that can be determined based on the following system of equations, representing measurements from four different satellites:

$$\tilde{\rho}^{(1)} = \left[\left(X^{(1)} - x\right)^2 + \left(Y^{(1)} - y\right)^2 + \left(Z^{(1)} - z\right)^2\right]^{0.5} + c\Delta t_r + c\Delta t_{sv}^{(1)} + c\Delta t_a^{(1)} + \mathrm{SA}^{(1)} + E^{(1)} + \mathrm{MP}^{(1)} + \eta^{(1)} \tag{5.1}$$

$$\tilde{\rho}^{(2)} = \left[\left(X^{(2)} - x\right)^2 + \left(Y^{(2)} - y\right)^2 + \left(Z^{(2)} - z\right)^2\right]^{0.5} + c\Delta t_r + c\Delta t_{sv}^{(2)} + c\Delta t_a^{(2)} + \mathrm{SA}^{(2)} + E^{(2)} + \mathrm{MP}^{(2)} + \eta^{(2)} \tag{5.2}$$

$$\tilde{\rho}^{(3)} = \left[\left(X^{(3)} - x\right)^2 + \left(Y^{(3)} - y\right)^2 + \left(Z^{(3)} - z\right)^2\right]^{0.5} + c\Delta t_r + c\Delta t_{sv}^{(3)} + c\Delta t_a^{(3)} + \mathrm{SA}^{(3)} + E^{(3)} + \mathrm{MP}^{(3)} + \eta^{(3)} \tag{5.3}$$

$$\tilde{\rho}^{(4)} = \left[\left(X^{(4)} - x\right)^2 + \left(Y^{(4)} - y\right)^2 + \left(Z^{(4)} - z\right)^2\right]^{0.5} + c\Delta t_r + c\Delta t_{sv}^{(4)} + c\Delta t_a^{(4)} + \mathrm{SA}^{(4)} + E^{(4)} + \mathrm{MP}^{(4)} + \eta^{(4)} \tag{5.4}$$

where $\tilde{\rho}^{(1)}$, $\tilde{\rho}^{(2)}$, $\tilde{\rho}^{(3)}$, and $\tilde{\rho}^{(4)}$ are the measured pseudoranges, $(X^{(i)}, Y^{(i)}, Z^{(i)})$ are the ECEF position coordinates of satellite i, (x, y, z) are the ECEF position coordinates of the receiver antenna, Δt_r is receiver clock bias, $\Delta t_{sv}^{(i)}$ is the clock bias of the SV, $\Delta t_a^{(i)}$ is the atmospheric delay, $\mathrm{SA}^{(i)}$ represents the deliberate corruption of the satellite signals under the policy of selective availability, $E^{(i)}$ represents error in the broadcast ephemeris data, $\mathrm{MP}^{(i)}$ represents multipath error, $\eta^{(i)}$ represents receiver tracking error noise, and c is the speed of light. The $()^{(i)}$ notation refers to the quantity in parenthesis referenced to the ith satellite.

Each of the above error sources is discussed separately in Sec. 5.4. In solving Eqs. (5.1)–(5.4), the effective SV positions are required. The position of the space-vehicle antenna phase center in ECEF coordinates can be computed with data derived from the GPS navigation messages, as described in App. E.