IGS Models for GNSS-Specific Effects

J. Ray (NOAA/NGS, USA )
G. Gendt (GeoForschungsZentrum/Potsdam, Germany)

Contents

- antenna phase model
- satellite orbit models
- satellite attitude models
- satellite signal polarization models
- ionospheric delay modeling
- inter-modulation signal delay biases
- SP3 orbit frame
- relativistic effects for GPS clocks
Antenna Phase Model

Accounts for non-ideal phase response of satellite transmit & ground receive antennas
- background in IGS Mail #5189 (17 Aug 2005)
- current values in igs05.atx file at IGS Central Bureau
  - antex format documented at IGS CB also
- note that values were determined empirically, based on fixed ITRF
- different model for every antenna type (or even individual)

Relation to other techniques
- limited to GNSS

Impact
- strongly affects network scale, scale-rate, & deformations
- radome effects can be quite large, but are often uncalibrated
- cm-level effect on station positions, including local ties
  - local site surveys should use consistent antenna models
Satellite Orbit Models

**Accounts for dynamical motion of satellites**
- most problematic is Solar Radiation Pressure (SRP) effect
  - usually treated highly empirically, with extra nuisance parameters (up to 9), velocity breaks, or stochastically
- approaches differ among Analysis Centers
  - limits any attempts to make “rigorous” combinations

**Relation to other techniques**
- analogous for any satellite technique

**Impact**
- SRP models strongly affect geocenter & LOD estimates, esp
- documentation in IERS Conventions would be desirable
  - but probably very difficult
- for higher accuracy new approaches may be needed
  - e.g., reduce systematic errors, eclipsing, albedo, etc
Satellite Attitude Models

Accounts for yaw variations, esp during eclipses
- current treatments are poorly documented
- mostly affects phase observations
  - strongly mitigated by double-differencing
- undifferenced methods require model and/or data editing
  - yaw rate parameters adjusted by some groups, fixed by others

Relation to other techniques
- analogous for any satellite technique that tracks signal phase

Impact
- can influence orbit parameters, clocks, & large-scale frame distortions
- better documentation would be desirable
- problems greatly reduced for newest IIR & later satellites
  - satellite yaw behavior simplified
Satellite Polarization Models

Accounts for variation in RHC phase rotation
- often called “phase wind-up”
  - varies as relative satellite-ground perspective changes
- model by Wu et al. (1993) widely used
  - mitigated by double-differencing

Relation to other techniques
- limited to GNSS

Impact
- effects very similar to attitude changes
- must be properly included to modeled carrier phase data
- could be documented in IERS Conventions
**Ionospheric Delay Modeling**

- **Removes propagation delay/advance due to charged particles in Earth’s atmosphere**
  - use frequency-dependence to measure effect directly with multi-frequency signals
    - usually, only lowest-order effect considered via linear combination of L1 & L2 data – increases obs errors
    - lowest-order effect equal for phase & code but opposite sign
  - neglected higher-order effects can be significant (~1 cm errors)
    - higher-order effects & models somewhat controversial

- **Relation to other techniques**
  - analogous for VLBI, DORIS, other radiometric techniques

- **Impact**
  - neglected effects can distort frame & bias satellite clocks (esp)
  - documentation in IERS Conventions would be helpful
Inter-modulation Signal Biases

Accounts for signal delays in satellite transmit &
ground receive systems
- mostly limits ability to mix data types from diverse receiver models
- also relevant for ionosphere mapping & time transfer
- problem will become much more complex as new GNSS signals become available

Relation to other techniques
- in principle, applies to VLBI but absolute delays usually ignored

Impact
- affects clock estimates & time transfer
- relevant for absolute ionosphere TEC measurements
- can also limit ability to resolve phase ambiguities
By IGS convention, orbits in crust-fixed frame
- eases user analysis without transforming to inertial frame
- requires that sub-daily Earth motions be projected into satellite positions
- with higher accuracy, increasing number of effects to track
  - SP3 format limits internal documentation

Relation to other techniques
- analogous for any satellite technique using SP3 format

Impact
- how best to document analysis models completely for users
- highest accuracy requires consistent treatment of effects by users
- inflexibility of SP3 format probably requires more generic approach in future
  - could be applied for other techniques & combinations
Relativistic Effects for GPS Clocks

**IGS follows IS-GPS-200 modeling**
- 1st-order time dilation & gravitation potential frequency shift applied in GPS oscillators (to be consistent with TT timescales)
- 2nd-order effect of non-circular orbits must be applied by users
- other dynamical effects follow IERS Conventions
- but higher-order time transformation effects are neglected
  - most important is due to Earth’s oblateness (order 100 ps)

**Relation to other techniques**
- analogous for any satellite technique with onboard clocks

**Impact**
- neglected effects only impact clock estimates (w.r.t. TT)
- “errors” are purely conventional
  - no problems if everybody follows same conventions
- IGS models probably should be documented in IERS Conventions
END