NGA GPS Ephemeris/Station/Antenna Offset Documentation

Source: http://sci.tech−archive.net/Archive/sci.geo.satellite−nav/2005−10/msg00527.html

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- *Date*: Wed, 19 Oct 2005 05:34:15 GMT

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NGA GPS Ephemeris/Station/Antenna Offset Documentation
  http://earth−info.nga.mil/GandG/sathtml/gpsdoc2005_10a.html



Effective date October 01, 2005



                    NATIONAL GEOSPATIAL−INTELLIGENCE AGENCY
                GPS PRECISE EPHEMERIDES, SATELLITE CLOCK PARAMETERS
                            AND SMOOTHED OBSERVATIONS



                                 PRECISE EPHEMERIS



Earth−centered Earth−fixed trajectory
Coordinate system:  WGS84 (G1150)
Position −− x,y,z (km)
Velocity −− dx/dt,dy/dt,dz/dt (dm/s)
GPS time −− year, day, hour, minute
Trajectory interval:  15 min.
Standard Trajectory referenced to satellite center of mass
Optional Trajectory referenced to satellite antenna phase center



                              SATELLITE CLOCK PARAMETERS



Clock parameters for each satellite:
     Time offset (microseconds)
     Frequency offset (10E−4 microsec/s = parts in 10E10)
Time interval for parameters: 15 min.
Satellite clock events: All events processed as reinitializations
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SMOOTHED OBSERVATIONS

Smoothed range and range difference observations (km) with corrections
  applied (see below)
GPS time of observation (year, day, seconds from beginning of day)
Standard deviation of observation (km)
Coordinate system: WGS84 (G1150)
Station coordinates: Position -- x,y,z (m), Epoch 2001.0
                     Velocity -- dx/dt,dy/dt,dz/dt (m/year)
Temperature (degrees Celsius)
Pressure (millibars)
Humidity (percent)
Data interval: 15 min.
Smoothing uses carrier phase to smooth range and range difference
  measurements collected at a 1.5 second rate for NGA and Air Force
  monitor stations and at a 30 second rate for IGS monitor stations
Minimum elevation angle for observation: 10 degrees
National Geospatial-Intelligence Agency and Air Force monitor station data
  collected and smoothed using similar procedures
  References: Computer Program Development Spec., Master Control
  Station, Ephemeris/Clock Computer Program, NAVSTAR GPS Operational
  Control System Segment, CP-MCSEC-302C, Part 1, Appendix A, 7 May 1993.
  Description of the Smoothing Algorithm in the NGA Monitor Station
  Network, (MSN29), Applied Research Laboratories, The University of
  Texas at Austin, GR-SGG-97-1, 3 April 1997.

PHYSICAL CONSTANTS

GM(Earth) = 398600.4418 km**3/s**2
GM(Sun)   = 132712400000 km**3/s**2
GM(Moon) = 4902.799186 km**3/s**2
Moon radius =   1738 km
Sun radius = 696000 km
Earth semi-major axis (a) = 6378.137 km
Inverse flattening (1/f) = 298.257223563
Earth angular velocity   = 0.72921158553 X 10**-4 Rad/s
Speed of light = 299792.458 km/s
Love's constant = 0.290
Solar constant = 4.560 X 10**-6 N/m**2
Astronomical Unit = 149597870.691 km

STATION COORDINATES (GEODETIC)
WGS84 (G1150) Epoch 2001.0

STATION COORDINATES (CARTESIAN)
WGS84 (G1150) Epoch 2001.0

Due to security concerns
surrounding the current threat situations,
the coordinates for the NGA/Air Force/IGS
stations have been removed.

Any such information needed about the NGA
stations should be requested, until
further notice, at: (314) 263−4120
or DSN 693−4120

CORRECTIONS APPLIED TO MEASUREMENTS

Ionospheric delay: 2−frequency, 1st order correction
Tropospheric refraction: Saastamoinen hydrostatic and wet zenith delay
models and Niell hydrostatic and wet mapping functions
Periodic relativistic effects

Satellite antenna offset (satellite body centered coordinates, meters)
Block II PRN's − Delta x= 0.2794, Delta y= 0.0000, Delta z= 0.9519
Block IIA PRN's − Delta x= 0.2794, Delta y= 0.0000, Delta z= 0.9519

Block IIR PRN 02 − Delta x= −0.0099, Delta y= 0.0061, Delta z= −0.0820
Block IIR PRN 11 − Delta x= 0.0019, Delta y= 0.0011, Delta z= 1.5141
Block IIR PRN 13 − Delta x= 0.0024, Delta y= 0.0025, Delta z= 1.6140
Block IIR PRN 14 − Delta x= 0.0018, Delta y= 0.0002, Delta z= 1.6137
Block IIR PRN 16 − Delta x= −0.0098, Delta y= 0.0060, Delta z= 1.6630
Block IIR PRN 18 − Delta x= −0.0098, Delta y= 0.0060, Delta z= 1.5923
Block IIR PRN 19 − Delta x= −0.0079, Delta y= 0.0046, Delta z= −0.0180
Block IIR PRN 20 − Delta x= 0.0022, Delta y= 0.0014, Delta z= 1.6140
Block IIR PRN 21 − Delta x= 0.0023, Delta y= −0.0006, Delta z= 1.5840
Block IIR PRN 22 − Delta x= 0.0018, Delta y= −0.0009, Delta z= 0.0598
Block IIR PRN 23 − Delta x= −0.0088, Delta y= 0.0035, Delta z= 0.0004
Block IIR PRN 28 − Delta x= 0.0019, Delta y= 0.0007, Delta z= 1.5131

Block IIR−M PRN 17 − Delta x= −0.00996, Delta y= 0.00599, Delta z= −0.10060

Station displacement due to tides

Yaw Bias: JPL yaw bias model for Block II and IIA satellites in eclipse

FORCE MODELING

Gravitational:
- EGM96 Earth gravity model truncated at degree 12 and order 12
- Solar and Lunar gravity using the DE403 ephemeredes, J2000 epoch, and IAU Resolutions on Astronomical Constants, Time Scales, and the Fundamental Reference Frame (1976−1980)
- Solid Earth tides

Non−gravitational:
- Radiation Pressure
  - The JPL TJPLXYZ03−II/IIA version model for Block II and IIA satellites
  - The JPL TJPLXYZ03−IIR version model for Block IIR satellites
- Thrusts
- Momentum dumps

Kinematic:
- Luni−solar and planetary precession (IAU Resolutions, as above)
- Nutation (IAU Resolutions, as above)
- Earth rotation (IAU Resolutions, as above)
- Polar Motion (using NGA initial values generated the week before the orbit fit) + diurnal and semi−diurnal effects
- UT1−UTC (using NGA initial values generated the week before the orbit fit) + Zonal tide effects + diurnal and semi−diurnal effects

Integration step size: 300 seconds, reduced to 10 seconds during eclipse boundary crossings

ORBIT ESTIMATION METHOD

Kalman Filter/RTS Smoother (Square Root Information implementation)
Initial conditions: From previous fit
Solution parameters:
- Satellite state vector in element form at trajectory epoch −−
  - semi−major axis
  - eccentricity * sin(argument of perigee)
  - eccentricity * cos(argument of perigee)
  - inclination
  - mean anomaly + argument of perigee
  - right ascension of the ascending node

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        Satellite clock parameters -- Time offset, Frequency offset
        Monitor station clock parameters (excluding master station) --
          Time offset, Frequency offset
        Polar motion parameters -- Pole and pole rate components along
          Greenwich meridian, Pole and pole rate components along
          meridian 90 deg west of Greenwich, Rate of change and
          acceleration of UT1-UTC
        Satellite radiation pressure parameters -- Radiation pressure
          scale, and Y-axis acceleration
        Tropospheric refraction -- One stochastic zenith delay
          parameter per station
Minimum range observation uncertainty(1-sigma):100 cm (IGS Stations)
                                               80 cm (AF Station 85130)
                                               40 cm (Other AF and NGA stations)
Minimum range difference observation uncertainty (1-sigma): 1.5 cm
Process noise in Kalman Filter:
        Radiation pressure (each satellite)--
             Decorrelation time   14,400 s
             Steady state sigmas --
                SCALE   0.05
                Y-AXIS  0.5 X 10**-12 km/s**2
        Tropospheric refraction variance rate: 2.89 cm**2/hr
        Station clock white noise spectral density: (each station) --
             Time offset       0.1111 X 10**-2 (microseconds)**2/s
             Frequency offset  0.1111 X 10**-8 (ppm)**2/s
        Satellite clock white noise spectral density: (each satellite)
           Time offset       0.1111 X 10**-2 (microseconds)**2/s
             Frequency offset  0.1111 X 10**-8 (ppm)**2/s
             Frequency drift   0.              (ppm/s)**2/s
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SATELLITE CLOCK ESTIMATION METHOD

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Kalman Filter/RTS Smoother (Square Root Information implementation)
Orbit solutions from above method are held fixed for satellite clock
  estimation
Solution parameters:
    Satellite clock parameters -- Time offset, Frequency offset
    Monitor station clock parameters (excluding master station) --
      Time offset, Frequency offset
    Tropospheric refraction -- One stochastic zenith delay parameter
      per station.
Minimum range observation uncertainty(1-sigma):100 cm (IGS Stations)
                                               80 cm (AF Station 85130)
                                               40 cm (Other AF and NGA stations)
Minimum range difference observation uncertainty (1-sigma): 15.0 cm
Process noise in Kalman Filter:
    Tropospheric refraction variance rate: 2.89 cm**2/hr



    Station clock white noise spectral densities:
      NGA stations (except USNO) and Air Force stations (except Colorado Springs):
             Time offset       0.1944 X 10**-8  (microseconds)**2/s
             Frequency offset  0.4440 X 10**-19 (ppm)**2/s
      NGA station at USNO and Air Force station at Colorado Springs:
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          Time offset       0.1380 X 10**-9  (microseconds)**2/s
          Frequency offset  0.4440 X 10**-19 (ppm)**2/s
     IGS stations:
          Time offset       0.3456 X 10**-8  (microseconds)**2/s
          Frequency offset  0.4440 X 10**-19 (ppm)**2/s



 Satellite clock white noise spectral densities:
     Satellite Block IIR Rubidium clocks
          Time offset       0.8640 X 10**-9  (microseconds)**2/s
          Frequency offset  0.1110 X 10**-18 (ppm)**2/s
          Frequency drift   0.               (ppm/s)**2/s
     Satellite Block II/IIA Rubidium clocks
          Time offset       0.1944 X 10**-8  (microseconds)**2/s
          Frequency offset  0.1110 X 10**-18 (ppm)**2/s
          Frequency drift   0.               (ppm/s)**2/s
     Satellite Cesium clocks
          Time offset       0.13824 X 10**-7 (microseconds)**2/s
          Frequency offset  0.1000 X 10**-17 (ppm)**2/s
          Frequency drift   0.               (ppm/s)**2/s
     Satellite 'Noisy' Cesium clocks
          Time offset       0.2000 X 10**-7  (microseconds)**2/s
          Frequency offset  0.1110 X 10**-16 (ppm)**2/s
          Frequency drift   0.               (ppm/s)**2/s



Reference:  Swift, E., Mathematical Description of the GPS Multi-Satellite
  Filter/Smoother, NSWCDD Report (Oct. 2001).



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