ISAP 2008
International Symposium on Antennas and Propagation
27 – 30 October 2008, Taipei, Taiwan
Taipei International Convention Center

Monitoring Flooding Water level on Lan-Yang River by Using Reflected GPS observations during storm weather of typhoon SEPTA, 2007/08/18

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Abstract

In this paper, the application and development of a highly integrated GPS receiver that employs reflected GPS signals for ground object detection and flood flow is described. Both right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) antennas are employed so that the direct and reflected signals can be simultaneously obtained. The objective of this study is to use the carrier phase and the compensation of ionospheric delay & tropospheric delay of the reflected and direct signals for the floodwater, surface soil moistures of riverbeds. During the development and test stage, the satellite's image, Precipitation and IR image of typhoon SEPTA are used and mapped with integrated software. The moving surface of floodwater at each instant is reflected by the carrier phase of the GPS signal reflected and the reflection point at that instant. With regard to the monitoring and forecasting of coastal flood tide height, floodplain, and floodwater levels, the reflection heights are accurate to within 30 cm

Keywords: Flood, Water level, Soil moisture, Global Positioning System

1. Introduction

A reflected GPS signal contains information on the reflecting object since the characteristics of the reflected signal vary considerably depending on the reflecting object. In this study, our objective is to determine the reflectivity of rivers and riverbeds with a rough surface and soil moisture [1], respectively, by using observations of the GPS L1 and L2 frequencies that are received with a highly integrated GPS receiver. Both RHCP and LHCP antennas are employed for monitoring riverbeds and rivers so that the direct and reflected signals can be simultaneously obtained for studying the soil moisture of riverside [5]. The direction of arrival of the signals may be that of the reflected signal or the line-of-sight of a particular satellite. The objective of this study is to use the carrier phase of the reflected signals and direct signals for the detection of flood water levels and soil moisture of riverbeds. An integer ambiguity algorithm has also been implemented for accuracy positions and the standard deviation of height on reflected floodwater or riverbed conducts roughness effect parameter and correction for classification of water or soil moisture. During the development and test stage, the satellite's images are used and mapped with the integrated software for ground object detection. In this measurement connection, the measurement for monitoring stream water level, soil classification of riverbed and ground object detection can be found in a related conference paper in [4].

2. METHODS

2.1. Ground Height Estimation

The RHCP and LHCP fixed position cause different altitude for same observation point when the mean of ground altitude is subject to estimated ground altitude of reflected area for each satellite [2]. Then, altitudes of RHCP position and LHCP position conduct the ground altitude. The height of the bridge is 10.5 m (from the bridge floor to the bridge pier). The altitude of the bridge floor is 11.25 m with regard to the ground sea level (shown in Fig. 1). In Fig. 1, a reflected point on the surface of a flowing stream is shown, and the line of sight between the satellite and the RHCP/LHCP receiver position is observed to be sloping. the authors use the GPS data for H^{i}_{RHCP} and H^{ti}_{LHCP} for the subtraction as well as the DTED level 2 (~30 M per pixel) mapping of $h_{undulation}$ [5]. The value of $h_{undulation}$ is provided from the output of the GPS solution tool in the GPS receiver to Note Book (control log command: BESTPOSITION). Thus, the local ground or water surface altitude is described by (1).

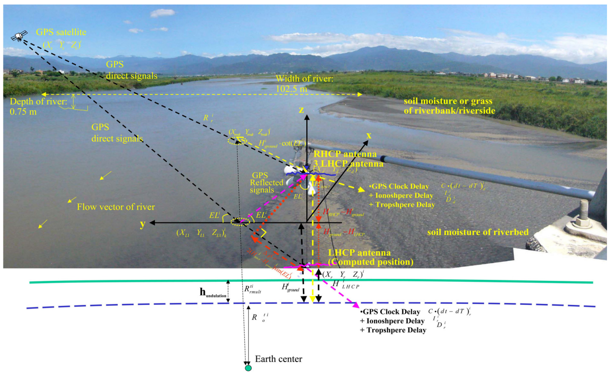

Fig. 1. Three LHCP antennas and one RHCP antenna set up on the 6.5-m pipe over the stream water surface at Lan Yang, Taiwan, on a sunny day

$$H^{i}_{ground} = \frac{(H^{i}_{RHCP} + H^{i}_{LHCP})}{2} - h_{undulation} \qquad (1)$$

Estimation of the reflection point is important software simulation process. The reflection point depends on the signal propagation path and propagation angle. As the positions of the antenna and satellite can be computed, the reflection point is constrained to the plane established by the two positions and the geocenter. In the determination of the reflection point, special care is exercised to estimate the altitude as one of the objectives is to estimate the ground object height through the processing of reflected signals.

2.2. Compensation for GPS ionospheric delays and tropospheric delays

Let us recall that GPS satellites broadcast signals at L1 and L2 frequencies. Let f_1 and f_2 and λ_1 and λ_2 be the frequencies and wavelength of L1 and L2, respectively. It is known that dual frequency measurements can be used to effectively ionospheric delays and tropospheric delays measurements at the two frequencies can be expressed as in Goad [3][4]

$$I_s = (f_2^2 / (f_1^2 - f_2^2))\left[\phi_{1s} + \phi_{2s} - (\lambda_1 N_{1s} + \lambda_2 N_{2s}) - (\varepsilon_{\phi 1s} + \varepsilon_{\phi 2s})\right] \quad (2)$$

$$\begin{aligned} D_s = {} & (f_2^2 / (f_1^2 - f_2^2))\left[(\phi_{1s} - \lambda_1 N_{1s} - \varepsilon_{\phi 1s})\right] - \\ & (f_2^2 / (f_1^2 - f_2^2))\left[(\phi_{2s} - \lambda_2 N_{2s} - \varepsilon_{\phi 2s})\right] - (R_s + C(dt - dT))_s \end{aligned} \quad (3)$$

Here, ϕ_{1s}, and ϕ_{2s} are the phases at the L1 and L2 frequencies, respectively. The subscript s is used to represent either the direct (d) signal or the reflected (r) signal. The terms on the right-hand side of (2)–(3) can be explained as follows. $c(dt - dT)_s$, the satellite clock time delay; I, the ionospheric delay for the L frequency; D, the tropospheric delay; N_{1s}, the integer ambiguity at the L1 frequency; and N_{2s}, the integer ambiguity at the L2 frequency. The remaining terms ε_{p1s}, $\varepsilon_{\phi 1s}$, ε_{p2s}, and $\varepsilon_{\phi 2s}$ represent noise. The Compensation for ionospheric and tropospheric errors is processing during storm weather typhoon SEPTA. Since dual frequency receivers are used, processing the dual frequency measurements can compensate for ionospheric errors. The tropospheric error is corrected using a tropospheric delay model. For this estimation, the integer ambiguities at L1/L2 band, ionospheric & tropospheric delaies and propagation angles for each satellite were reserved for enhanced height of ground estimation model.

3. MEASUREMENTS AND RESULTS

In this section, the results of field experiments will be presented.

3.1 Reflected Points Results

The measure and altimetry elevation for Stream flow, ground surface through out the reflected GPS signals at different location was described. So that the reflected area of river, riverside (bare soil) and riverbed (soil moisture) on Lan-Yang Bridge on Lan-Yang river, Yi Lan, Taiwan was made and described (was showed as Fig. 2) with the results. The reflection area and

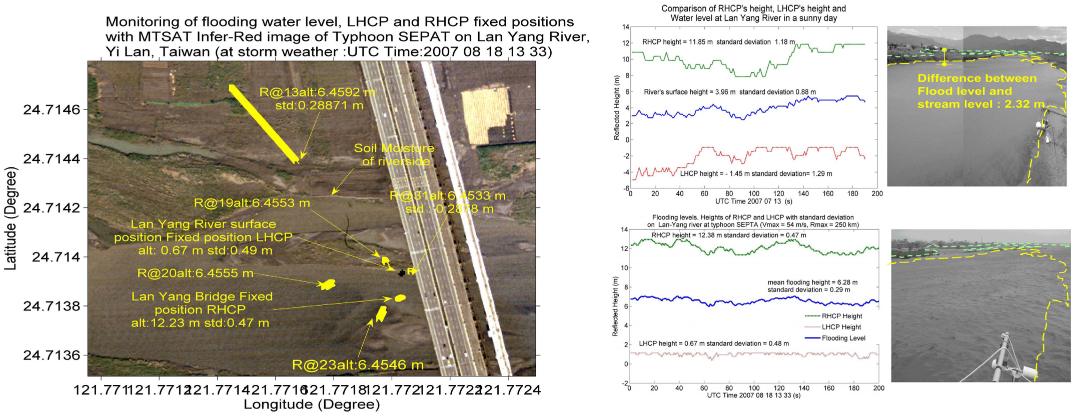

Fig. 2. The reflection area and receiver positions along with their estimated altitudes on Lan-Yang Bridge, Yi Lan, Taiwan during storm weather. The difference of stream level and flood water level (during storm weather: typhoon SEPTA 2007/08/18) is 2.32 m .

receiver positions along with their estimated altitudes on Lan-Yang Bridge, Yi Lan, Taiwan. The water level for PRN 19, PRN 20, PRN 23, and PRN 31 are amount to 6.45 m and 6.46 m, standard deviation for water level are range 0.28 m. The ground height for soil moisture of the riverbed PRN PRN 13 is amount to 6.46 m and 6.47 m, standard deviation for soil surface of riverbed is range 0.29 meter. Flood water level is $6.45\text{m} \pm 0.28\text{m}$ during the storm weather (typhoon SEPTA 2007/08/18) and the stream water level is $3.96m \pm 0.88m$ on a sunny day (2007/07/13) in Lan-Yang River, Yi Lan, Taiwan. The difference between two levels is $2.32m \pm 0.28m$.

3.2. Signals Analysis Results

Fig. 3. shows as comparisons of monitoring flooding of Lan-Yang River, RHCP, LHCP position and Precipitation at storm weather of typhoon SEPAT. Comparison of IR image for typhoon SEPTA, Flooding water level, RHCP, LHCP height. (UTC Time: 2008 08 18 13 33). The IR image and precipitation during typhoon SEPTA is from typhoon database of Taiwan Central Weather Bureau. The Radius of SEPTA is 250 km and Pressure of SEPTA is 960 hPa. Figure. 3. predicts and shows as the differences between tropospheric delay for PRN 13 of RHCP and tropospheric delay for PRN 19 of LHCP are range 1.856 ~ 2.419 m and 6.234 ~ 6.248 m. Then, the differences between tropospheric delay for PRN 13 of RHCP and tropospheric delay for PRN 13 of LHCP are 10.1 ~ 11.6 m. the differences between tropospheric delay for PRN 31 of RHCP and tropospheric delay for PRN 31 of LHCP are 8.32~ 9.80 m. The tropospheric delay for PRN 23 of RHCP and tropospheric delay for PRN 23 of LHCP are range －5.35 ~ －6.80 m and 4.80 ~ 4.86 m across precipitation of Yi-Lan area at an instant. Rain of precipitation: 40 mm and accumulated precipitation: 250 mm.

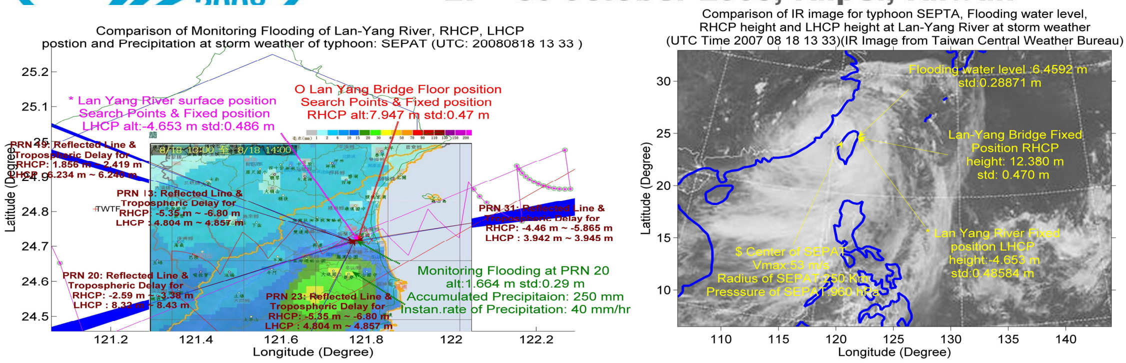

Fig. 3. Comparison of monitoring flooding of Lan-Yang River, RHCP, LHCP position, IR image for typhoon SEPTA and Precipitation at storm weather of typhoon SEPAT. (UTC Time: 2008 08 18 13 33)

4. CONCLUSION

The results of this study demonstrate the usefulness of the ground height estimation model in estimating the altitude of the floodwater, river water, riverside, and riverbed rapidly and with a high accuracy. The study has shown that the accuracy performance of the developed algorithms is robust with respect to the GPS L1/L2 signature distributions for the river water, riverbank, and riverside. This algorithm can be used for obtaining the reflectance spectra by monitoring the flood level in storm weather. This paper can guarantee optimum performance in monitoring high accuracy (standard deviation = 0.28 m; approximately 45~50% of improved accurate of water level) flood water level in storm weather, rough surface of riverbed by using instant GPS ionospheric delay and tropospheric delay correction model and the correction of undulation height.

Acknowledgments

The authors would like to thank Mr. C. H. Chen for his help with the GPS observations during storm weather. The authors also thank Dr. Wickert and Dr. Georg Beyerle for their suggestions and assistance with the instantaneous ionospheric delay and tropospheric delay effects in real-time weather data and for sharing their research method during the author's visit to GFZ, Berlin, in 2007

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