TABLE E.2 Equations for Calculating Satellite ECEF Position Based on Navigation Message Ephemeris Parameters and Time

$\Delta t_r = Fe\sqrt{A}\sin(E_k)$	s	Relativistic correction term
$\Delta t_{sv} = a_0 + a_1(t_{sv} - t_{oc}) + a_2(t_{sv} - t_{oc})^2 + \Delta t_r$	s	Correction to satellite clock
$t = t_{sv} - \Delta t_{sv}$	s	Corrected message transmission time
$A = (\sqrt{A})^2$	m	Orbit semimajor axis
$n_0 = \sqrt{\frac{\mu}{A^3}}$	rad/s	Computed mean motion
$t_k = t - t_{oe}$	s	Time from ephemeris reference epoch
$n = n_o + \Delta n$	rad/s	Corrected mean motion
$M_k = M_0 + t_k n$	rad	Mean anomaly
$E_k = M_k + e\sin(E_k)$	rad	Kepler's equation for eccentric anomaly
$v_k = \arctan 2\left(\frac{\sqrt{1-e^2}\sin(E_k)}{1-e\cos(E_k)}, \frac{\cos(E_k)-e}{1-e\cos(E_k)}\right)$	rad	True anomaly
$\phi_k = v_k + \omega$	rad	Argument of latitude
$\delta u_k = C_{us}\sin(2\phi_k) + C_{uc}\cos(2\phi_k)$	rad	Arguemnt of latitude correction
$\delta r_k = C_{rs}\sin(2\phi_k) + C_{rc}\cos(2\phi_k)$	m	Radius correction
$\delta i_k = C_{is}\sin(2\phi_k) + C_{ic}\cos(2\phi_k)$	rad	Inclination correction
$u_k = \phi_k + \delta u_k$	rad	Corrected argument of latitude
$r_k = A[1 - e\cos(E_k)] + \delta r_k$	m	Corrected radius
$i_k = i_0 + \delta i_k + t_k \Delta \dot{i}$	rad	Corrected inclination
$x'_k = r_k\cos(u_k)$	m	x position in orbital plane
$y'_k = r_k\sin(u_k)$	m	y position in orbital plane
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe}$	rad	Corrected longitude of ascending node
$x_k = x'_k\cos(\Omega_k) - y'_k\cos(i_k)\sin(\Omega_k)$	m	Satellite x ECEF coordinate
$y_k = x'_k\sin(\Omega_k) + y'_k\cos(i_k)\cos(\Omega_k)$	m	Satellite y ECEF coordinate
$z_k = y'_k\sin(i_k)$	m	Satellite z ECEF coordinate

A few comments are appropriate concerning Table E.2. The variable t_k is the actual total time difference between the time t and the ephemeris reference time t_{oe}. The calculation must account for beginning or end of week crossovers; that is, if t_k is greater than 302,400 s, subtract 604,800 seconds from t_k. If t_k is less than −302,400 s, add 604,800 s to t_k. The equation for E_k must be solved iteratively. Various iterative solution techniques are considered in Ref. 144.

Table E.3 [34] contains a complete example set of ephemeris parameters. When these ephemeris parameters are used in the equations of Table E.2, the space-vehicle (satellite) time offset and ECEF satellite antenna coordinates can be determined. The results of these calculations are shown in Table E.4.

E.3 Atmospheric Model

In this section the Klobuchar ionospheric correction model is presented [73, 86, 87]. The variable definitions and units are summarized in Table E.5. This model should be used only by users with single-frequency receivers that are not