3.2.1.2.2.1.2 GPS Ionospheric Delay Model

The ionospheric delay model described below is based upon the GPS Standard Positioning Service equations (Klobuchar [5]) and has some modifications (Lear [4]) to account for vehicles at varying altitudes below the ionospheric region (i.e., up to an altitude of about 280 km). This model utilizes the satellite broadcast data words containing the ionospheric alpha and beta polynomial coefficients (ICD-GPS-200 [1]).

The correction is as follows:

$$\Delta\rho_{IONO} = c \cdot F \cdot [5x10^{-9} + A\cos\left(\frac{2\pi(t - 50400)}{T}\right)] \quad \text{(meters)} \qquad \text{[Eq. 3-94]}$$

where

$$A = \alpha_0 + \alpha_1 \phi_{IP}^m + \alpha_2 (\phi_{IP}^m)^2 + \alpha_3 (\phi_{IP}^m)^3$$ (amplitude of vertical delay), [Eq. 3-95]

$$T = \beta_0 + \beta_1 \phi_{IP}^m + \beta_2 (\phi_{IP}^m)^2 + \beta_3 (\phi_{IP}^m)^3$$ (period of the model (sec)), [Eq. 3-96]

(Note: If $T < 72000$ then set $T = 72000$)

$$t = [(43200)(\lambda_{IP}/\pi) + t_{GPS}] \text{ modulo } 86400$$ (local time (sec)), [Eq. 3-97]

$$\phi_{IP}^m = \phi_{IP} + \frac{0.064}{\pi}\cos(\lambda_{IP} - 1.617\,\pi)$$

(geomagnetic latitude of IP wrt. geomagnetic pole (rad)), [Eq. 3-98]

$$\phi_{IP} = lat + \Psi\cos(azim)$$ (geodetic latitude of ionospheric intersection point (IP) (rad)), [Eq. 3-99]

$$\lambda_{IP} = lon + \frac{\Psi\sin(azim)}{\cos\phi_{IP}}$$ (geodetic longitude of IP (rad)), [Eq. 3-100]

(Note: If $\lambda_{IP} < 0$ then set $\lambda_{IP} = \lambda_{IP} + 2\pi$)

$$\Psi = \cos^{-1}\left[\frac{\cos(elev)}{\gamma}\right] - elev$$ (earth-central angle from receiver to IP), [Eq. 3-101]

$c = 2.99792458 \times 10^8$ (speed of light, m/s),

$$F = \frac{\sqrt{1.028}\,\gamma}{\sqrt{\sin^2(elev) + 1.028\,\gamma^2 - 1}} \quad \text{(obliquity factor),} \qquad \text{[Eq. 3-102]}$$

$$\gamma = \frac{R_e + h_{IP}}{R_e + h}\,, \qquad \text{[Eq. 3-103]}$$

R_e = average earth radius = 6367.45 km,

h_{IP} = ionospheric intersection point altitude = 280km,

$\{\alpha_n, \beta_n\}$ = satellite broadcast cubic equation coefficients,

azim, *elev* = azimuth and elevation from the receiver to the satellite (rad),

lat, *lon* = geodetic latitude and longitude of the receiver (rad),

h = receiver altitude (up to 280 km) (km),

t_{GPS} = GPS time at the receiver (sec).