GPS Time Synchronization

Abstract—GPS technology can be used as an inexpensive, readily available method for high precision timing and measurement of event simultaneity. [1] However, knowledge of the error inherent in the timing and position accuracy of the GPS module being used is necessary for the use of such devices in this capacity. Research has been done on the timing accuracy of a GPS module (Leadtek GPS-953W) as compared to a different baseline module (Motorola UT-Plus Oncore). In this paper we independently investigate the timing and position accuracy of a Leadtek GPS-9543LP receiver by a different method: comparing the signal to that of an identical module.

I. INTRODUCTION

As noted in Berns et al. [1], the Global Positioning System (GPS) provides a method of synchronized tracking that is extremely accessible due to the low cost and easy set up involved. Additionally, due to the nature of the satellite network this system can be used anywhere in the world. The Berns paper measured the error in a Leadtek GPS-953W receiver chip as compared to a different receiver, the Motorola UT-Plus Oncore, which was used as a baseline. This paper will expand on that research by explaining results we obtained independently measuring the error in the timing of the Leadtek GPS-954LP receiver.

GPS SYSTEM:

GPS is a global satellite network consisting of at least 24 satellites maintained by the US Department of Defense (DoD). Each satellite houses an atomic clock and transmits a "GPS time" given according to this clock. Only a small adjustment—the periodic addition of leap seconds—is needed to make this time equivalent to Universal Time Coordinated (UTC). Most GPS receivers make this adjustment automatically, so the time reported to the user is UTC. The satellites broadcast regularly recalculated and updated ephemeredes, so their position in space can be accurately calculated as well. Using this information, a ground-based receiver can accurately track time and triangulate its position provided that there are at least four satellites in view. This effectively provides researchers with an accurate timing system that is a viable alternative to acquiring and constantly recalibrating a set of atomic clocks. [1], [2]

GPS RECEIVER LEADTEK GPS-9543LP:

We used a commercially available GPS receiver, Leadtek Research, Inc. model GPS-9543. This is a 12-channel GPS receiver chip whose small size and low power consumption lends itself to easy integration in a hand-held module or circuit board, such as the set-up we used. The basic specifications of this chip are [3]:

- 1-pulse-per-second (1PPS) signal.
- 3.3 V power requirement.
- Reacquisition time of 0.1 seconds.
- Supports standard NMEA-0183 and SiRF Binary protocol.

Fig. 1. GPS receiver module. [3]

The apparatus we used consists of two antennae connected to circuit boards we designed for the specific purpose of housing the GPS timing chips. Each board includes a pin for antenna power, PPS signal output, ground connection and connection to an oscilloscope. The signal output is sent to a serial port, of which each board has two.

II. TIMING ERROR.

To measure the error in the timing we used an oscilloscope to histogram the difference in the pulses by triggering the signal of one chip off that of the second chip. The below histogram was generated using ~230 thousand hits. The green and black spikes are due to power surges from inclement weather.

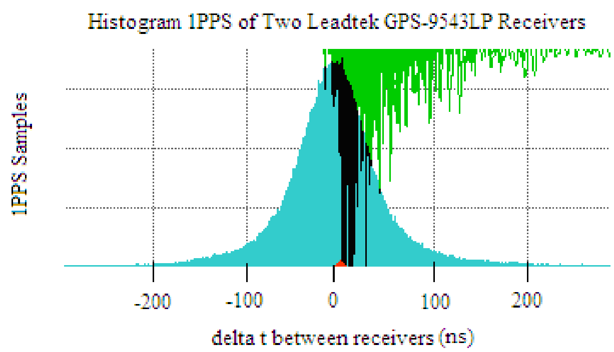

Fig. 2. Histogram of time difference between identical GPS receivers.

The mean of the histogram is -6.086 ns and the standard deviation is 62.703 ns. Early in the measurement process, the mean tended to decrease with time, but it eventually reached a plateau in the -4 ns to -10 ns range. This clearly illustrates that there is a systematic shift in the data. In order to test whether this error was inherent in the receiver, we switched the leads to the oscilloscope. We obtained a similar result, which signifies that the systematic error is indeed inherent in the receiver's timing capabilities. From this result, we can calculate the error in an individual receiver's timing capabilities. Because each chip is independent, we can use $\sigma_{histogram} = \sqrt{2}\sigma_{receiver}$ to obtain a value of $\sigma_{receiver}$ = 44.338 ns.

IV. CONCLUSIONS

The Berns paper [1] found a standard deviation of approximately 45 ns for the histogram of the Leadtek GPS-953W signal versus the Motorola UT-Plus Oncore signal. Since these receivers are not identical, the procedure we used to find the error inherent in one receiver can not be applied. However, assuming the Oncore as a baseline gives an error of ~45 ns for the Leadtek GPS 953W. Our measurement for the error in the Leadtek GPS-954LP is very close to this, suggesting that this module is also a good candidate for use in high precision timing and measurement of event simultaneity.

V. REFERENCES

[1] H. G. Berns, T. H. Burnett, R. Gran and R. J. Wilkes, "GPS Time Synchronization in School-Network Cosmic Ray Detectors," *IEEE Trans. Nucl. Sci.*, vol. 51, no. 3, June 2004.

[2] USNO NAVSTAR Global Positioning System, <http://tycho.usno.navy.mil/gpsinfo.html>

[3] Leadtek GPS 9543 Module (SiRFStarII), <http://www.leadtek.com/gps/gps_9543_1.html>