# IGS Models for GNSS-Specific Effects

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# 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**

# SP3 File Orbit Frame

- *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