12.540 Principles of the Global Positioning System
Lecture 14

Prof. Thomas Herring

Propagation Medium

- Summary
  - Paper topics from those not yet submitted
  - Review homework #1
  - Homework #2. Due April 17, 2002
- Propagation:
  - Signal propagation from satellite to receiver
  - Light-time iteration
  - Basic atmospheric and ionospheric delays
  - Propagation near receiving antenna

Propagation

- Basics:
  - Signal, tagged with time from satellite clock, transmitted.
  - About 66 msec (20,000 km) later the signal arrives at GPS receiver. Satellite has moved about 66 m during the time it takes signal to propagate to receiver.
  - Time the signal is received is given by clock in receiver. Difference between transmit time and receive time is pseudorange.
  - During the propagation, signal passes through the ionosphere (10-100 m of delay, phase advance), and neutral atmosphere (2.3-30 m depending on elevation angle).

Propagation

- To determine an accurate position from range data, we need to account for all these propagation effects and time offsets.
- In later lectures, examine ionospheric and atmospheric delays, and effects near antenna.
- Basic clock treatment in GPS
  - True time of reception of signal needed
  - True time of transmission needed (af0, af1 from broadcast ephemeris initially OK)
  - Position of satellite when signal transmitted

Times

- RINEX data files, tag measurements by reception time as given by the receiver clock. The error in the receiver time must be determined iteratively
- For linearized least squares or Kalman filter need to establish non-linear model and then estimator determines adjustments to parameters of model (e.g. receiver site coordinates) and initial clock error estimates that "best" match the data.

Non-linear model

- Basics of non-linear model:
  - Rinex data file time tags give approximate time measurement was made.
  - Using this time initially, position of satellite can be computed
  - Range computed from receiver and satellite position
  - Difference between observed pseudorange and computed ranges, gives effects of satellite and receiver clock errors. In point positioning, satellite clock error is assumed known and when removed from difference, error in receiver clock determined.
  - With new estimate of receiver clock, process can be iterated.
  - If receiver position poorly known, then whole system can be iterated with updated receiver coordinates.

Sensitivities

- Satellites move at about 1km/sec, therefore an error of 1 msec in time results in 1 m satellite position (and therefore in range estimate and receiver position).
- For pseudo-range positioning, 1 msec errors OK. For phase positioning (1 mm), times needed to 1 μsec.
- (1 μsec is about 300 m of range. Pseudorange accuracy of a few meters in fine).

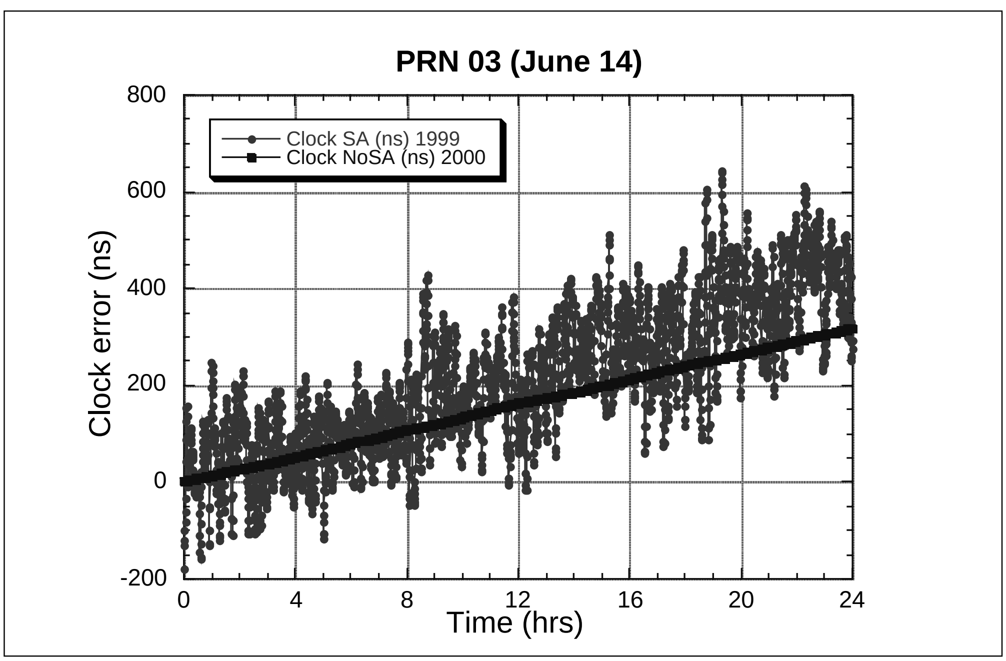
"Light-time-iteration"

- To compute theoretical range; two basic methods used
  - (a) "Doppler shift corrections" ie. Account for rate of change of range during propagation time
  - (b) "Light-time-iteration" Method most commonly used.
- Light time iteration: Basic process is to compute range using simple Cartesian geometry but with position of receiver at receive time and position of transmitter at transmit time.

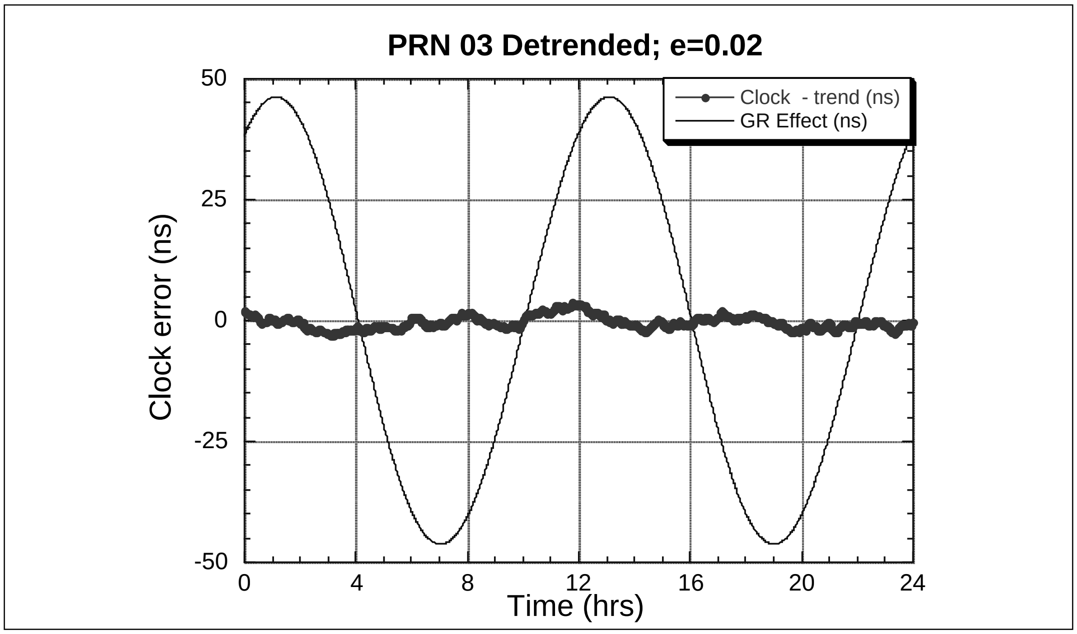
Light-time-iteration

- Light time iteration must be computed in a non-rotating frame
- Reason: Consider earth-fixed frame: one would simply compute Earth fixed coordinates at earlier time. In non-rotating frame, rotation to inertial coordinates would be done at two different time (receiver when signal received; transmitted when signal transmitted).
- Difference is rotation of Earth on ~60 msec. Rotation rate ~460 m/sec; therefore difference is about 30 meters.

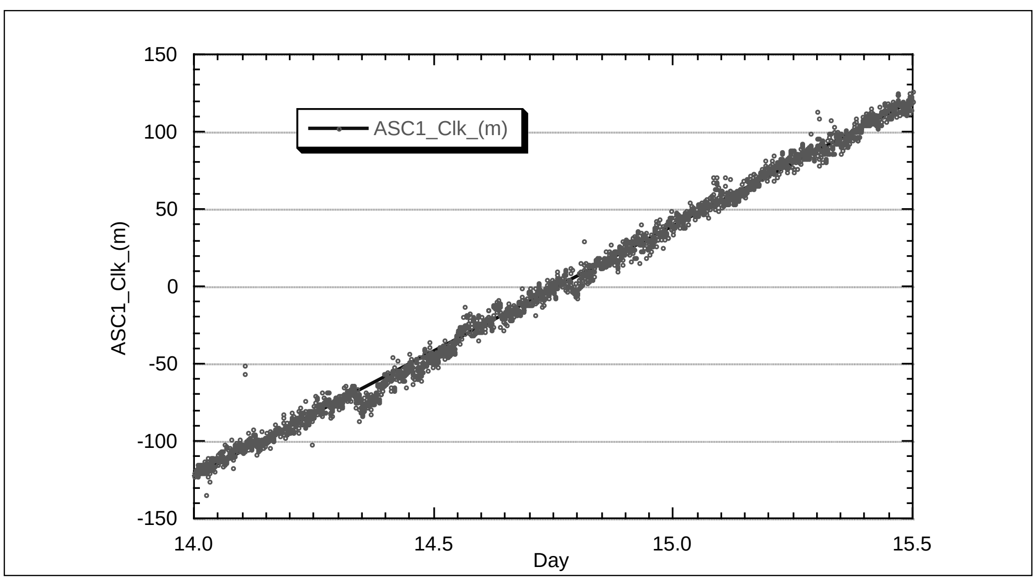
Clock errors



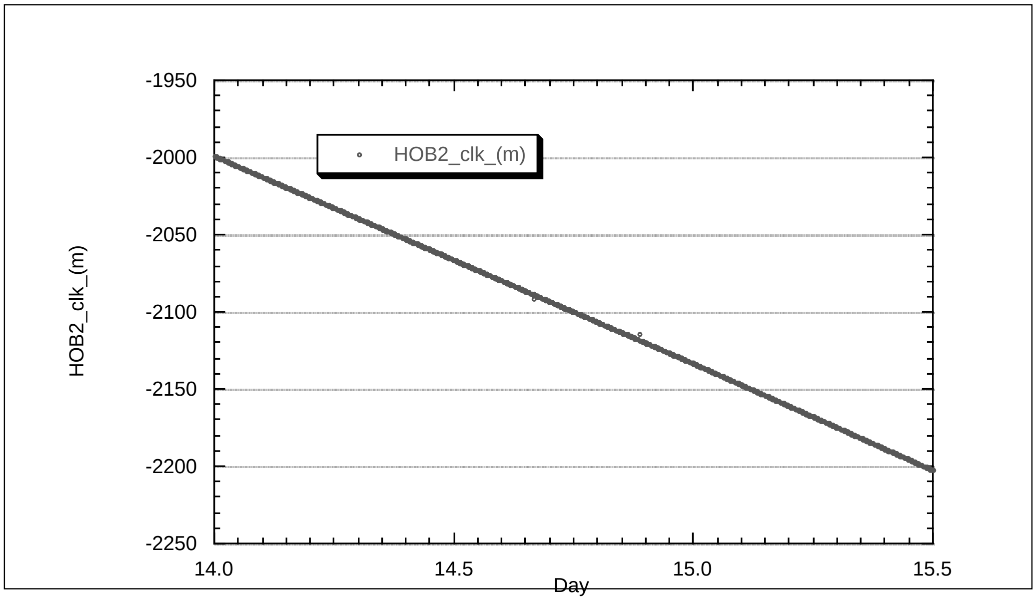
Detrended



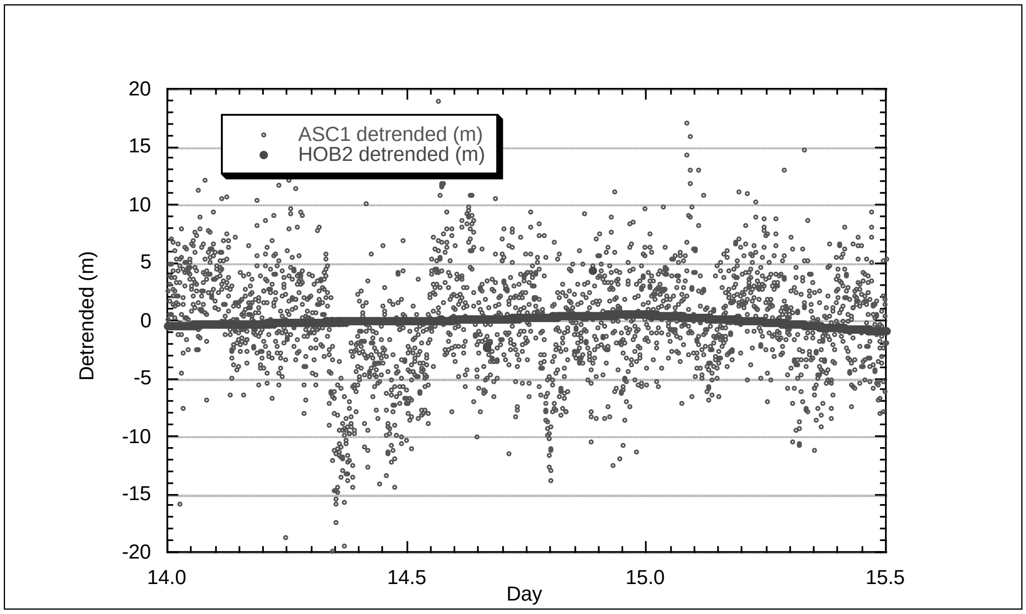
Receiver clocks: ASC1



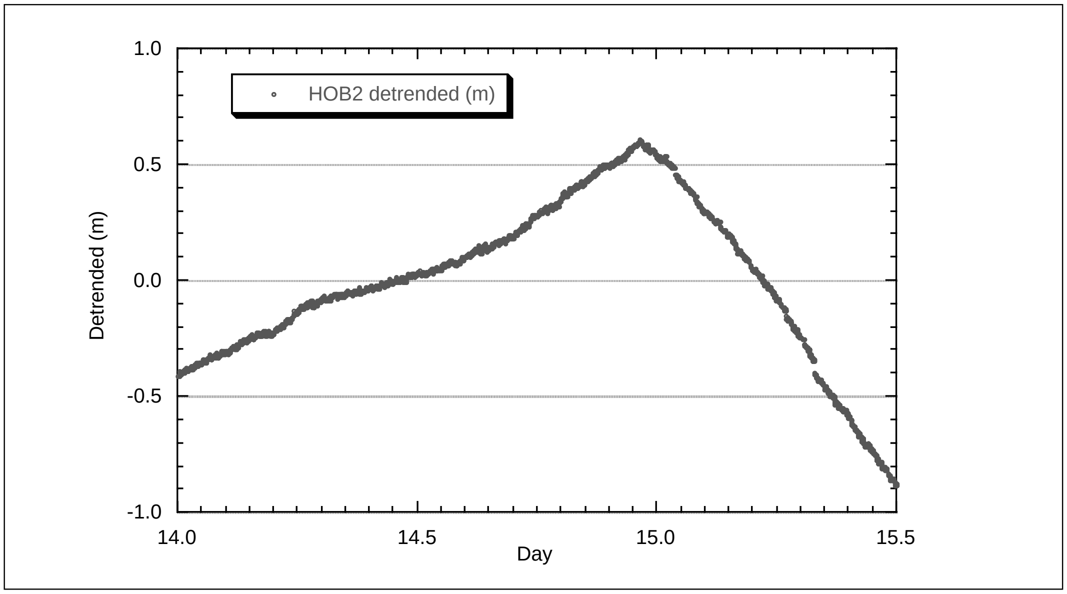
Receiver Clock: HOB2 Hydrogen Maser



ASC/HOB2 Detrended



HOB2 only



Summary of clocks

- In some cases; clock are well enough behaved that linear polynomials can be used.
- Most commonly: receiver clocks are estimated at every measurement epoch (white noise clocks)
- Errors in receiver clocks are often thousands of km of equivalent time. Homework #2 will show a “bad” clock in receiver.