

## Soil moisture estimation using low-cost GPS multipath receiver.

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GPS is a very useful tool for providing global position information on the earth. The GPS receiver identifies its position by receiving the electromagnetic waves emitted from the GPS orbiting satellite. However, the GPS receiver receives not only the direct electromagnetic wave but also the reflected wave at the ground, so this multipath affects the receiving accuracy. Since the transmitted radio waves of GPS satellites use electromagnetic waves in the 1GHz band, when reflected off the ground, if there is a place with a lot of water, the reflected wave will be delayed based on the amount of soil moisture. Therefore, we employed low-cost GPS receiver and the satellite's signal to noise ratio (SNR) data is extracted from the NMEA sentence output from the receiver to find fluctuation of the SNR which is affected by the multi-path signal. First, satellite number and travel direction (ascending or descending) were selected because only three or four satellite could be used for the analysis and each satellite had its own characteristics of the multipath noise. We chose #7, 28 and 30 for our analysis. Theoretical superposition of waves gave the SNR oscillations with the angle shift at the SNR peaks and also the peak value. The relationship between the elevation angle of the satellite and SNR was plotted on the graph to figure out how phase shift or SNR peak were affected by soil moisture. However, only the change of the SNR peak value was observed with our low-cost system. When the peak of SNR oscillation and the soil moisture were plotted, a positive proportional relationship was obtained, and the RMSE was about 3%. It had the similar accuracy as TDR, regardless fine or cloudy weather, probably because the reflection near the ground was the targeted area. Also measurement area of several to tens meter is appropriate for the field measurement in Asian country where land use changes in relatively small scale. Although, effective calibration will be needed, our preliminary experiment showed the possibility of soil moisture measurement by low-cost GPS multipath receiver.

Keywords: GPS, multipath, soil moisture