Assessing the Compatibility of Microwave Geodetic Systems

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Overview

• Examine the compatibility of VLBI and GPS systems by comparing clock and atmospheric delay estimates from the two systems
• Data Analyzed:
  – End of the CONT96 VLBI experiments
  – Additional 20 global stations used in GPS analysis
Analysis Technique

• VLBI: CALC+SOLVK Kalman filter
  – Clock process noise consistent with $10^{-14}$ Allan standard deviation at 1000 seconds; Quadratic terms removed a priori.
  – Atmospheric process noise: Derived from delay-rate variance: Typical random walk values 10 mm/sqrt(hr); variations of factor of three about this value
  – Constant zenith delay based on station height and zero water vapor
Analysis Technique

• GPS: GAMIT program
  – Clocks estimated epoch-by-epoch relative to Fairbanks/Gilcreek clock
  – Phase clocks aligned with clocks from pseudo-range estimates
  – Atmospheric delay estimated with piece-wise linear function with nodes every 2-hours. Stochastic noise 20 mm/sqrt(hr)
  – Constant a priori zenith delay.

Some effects that might be expected: Clock effects

• GPS is controlled by 10.23 MHz oscillators
• On the Earth’s surface these oscillators are set to 10.23x(1-4.4647x10^{-10}) MHz (39,000 ns/day rate difference)
• This offset accounts for the change in potential and average velocity once the satellite is launched.
• The first GPS satellites had a switch to turn this effect on. They were launched with “Newtonian” clocks
Corrections terms

- Propagation path curvature due to Earth’s potential (a few centimeters)

\[ \Delta t = \frac{2GM}{c^2} \ln \left( \frac{R_r + R_s + \Delta R}{R_r + R_s - \Delta R} \right) \]

- Clock effects due to changing potential

\[ \Delta t = \frac{\sqrt{GM}}{c^2} e \sqrt{a} \sin E \]

- For \( e = 0.02 \) effect is 47 ns (14 m)

Relativistic Effects (SA off)

50 ns = 15 m

PRN 03 Detrended; \( e = 0.02 \)

Clock error (ns)

Time (hrs)
Comparisons

- Atmospheric delays:
  - Easiest comparison because apriori zenith delay chosen as constant and the same apriori used for VLBI and GPS
- Clocks:
  - Clocks are more difficult to compare because:
    - No absolute standard for either system (show clocks relative to Fairbanks/Gilcreek)
    - VLBI has different quadratic removed each day. Clocks relative to ensemble
    - GPS also referred to Fairbanks. Only linear trend removed each day.

Fairbanks Atmospheric delays
Zoom Wettzell (Sept 30-Oct 2)

KOKEE Atmosphere
NyAlison Atmosphere

Zoom of NyAlison (Sep 30-Oct 2)
Clock comparisons

- Clock comparison are “complicated” by the removal of trends from VLBI results (can be corrected but currently time-consuming).
- Absolute offsets can not be compared because of VLBI group delay ambiguities; the GPS alignment of phase and range; unknown delays in VLBI and GPS electronics
- Examine difference of Wettzell and Fairbanks clocks

Wettzell-Fairbanks comparison

- Green GPS; Brown VLBI
- Linear trends removed each GPS day
- Linear and quadratic (apriori) from VLBI each day
- "Quadratic" in VLBI probably due to apriori quadratic in VLBI analysis
Wettzell-Fairbanks with VLBI quadratic removed

Likely phase connection problem in GPS

Not clear why difference in behavior; GPS shows atmospheric delay fluctuation not seen in VLBI estimates (separation problem?)
Conclusions

• Initial study of comparison between VLBI and GPS clock parameters and atmospheric delay estimates.
• Initial results indicate that clocks are comparable quality (no smoothing in GPS)
• Next steps:
  – Accounting for clock rates and accelerations applied to VLBI
  – More consistency in mapping functions and gradients
  – Effects of model changes in GPS (antenna phase centers) on clock comparisons
  – Time dependent process for GPS atmospheres (validation using VLBI data)
• Possible use of GPS atmospheres and clocks in the analysis of VLBI?