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Dynamic Characteristics of High-Rate GPS Observations for Seismology

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High-rate GPS observations, say, higher than 1Hz sampling, are increasingly important in application to geophysics, in particular, to seismology. A number of researches using high-rate GPS data have shown possible ground vibration due to earthquakes. Since GPS is not using pendulum, it can record not only long period seismic wave but also permanent displacements as well as high frequency ground vibration. Therefore, application of high-rate GPS, combined with low-rate GPS, to seismology is expected to provide a new insight in understanding whole aspects of earthquake process.

Ground vibration due to an earthquake includes a wide spectrum of frequencies. Generally, the seismic energy in frequency spectrum decreases toward higher frequency with a corner frequency in several to tens of hertz, depending on earthquake magnitude. Therefore, GPS should be able to acquire tens of hertz to grasp its wide frequency range.

In this study, we investigated dynamic characteristics of the high-rate GPS receivers capable of outputting the observations at up to 50 Hz. This higher output rate, however, doesn't mean higher dynamics range of the GPS observations. Since many GPS receivers are designed for low dynamics applications, such as static survey, personal and car navigation, the bandwidth of the loop filters tend to be narrower in order to reduce the noise level of the observations. The signal tracking loop works like a low-pass filter. Thus the narrower the bandwidth, the lower the dynamics range. Many high precision applications utilize carrier phase measurements, and the typical bandwidth of the phase tracking loop is about 10 Hz. That means the phase observations hardly capture the antenna motion higher than 10 Hz. In order to avoid this limitation, high-rate GPS receivers might use wider loop bandwidth for phase tracking. In this case, the GPS observations are contaminated by higher noise level in return.

In addition to the limitation of the loop bandwidth, higher acceleration due to earthquake may cause the steady state error in the signal tracking loop. As a result, kinematic solutions experience undesirable position offsets. In order to examine those effects of the high-rate GPS observations, we made an experiment using a GPS signal simulator and Trimble Net-R8 receivers. We set up the kinematic navigation simulation in which the rover receiver is set on the perimeter of the circle with 1m of diameter and the reference station is set at the center of the circle. The rover receiver rotates along the circle with 2Hz in period. This gives about 4G acceleration toward the center of the circle to emulate a high frequency and high acceleration earthquake motion. The simulation results suggested that the position fix solutions were obtained nearly 100% in case sampling rate is 10Hz or lower. On the contrary, if the sampling rate is 50Hz, rate of position fix became less than 70%.

Our experiment suggested that, in the given environments and receiver sets, 10Hz or less sampling interval is recommended to track the ground motion in significant reliability, though the result is still preliminary. Implementation of 10Hz-sampled GPS data in seismic network may be recommended in the present status. We will further continue experiments and find more conclusive results for suitable arrangements in high rate GPS observation.