_k - c\delta^i + \xi_k^i, \tag{1}$$

where $C_k^i$ is the C/A code measurements between receiver $k$ and satellite $i$; $\rho_k^i$ is the geometric distance; $I_k^i$ and $T_k^i$ are the ionospheric and tropospheric delay; $\delta_k$ and $\delta^i$ are receiver and satellite clock errors; $\xi_k^i$ is the unmodeled errors of code measurements, which may include phase wind-up, random noise, phase center offset ….etc.

The GPS common-view is that two local receiver references are compared simultaneously to a "common view" satellite clock. It is shown as follow:

$$C_{km}^i = \rho_{km}^i + I_{km}^i + T_{km}^i + c\delta_{km} + \xi_{km}^i \tag{2}$$

Where $C_{km}^i$ means the common-view C/A code measurement between receiver $k$ and receiver $m$ with satellite $i$. $\rho_{km}^i$, $I_{km}^i$, $T_{km}^i$, $\delta_{km}$ and $\xi_{km}^i$ are the geometric distance, the ionospheric delay, tropospheric delay, receiver clock error and unmodeled errors of code measurement between receiver $k$ and receiver $m$ with satellite $i$, respectively. The satellite clock error is eliminated by the common-view method.

The time difference between two receiver references $m$ and $k$ by GPS AV method using C/A code is given by:

$$C_{km}^{AV} = \left(\sum_i \omega_k^i C_k^i - \sum_j \omega_m^j C_m^j\right) = C_k^{GPS} - C_m^{GPS} \tag{3}$$

where $C_k^{GPS}$ is the C/A code measurement between receiver $k$ and GPS satellite system time, and $\omega_k^i$ is the weight of receiver $k$ and satellite i.

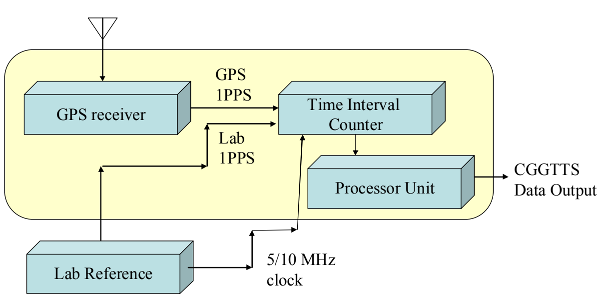


Figure 1. System configration of GPS remote calibration system

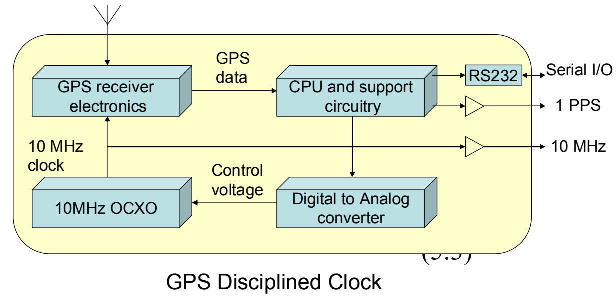


Figure 2. A diagram for the used GPS disciplined clock

## III. System Configration

Fig. 1 is a system configuration description of designed GPS remote calibration system. Its hardware was composed with a time interval counter card, a GPS receiving modular and a controller. The counter card was manufactured with modeled number GT200 by Guide Technology, Inc [4]. The Trimble ThunderBolt GPS disciplined clock [5] was used as the GPS receiving modular as demonstrated in Fig. 2. A personal computer with Redhat Linux operation system was utilized for the controller. The software is written by C language which controlled the GPS modular, the counter card,

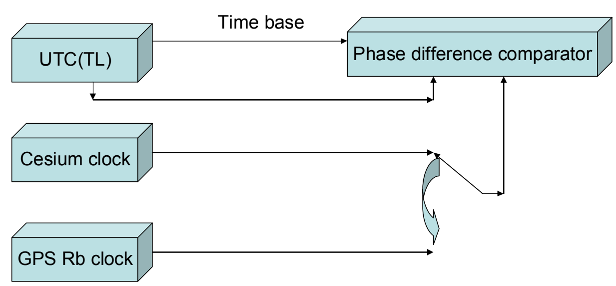


Figure 3. A simplifized diagram for GPS disciplined clock

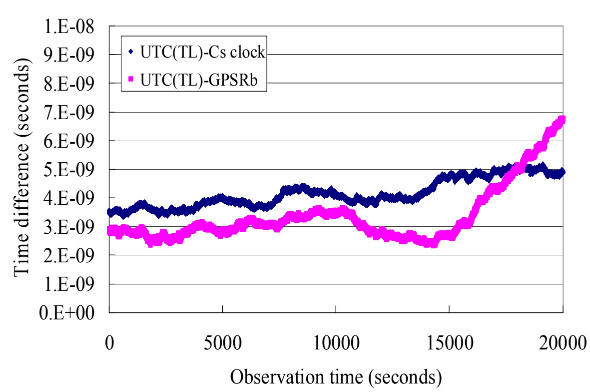


Figure 4. Inside labotory test of tested clocks.

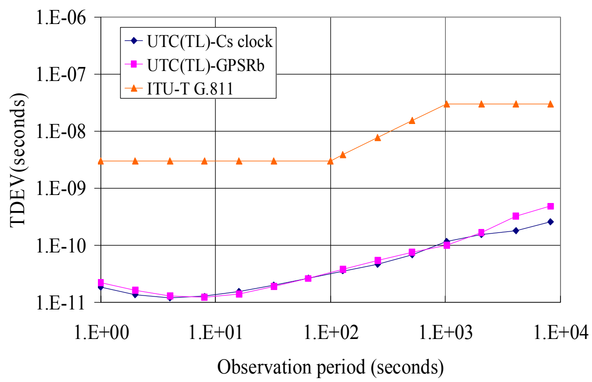


Figure 5. TDEV's of Fig. 4.

and data collecting.

## IV. Experimental Results

To verify the performance of tested cesium clock and GPS rubidium clock, a in-laboratory test was performed. A simplified diagram is disputed in Fig. 3 and the coordinated universal time(UTC) of telecommunication laboratories(TL) was utilized as the reference standard. UTC(TL) is a hydrogen maser base time scale steered by a 9-cesium-clock ensemble. A SRS620 counter was used as the phase difference comparator to measure the characteristic between reference

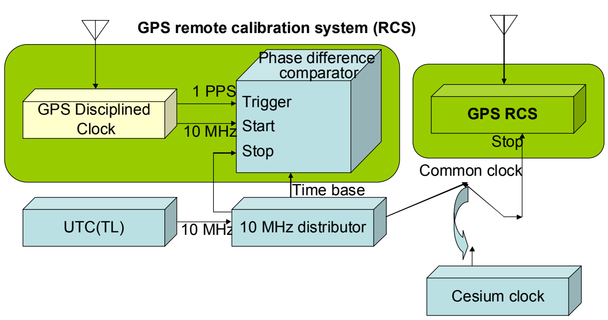


Figure 6. Common clock test an inside labotory test of cesium clock.

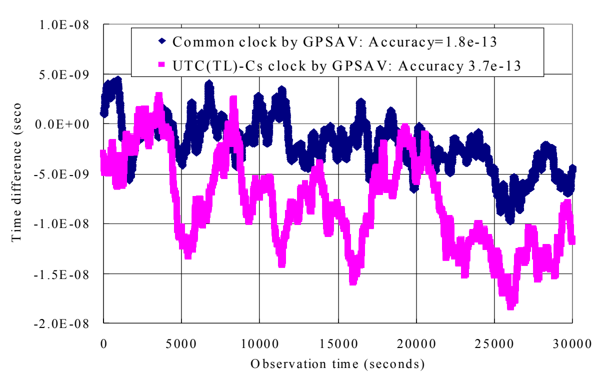


Figure 7. The perfomance of above tests in Fig. 6.

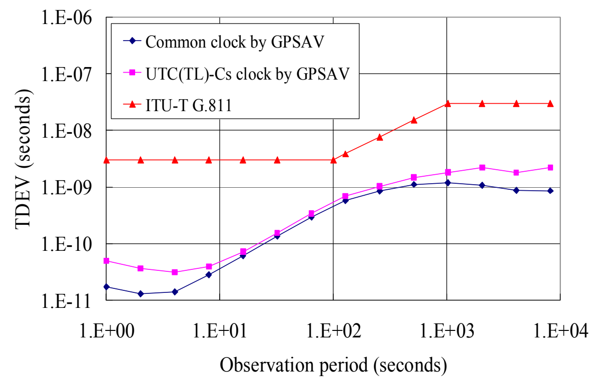


Figure 8. TDEV's of Fig. 7.

standard and test oscillator. The accuracy of the tested cesium clock is $7.5x10^{-14}$ and the value of $2.9x10^{-13}$ is for the GPS rubidium clock as illustrated in Fig. 4. Fig. 5 shows the TDEV's [6] of mentioned test in Fig. 3 and the requirements for ITU-T G.811 [7] are also shown in the same figure. It demonstrates that both tested cesium clock and GPS rubidium clock have better characteristic than the ITU-T G.811 requirements.

A short baseline common clock test and an inside laboratory test by GPS all-in-view are performed. Fig. 6 is the diagram of these tests. The test results are shown in Fig. 7. The accuracy of the common clock test for GPS all-in-view is $1.8x10^{-13}$. The accuracy of the test cesium clock by GPS all-in-view method is $3.7x10^{-13}$. Fig. 8 shows the TDEV's of inside laboratory tests by GPS all-in-view in Fig. 6 and the requirements for ITU-T G.811 are also shown in the Fig. 8, too. It demonstrates that both short baseline common clock test and tested cesium clock have smaller TDEV's than the ITU-T G.811 requirements.

A filed test was arranged as illustrated in Fig. 9. The reference station is located at TL and the time base was UTC(TL). The remote site is at Vanung University(VNU). The distance between reference site and remote site is about 10 km. The environmental condition of remote side was not controlled within 22 to 24 degree C. The performance of the tested cesium clock by GPS all-in-view is depicted in Fig. 10. The accuracy of the test cesium clock is $1.7x10^{-12}$. The

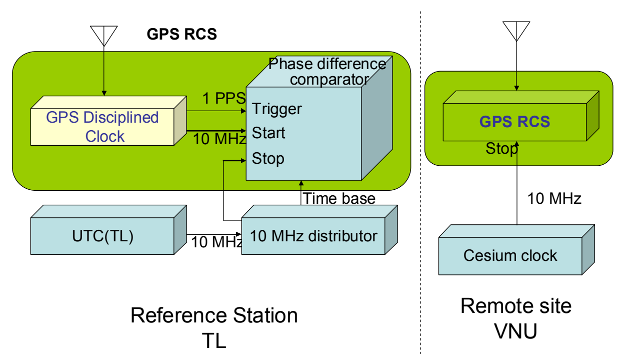


Figure 9. Field test of cesium clock.

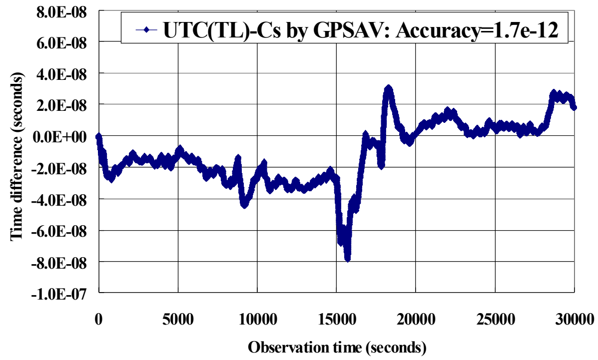


Figure 10. The perfomance of field test in Fig.9.

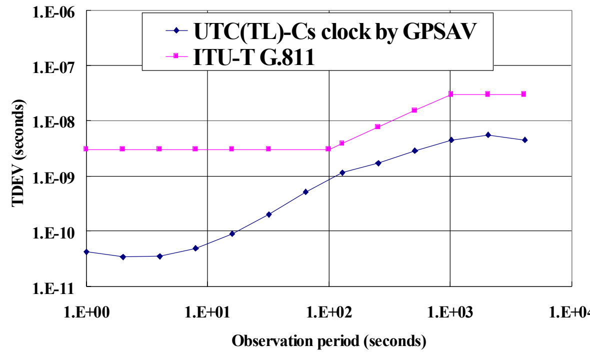


Figure 11. TDEV's of Fig. 10.

TDEV's of this field test are shown in Fig. 11. It illustrates that the tested cesium clock under uncontrolled environment still has smaller TDEV's than the ITU-T G.811 requirements.

## V. Conclusion

A new design of GPS remote time and frequency calibration system is presented. Its hardware was composed with a time interval counter card, a GPS receiving modular and a controller.

A series of test were executed to valuate this system. The short baseline common clock test with hydrogen maser was studied for the system noise level. The direct phase comparison in laboratory, GPS short baseline test in laboratory, and GPS field test within 10km between UTC(TL) and cesium clock were also experimented.

The accuracy and stability of the experimental result of the short baseline common clock with hydrogen maser reached to a few parts of $10^{-13}$ and the TDEV values were 10 times lower than the ITU-T G.811 requirements. The designed system with the capability could be applied for the remote time/frequency calibration and for the monitoring the performance of the primary reference clocks of the digital telecommunication network, too.

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