Mitigation of Standing Multipath Based on Time-Frequency Analysis and Adaptive Filtering

Jiying Liu*, Bo Chen, Chao Xu, and Xiaojun Duan
Department of Mathematics and Systems Science, College of Science,
National University of Defense Technology, Changsha, P. R. China.
*Corresponding author: gene0572@163.com

Background

Geostationary Earth Orbit (GEO) satellites have been widely used in satellite navigation systems such as Beidou and some augmentation systems of GPS. Because GEO satellites are almost stationary relative to the earth, some multipath signals are varying very slowly. This feature will cause the so called "standing multipath" [1], which can dramatically decrease the accuracy of positioning. Multipath errors are related to the characteristics of the signal, the processing method in the receiver, the antenna and signal receiving scenario. These complex factors make it quite difficult to eliminate the multipath errors.

Some approaches combined by radio frequency (RF) and post-processing methods have been proposed to mitigate the standing multipath errors. For example, a code noise and multipath (CNMP) monitor is proposed to reduce the error on the measurements in Wide Area Augmentation System (WAAS) [1]. However, It still remain some shortages.

Main Works

- We use a novel Data-Driven Time-Frequency Analysis (DDTF) method [2] to model the characteristic of the standing multipath errors.
- As an improvement of CNMP monitor, we have proposed a coefficient-adaptive filter. The coefficients of this filter are estimated according to the modeling of the standing multipath errors.

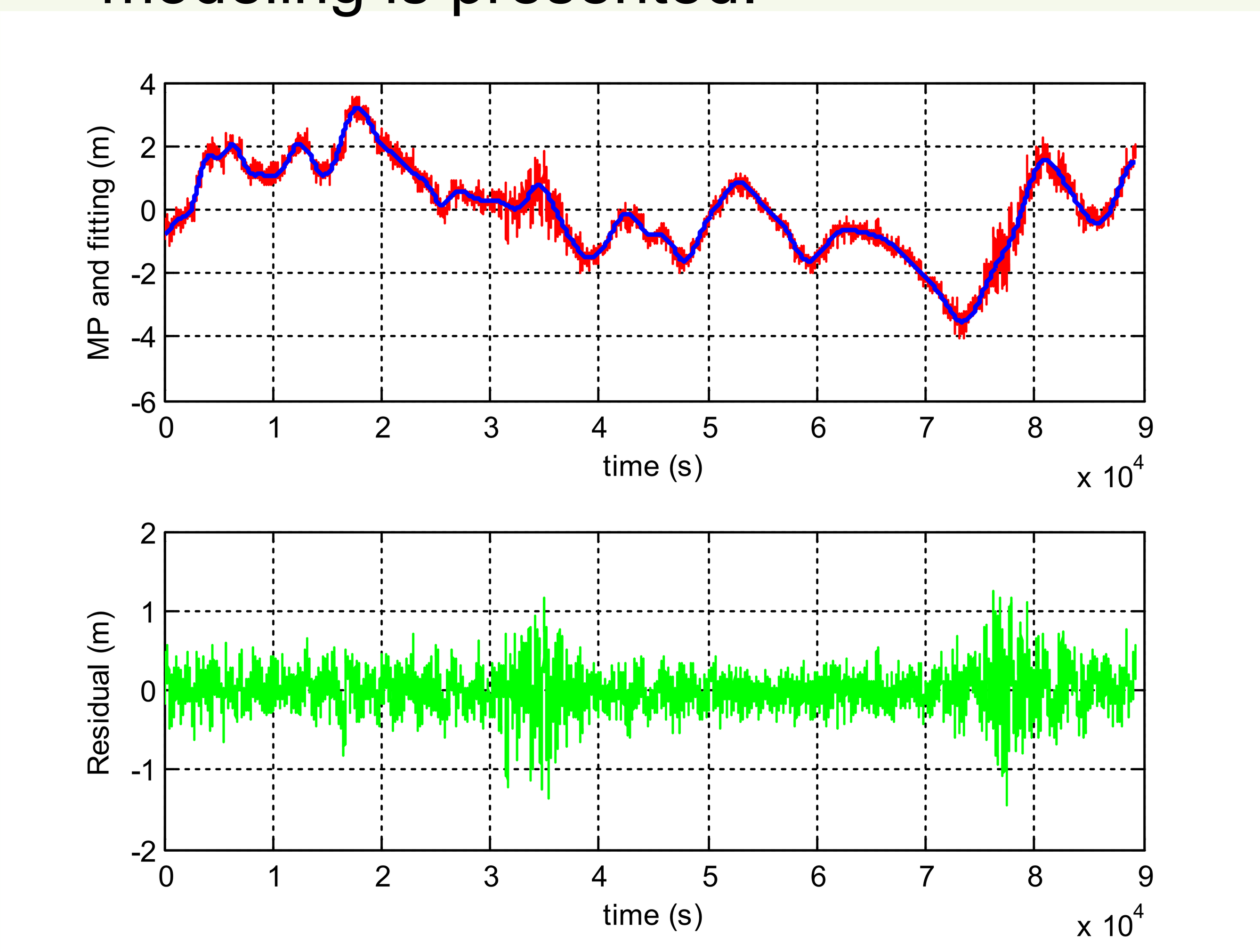
Time-Frequency Analysis

We use the measurements from the two GEO satellites in Japanese Multi-functional Satellite Augmentation System (MSAS), and analyze the Code-Minus-Carrier (CMC). However, the MSAS only transmit single-frequency signal, So the CMCs is the multipath error without ionospheric correction.

Japanese MSAS GEO Satllites L1 C/A measurements

File name	beginning (week：second)	ending （week：second）
data_20110112	1618:271792	1618:361103
data _20110114	1618:463967	1618:530022
data _20110115	1618:555260	1619:39805

This figure shows the modeling of one of the GEO signal CMCs by DDTF method. On the upper subfigure, the red curve is the original CMCs and the blue curve is the modeled one. On the bottom one, the residual of modeling is presented.



These results have inspired the construction of the adaptive filter to mitigate the multipath in GEO code measurements better.

Adaptive Filtering

The CNMP monitor in [1] is acting as:

$$CMCB(t_1) = C(t_1) - \Phi(t_1);\ CMC(t_1) = 0$$

$$CMCB(t) = CMCB(t-T) + \frac{1}{N}\left(C(t) - \Phi(t) - CMCB(t-T) - \delta\Delta I(t)\right)$$

$$CMC(t) = C(t) - \Phi(t) - \delta\Delta I(t) - CMCB(t)$$

where $\delta\Delta I(t) = \Delta CMC(t) - \Delta CMC(t-T)$

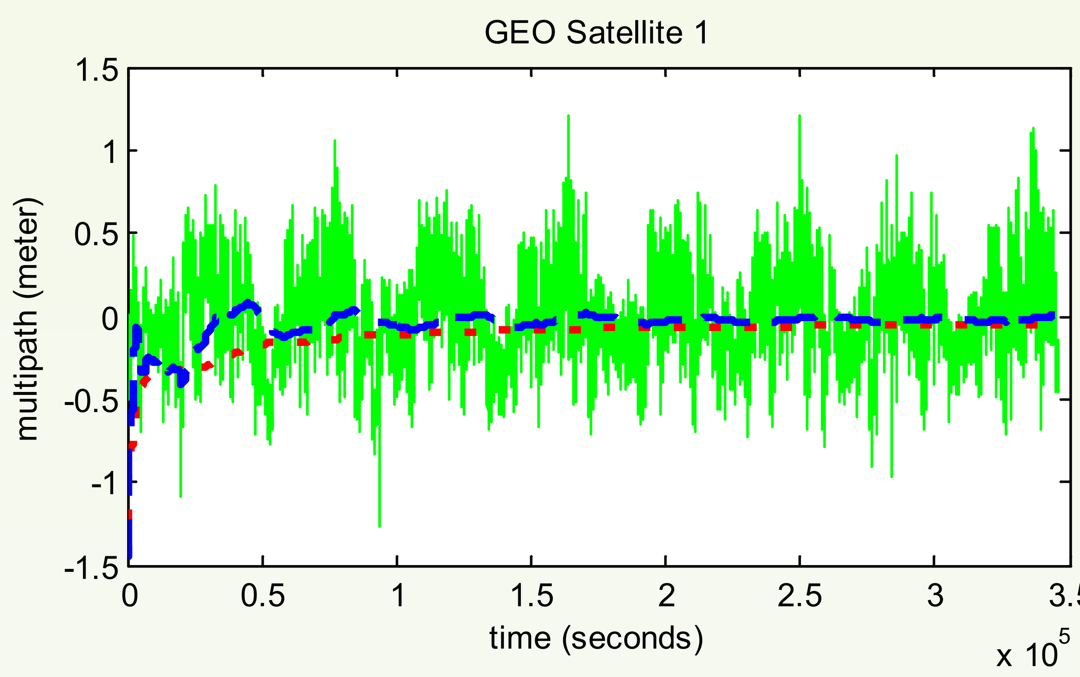
From the formulas, we can see that they actually formed a filter with constant coefficients. According to our analysis of the standing multipath, this filter may not work very well, because the characteristics of the multipath is time-varying.

With the modeling by DDTF, we have proposed a adaptive filtering for mitigation of standing multipath. The main iteration of our filter is:

$$M_{k+1} = \alpha M_k + (1-\alpha)(C_k - \Phi_k - tec_k)$$

where the coefficient α is calculated from the DDTF analysis.

This figure shows the results of the proposed adaptive filter. The green curve is the multipath. The blue line is the residual processed by CNMP method. The red curve is the residual of the improved filter.



Conclusion

- The DDTF method can model the standing multipath of the signal from GEO satellites well.
- Our proposed adaptive filtering whose coefficient is calculated from DDTF can significantly eliminate the standing multipath.

References

1. *F. Grass, Wide Area Augmentation System Research and Development, Report 2004.*
2. *T. Hou, and Z. Shi, Data-Driven Time-Frequency Analysis, arXiv: 1202.5621v1.*

The authors would like to thank Prof. X. Cui at Tsinghua University in China for providing us MSAS Data. This work is supported by the NSF of China (60974124), the PNCET in China, the key lab open foundation for Space Fight Dynamics technique (SFDLXZ-2010-004).