Effect of Delays in Simulated GPS Signals on the Reacquisition Time of a GPS Receiver

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ABSTRACT

In this study, the effect of delay in a simulated Global Positioning System (GPS) signal on the reacquisition time of a GPS receiver was experimentally analyzed. For this purpose, not only conventional GPS signals but also signal loss and subsequent delay were simulated. The proposed simulator was implemented with a software-defined radio, and the resulting simulated GPS signals were received and processed with a commercial GPS receiver. The results of the experiment show that as the delay increases, the reacquisition time also increases, thus confirming that the delay must remain within 0.5 s to maintain a reacquisition time within the hot start range of the receiver.

Keywords: GPS simulation, reacquisition time, software-defined radio.

1. INTRODUCTION

The recent development of autonomous driving technology has increased the demand for navigation technologies with higher performance. In general, Global Positioning System (GPS) is mainly used for positioning in an outdoor environment with open sky as GPS can provide accurate position information with high availability (Misra & Enge 2011). For environments where the reception of GPS signals is difficult, navigation technologies using various techniques have been studied. For example, long-range navigation (Loran) uses stronger signals from the ground for navigation, making it more robust than GPS (Son et al. 2018). Also, methods generating position solution from the surrounding environment using sensors, such as vision sensors (Kim et al. 2014), ultra-wide band (UWB) radar (Shin et al. 2017), and ultrasonic sensors (Rhee & Seo 2019), have been studied. However, in addition to these studies, studies have been conducted to improve the performance of GPS receivers such as differential GPS (Yoon et al. 2016, Odijk et al. 2017) and GPS receivers with inertial navigation system (INS) (Qi & Moore 2002, Liu et al. 2018).

The performance of GPS receivers comprises not only the accuracy of the navigation solution, but also the speed at which signals can be received and processed. Among the performance metrics, the reacquisition time, i.e., the time to reacquire GPS signals and calculate the navigation solution after a loss of signals for a short period of time, is becoming more important as the possibility of signal loss increases in urban areas due to high buildings and tunnels.

There is no international standard for measuring the reacquisition time of a GPS receiver, and it varies according to the manufacturer. However, it is common to utilize simulated GPS signals to measure the reacquisition time of a GPS receiver as live sky GPS signals are likely to have unknown errors, such as multipath and ionospheric scintillation (Seo et al. 2009), which can affect the acquisition of GPS signals. A GPS simulator can be used to generate GPS signals that are not affected by such errors (Perdue et al. 2015). To measure the reacquisition time of a GPS receiver, a controlled signal loss of a certain period should be implemented. This can

be implemented by physically separating the connection between the receiver and the simulator, such as disconnecting cables or using a controllable attenuator during the simulation, or by simulating the GPS signals, stopping the simulation for a certain period of time, and then simulating the GPS signals again after the signal loss. Then, the time difference between the end of the GPS signal loss and the first position output from the receiver is the measured reacquisition time of that receiver.

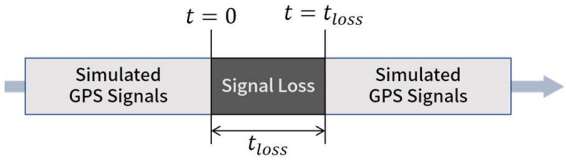
If there is a delay in the simulated GPS signals, the reacquisition time of a receiver may change. To the best of our knowledge, no studies have analyzed the effect of such delay on the reacquisition time of GPS receivers. Therefore, in this work, a GPS simulator that can control the amount of delay after the signal loss is proposed, and the effect of delay in the simulated GPS signals on the reacquisition time is analyzed. The signal loss and delay are implemented by direct manipulation of the baseband binary signals in the simulation process. Then, the baseband binary signals are modulated with a software-defined radio (SDR) platform and transmitted to a commercial GPS receiver to measure the reacquisition time.

2. DELAYS IN SIMULATED GPS SIGNALS

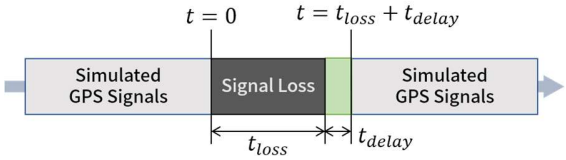
For general use, a GPS simulator receives the desired position and time as the input parameters, then generates simulated GPS signals with respect to these parameters for processing by a GPS receiver. When the simulated signals are received and processed with a GPS receiver, the receiver's clock is synchronized to the desired time of the simulated signals.

To measure the reacquisition time of a GPS receiver via a GPS simulator, the receiver tracks the simulated GPS signals until signal loss; thus, the receiver's clock is synchronized to these signals. However, after signal loss, even if the signals are received again, the receiver's clock is not immediately synchronized because the reacquisition has not yet been done. Herein, we represent the time during the measurement process with respect to the starting point of the signal loss (i.e., $t = 0$ at the start of signal loss).

Fig. 1 illustrates the signals received by the GPS receiver over time in the ideal case where there is no delay after signal loss (Fig. 1a) and the case where there is (Fig. 1b). Ideally, after a signal loss with a duration of $t = t_{loss}$, the GPS receiver will receive the signals that are simulated for $t = t_{loss}$. However, if a delay of t_{delay} occurs in the simulation process after the signal loss, the receiver receives the simulated signals for $t = t_{loss}$ at the time $t = t_{loss} + t_{delay}$. This kind of delay can affect the reacquisition time.



(a) No delay after signal loss



(b) Delay after signal loss

Fig. 1. Signals received by the GPS receiver over time.

3. SYSTEM CONFIGURATION

To examine the effect of delays during the process of measuring reacquisition time, the GPS simulator should be able to control the amount of the delay. Therefore, a GPS simulator that can implement both the signal loss and the delay within the simulated GPS signals is proposed. The signal loss can be implemented by simulating GPS signals with extremely low gain, such that the receiver cannot track the simulated signals. For the delay after the signal loss, empty data are simulated after the signal loss for the desired amount of time.

As such features are not implemented in commercial GPS simulators, the proposed features are implemented with an SDR. The baseband GPS signal generation process is developed based on gps-sdr-sim, an open source GPS simulator software (Ebinuma 2018). After the baseband signal binary file is generated by the modified GPS simulation software, the signals are modulated with the Ettus Universal Software Radio Peripheral (USRP). Then, u-blox EVK-M8T, a commercial GPS receiver, is connected to the USRP with an RF cable to receive and process the simulated GPS signals. Because USRP and the receiver are connected via a wired cable, the simulated signals are not broadcast over air. Finally, the reacquisition time is measured by analyzing the output messages from the u-blox receiver and measuring the time required to obtain the 3D fix.

4. EXPERIMENTAL RESULTS

Based on the system proposed in Section 3, we measured the reacquisition time for the simulated GPS signals with respect to the delay. Fig. 2 shows the experimental results along with the time to first fix (TTFF) specification of EVK-M8T (u-blox 2016). The output rate of the GPS receiver is set to 10 Hz; therefore, the resolution of the measured reacquisition time is 0.1 s. The GPS signals were simulated for the same locations and times, and the range of the delay was 0-1 s with increments of 0.1 s. The duration of the signal loss was set to 30 s. Each configuration was assessed 10 times and the results were averaged.

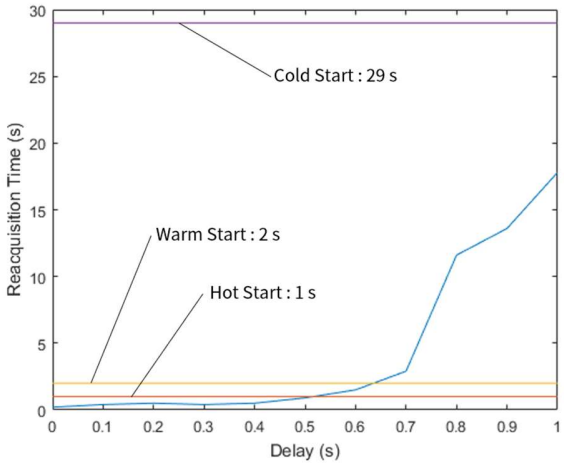


Fig. 2. Reacquisition time for the simulated GPS signals with respect to the delay.

As shown in Fig. 2, the reacquisition time increases as the delays in the simulated GPS signals increase. According to the results, to maintain the reacquisition time in the hot start range, the delay should be maintained at less than 0.5 s.

5. CONCLUSION

In this study, we experimentally analyzed the effect of delay in the simulated GPS signal when measuring the reacquisition time of a GPS receiver. For this purpose, we proposed a simulator that simulates both the signal loss and the delay after signal loss, as well as the conventional simulated GPS signals. The proposed simulator was implemented using modified open-source GPS simulation software and USRP, and the simulated signals were received and processed with u-blox EVK-M8T, a commercial GPS receiver. As a result, the reacquisition time increased with increasing delay, and it is confirmed that the delay should be maintained within 0.5 s to ensure a reacquisition time within the hot start TTFF range of a receiver.

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