NGA GPS Ephemeris/Station/Antenna Offset Documentation −− Oct. 2005

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NGA GPS Ephemeris/Station/Antenna Offset Documentation
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



                           SMOOTHED OBSERVATIONS
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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
- Satellite clock parameters −− Time offset, Frequency offset
- Monitor station clock parameters (excluding master station) −−

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          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:
             Time offset       0.1380 X 10**−9  (microseconds)**2/s
             Frequency offset  0.4440 X 10**−19 (ppm)**2/s
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        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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