Combining Pseudorange, Carrier Phase and Doppler GNSS Measurements for Multipath Mitigation

Mohamed SAHMoudi* and Khairol Amali AHmad*
* Dept. of Electronics, Optronics and Signal Processing, Institut Supérieur de l’Aéronautique et de l'Espace (ISAE), Université de Toulouse, Toulouse, France
Tel: +33 (0)5 61 33 8955 – e-mail: mohamed.sahmoudi@isae.fr

ABSTRACT

Nowadays, there have been increasing demands for robust positioning and navigation in urban and indoor environments. In meeting these demands, filters are being designed to take advantage of the carrier phase measurement for reducing the noise in the pseudorange measurement because of the complementary advantage between the pseudorange and carrier-phase measurements. This is the principle of carrier-phase smoothing [1]. Nevertheless, while the noise in the measurement for the navigation solution was reduced, the effect of multipath was not being reduced as much due to the biased nature of the multipath signal on the pseudorange, which means that the operation of averaging is not efficient to combat multipath. In mobile and urban applications, frequent signal outages do occur. This will cause a ‘cycle slip’, where all of the smoothed pseudorange information will be lost, and the accuracy of the pseudorange will revert back to be the same as the unsmoothed one. Another persisting condition is that, the time constant of the filter had to be limited because the ionospheric phase advance has a different sign from the pseudorange ionospheric delay. This situation leads to a condition where, while a longer time constant will better reduce the multipath effect, it will also introduce a contradictory effect in a form of ionospheric bias in the smoothed measurements [2, 3, 4].

It has been proven that the Doppler smoothing technique is better than the carrier-phase smoothing when dealing with cycle slip in severe multipath environments [5]. However, the carrier-phase smoothing provides better accuracy than the Doppler smoothing whenever in an environment where there is no cycle slip problem. Facing with these challenges of multipath, cycle slip and ionospheric divergence, the combination of carrier-phase smoothing and Doppler smoothing techniques has been considered to be a very promising approach in improving the GNSS robustness.

Hatch filter has been well known for processing the carrier-phase smoothed pseudorange. However, there had also been several other filters which had been used for the same purpose such as the complementary filter [6], and the Kalman filter [7]. Combining pseudorange and carrier-phase measurements by the Kalman filter opens up potential flexibility in the processing approach. However, some adaptation has to be made to the Kalman filter algorithm since its theoretical foundation is based on Gaussian white noise, whereas in multipath environments, the noise is colored.

One approach in modeling the colored multipath noise for Kalman filtering is by using the first order gauss-markov process. Then, we use the state-vector augmentation technique on Kalman to handle the colored noise.

In the literature, it is not yet documented any comparative study between existing carrier smoothing measurements combination methods. Therefore, the objective of this paper is to analyze the performance of these approaches in realistic multipath environments. The first part of the paper briefly reviews the considered algorithms; Hatch filter [1] and Kalman filter with the state-vector augmentation for colored noise [7]. The second part shows their results in different situations. In the third part, we use a statistical model for the GNSS urban channel and derive the corresponding Kalman combination filter.

REFERENCES


