MULTIPATH FILTERING IN THE SPACEBORNE ENVIRONMENT: SIMULATION STUDY

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Introduction

Low-cost spaceborne GPS positioning applications will not use extensive GPS hardware to mitigate the multipath effects. To achieve unbiased position solutions, multipath effects have to be reduced in the processing software. Spaceborne multipath simulation studies will demonstrate some of the multipath characteristics. Hatch-type filtering with different weighting schemes can reduce C/A-code multipath effects.

Multipath Effects

Multipath refers to a phenomenon whereby a signal reaches an antenna via two or more paths. Typically, an antenna receives the direct signal and one or more of its reflections from objects in the vicinity of the antenna.

Impact of multipath depends on:

- Amplitude of the reflected signal relative to direct signal.
- Delay of the reflected signal relative to direct signal.
- Phase of the reflected signal relative to direct signal.
- Rate of change of the relative phase of the two signals.

Methodology

GPS Positioning

Position estimates of the CHAMP satellite, computed with the University of New Brunswick GPS single-receiver positioning package have been used.

Simulated Multipath Measurements

To simulate the multipath effect on the code range a non-coherent dot product discriminator was assumed in the analysis. For this discriminator, multipath error due to a single dominant reflector was computed. For nearby reflectors (multipath error < 30 m for the C/A-code) it was assumed that the multipath error is much smaller than the chip width. Antenna gain pattern and signal polarization were not taken into consideration.

Hatch-type Filtering

Carrier smoothing of code multipath and noise, Hatch [1982]:

$$\hat{M}_{CA_t} = w_a M_{CA_t} + w_b(\hat{M}_{CA_{t-1}} + M_{\Phi_t} - M_{\Phi_{t-1}}),\quad \hat{M}_{CA_1} = M_{CA_1}$$

Where:

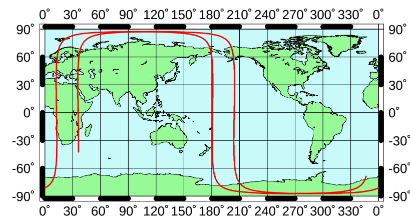
M_{CA_t} is the C/A-code multipath plus noise,

M_{Φ_t} is the L1 carrier-phase multipath plus noise,

w_a, w_b are weighting coefficients.

Data Description

Low Earth Orbiter Groundtrack (3 hour sample)



Orbit Parameters

semi-major axis = 6823.287 km
eccentricity = 0.004001
inclination = 87.277 deg
rev/day = 15.40
|velocity| ≈ 7.5 km/s

Data Availability

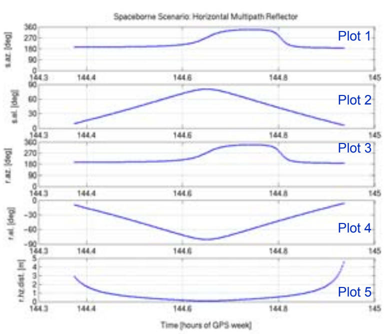
Observations start:
0:00:00 UTC 5 Jan 2002

Observations end:
23:59:50 UTC 5 Jan 2002

Observation interval: 10 seconds

Multipath Simulation

Multipath Geometry



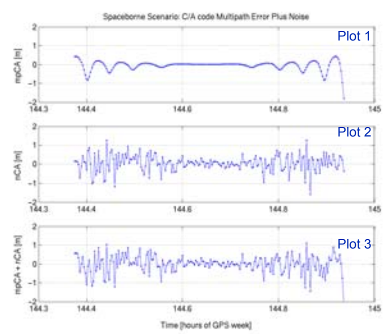
Multipath Simulator Inputs:
- Direct signal elevation angle (Plot 1).
- Direct signal azimuth angle (Plot 2).

Multipath Simulator Parameters:
- Height of antenna above the reflection surface = 0.5 m.
- Reflection coefficient = 0.5.

Plots show one arc of 203 epochs of PRN 2.

Plot 3: Reflected signal azimuth.
Plot 4: Reflected signal elevation.
Plot 5: Reflection point antenna phase centre horizontal distance.

C/A-code Multipath Plus Noise



Plot 1: Simulated C/A-code multipath time series.

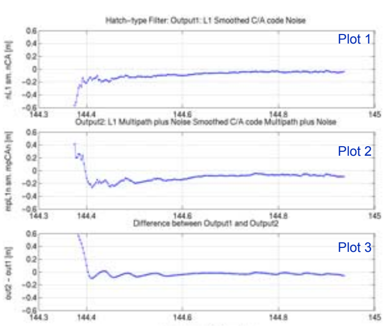
Plot 2: Simulated C/A-code noise time series: white noise with standard deviation of 50 cm, scaled by elevation angle.

Plot 3: Simulated C/A-code multipath plus C/A-code noise time series.

Filtering Process

Weighting Scheme 1

$$w_a = 1/M,\ w_b = (M-1)/M$$



Where M is the number of epochs in the filter.

Plot 1: Filtered C/A-code noise time series.

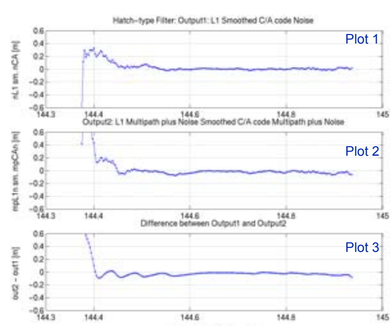
Plot 2: Filtered C/A-code multipath plus noise time series.

Plot 3: Effect of the C/A-code multipath on the filter. Difference between plots 1 and 2.

Comments:
- Convergence to near 0 mean takes about 15 minutes.
- Filter divergence at the end of the filtering interval is about 5 cm.

Weighting Scheme 2

$$w_a = w_1/(w_1 + w_2)$$
$$w_b = w_2/(w_1 + w_2)$$
$$w_1 = 1/\sigma^2(n_{CA_t})$$
$$w_2 = 1/(\sigma^2(\hat{n}_{CA_t}) + 2\sigma^2(n_\Phi))$$



Plot 1: Filtered C/A-code noise time series.

Plot 2: Filtered C/A-code multipath plus noise time series.

Plot 3: Effect of the C/A code multipath on the filter. Difference between plots 1 and 2.

Comments:
- Convergence to near 0 mean takes about 6 minutes.
- Filter divergence at the end of the filtering interval is about 2 cm.

Conclusions

Hatch-type filter with weighting scheme 2 performs better than the Hatch-type filter with weighting scheme 1.

Alternative multipath mitigation techniques
- Fixed-length filter,
- Multipath de-weighting,
- Spectral analysis-determined multipath frequency removal.

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ENV#14

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