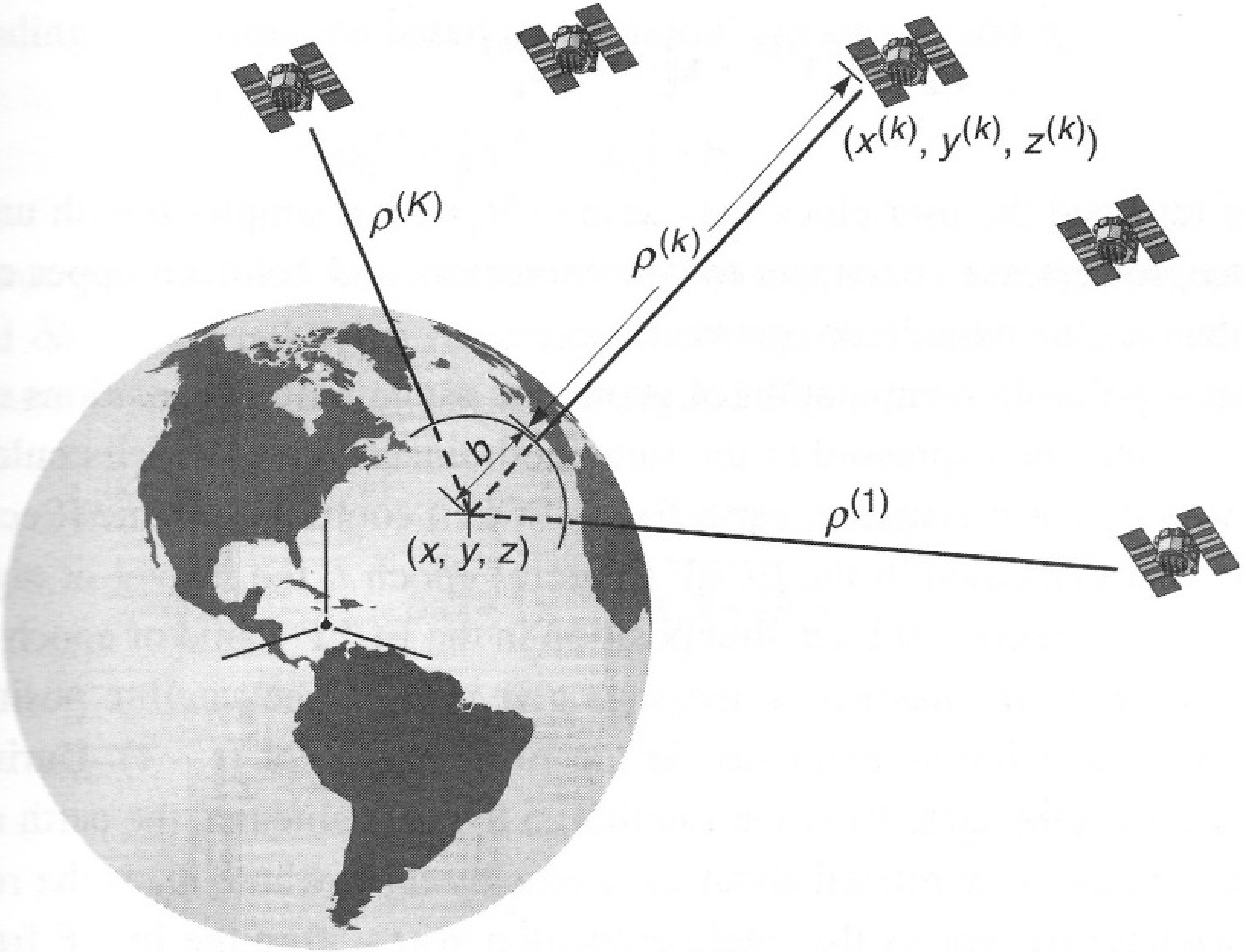

$(x^{(k)}, y^{(k)}, z^{(k)})$
$\rho^{(K)}$
$\rho^{(k)}$
b
$\rho^{(1)}$
(x, y, z)

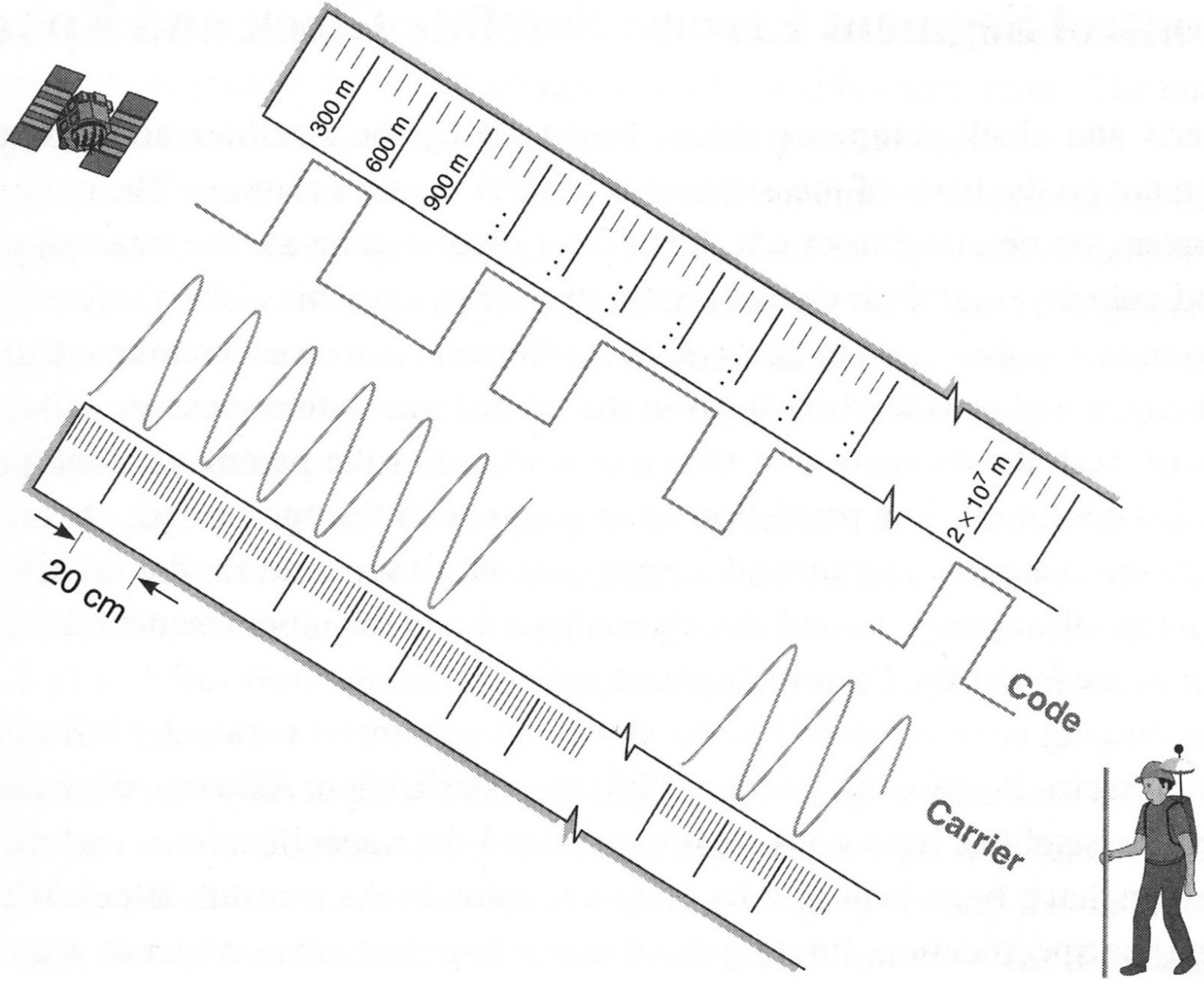
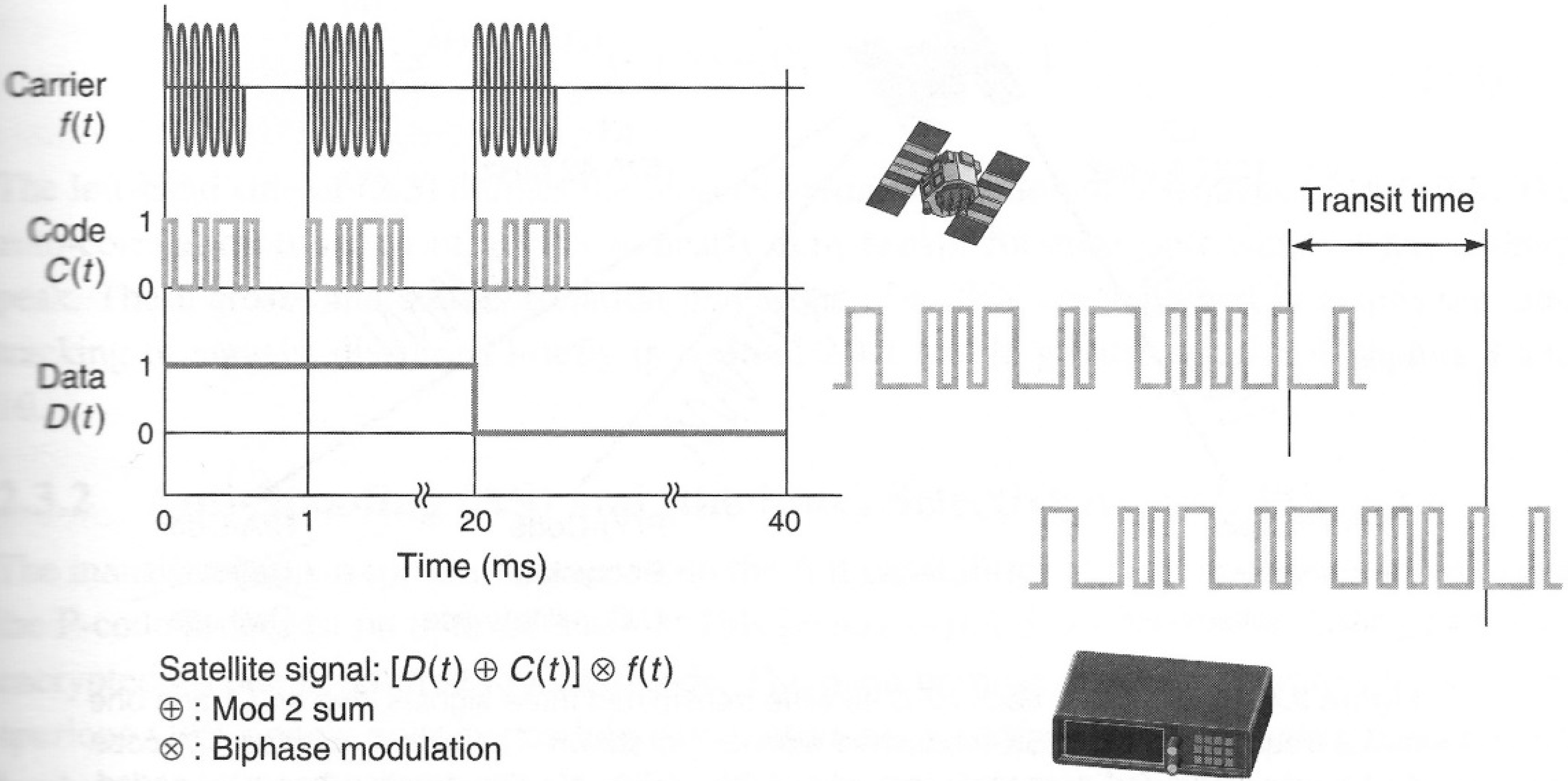


Figure 5.4 A conceptual representation of the code and carrier phase measurements with a tape measure.



Carrier
$f(t)$
Code
$C(t)$
1
0
Data
$D(t)$
1
0
0
1
20
40
Time (ms)
Transit time
Satellite signal: $[D(t) \oplus C(t)] \otimes f(t)$
$\oplus$: Mod 2 sum
$\otimes$: Biphase modulation

Navigation or Pseudorange Solution

$$F = PR - \left[\left(x - x_s \right)^2 + \left(y - y_s \right)^2 + \left(z - z_s \right)^2 \right]^{1/2} - c(dt) = 0$$

PR = pseudorange
x,y,z = receiver position
x_s , y_s , z_s = satellite position (at transmit time)
c = speed of light
dt = receiver clock bias

In this equation the pseudorange is observed, the satellite position is fixed from ephemeris data, the speed of light is known, the four remaining unknowns are x,y,z,dt and therefore require observations to four satellites to make a unique solution. With more observations you can make a least squares estimation to increase the precision of the result. dt is a nuisance parameter which is of no interest, but you must compute it.

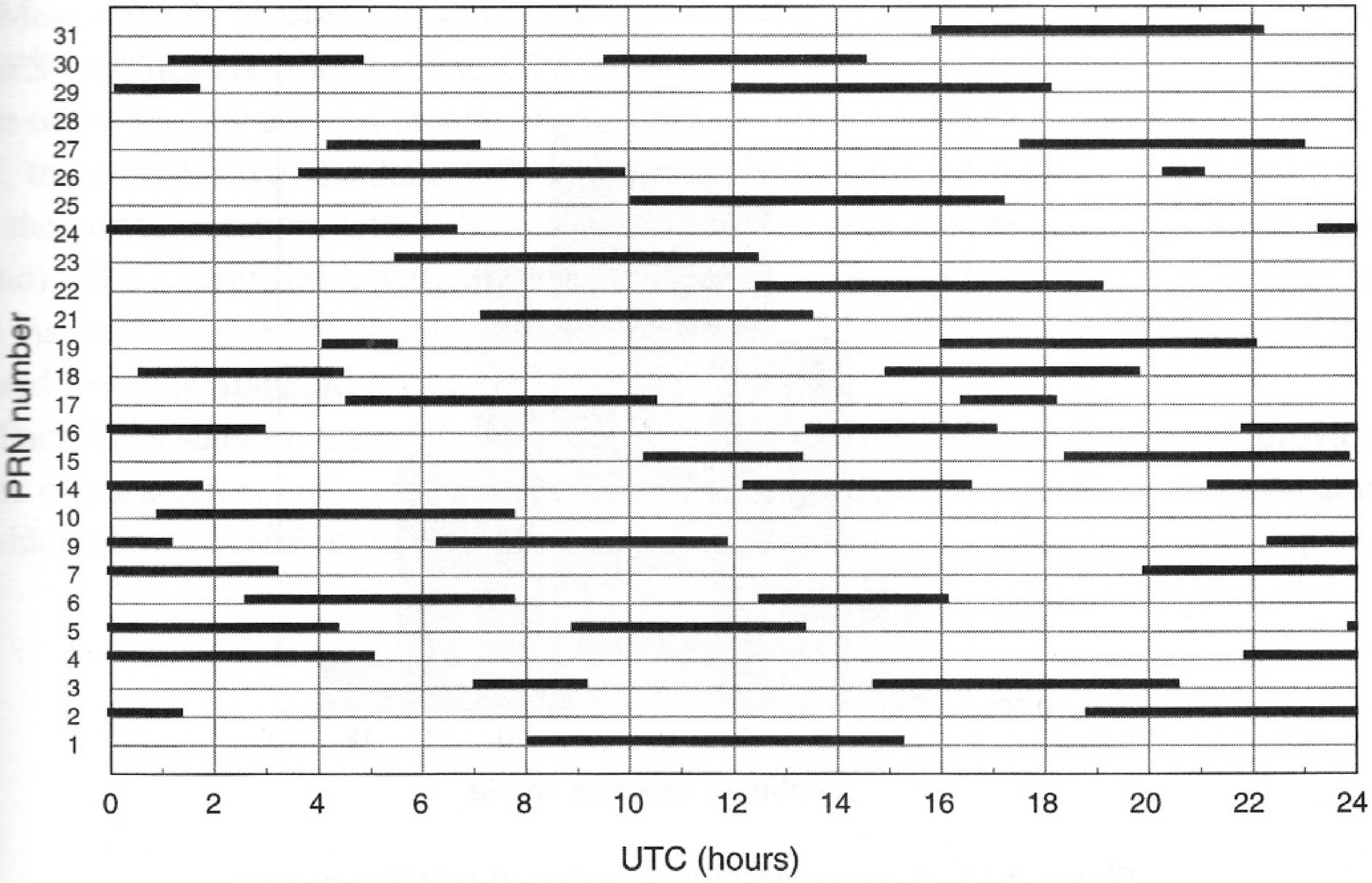


Figure 4.15 Satellite visibility (rise and set times) at Lexington, Massachusetts, plotted for a day in 1998.

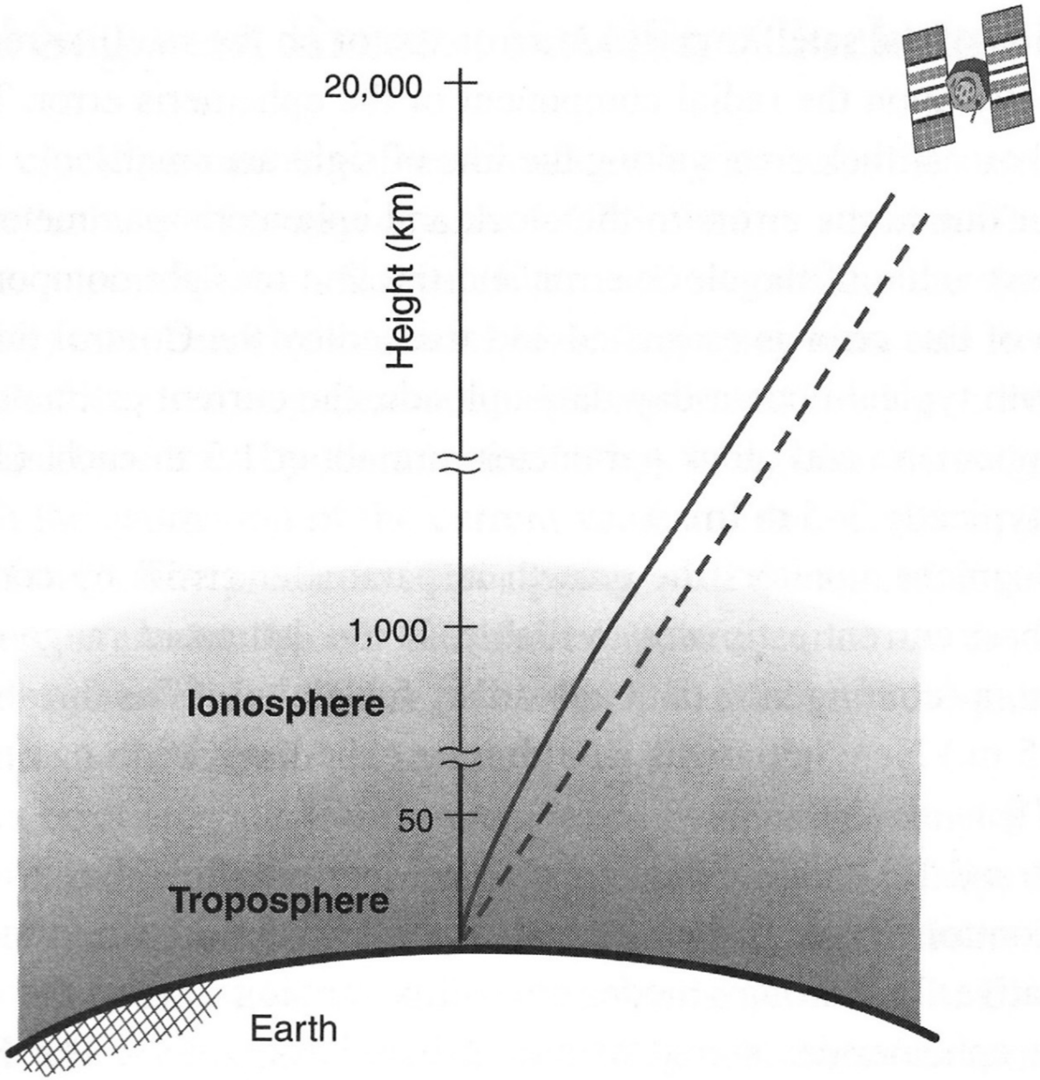


Figure 5.6 Refraction of GPS signals in the earth's atmosphere results in changes to both speed and direction. Increase in path length due to bending of the signal ray, greatly exaggerated above, is generally insignificant. The effect of the change in speed of propagation, however, can result in pseudorange measurement error of several meters or more.

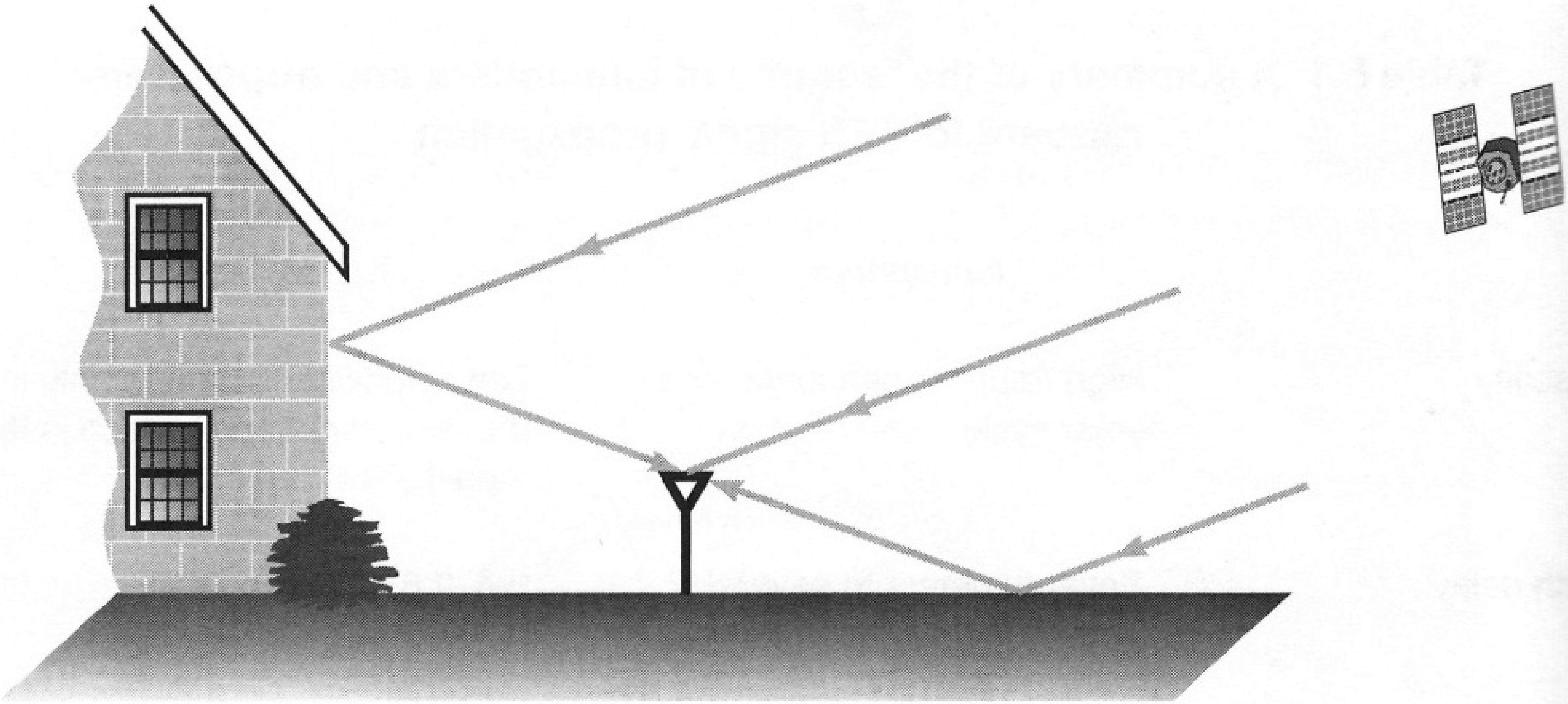
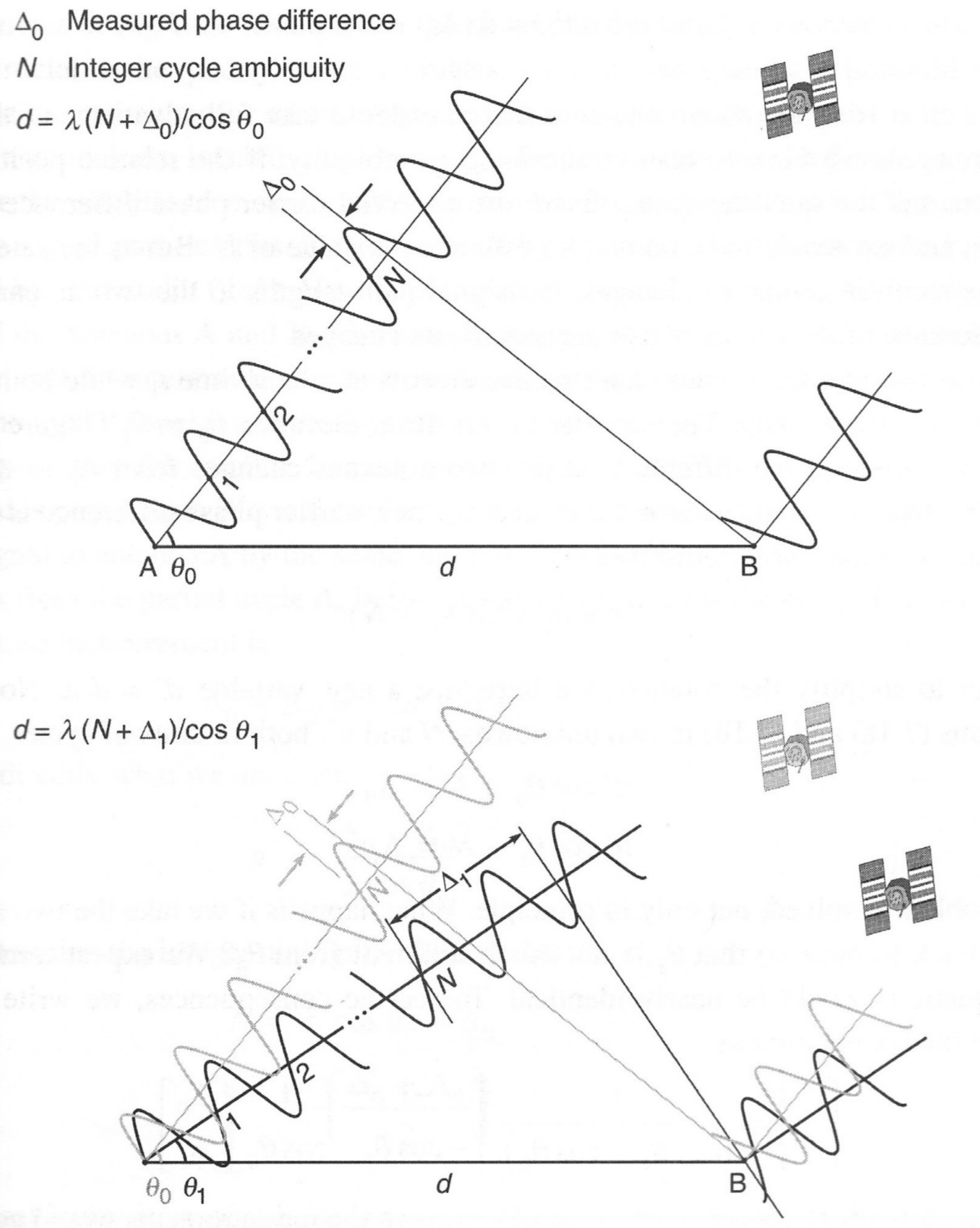


Figure 5.12 Multipath: The signal may reach an antenna via more than one path. A reflected signal is a delayed and usually weaker version of the direct signal.



Δ0 Measured phase difference
N Integer cycle ambiguity
d = λ(N + Δ0)/cos θ0
Δ0
N
2
1
A θ0
d
B
d = λ(N + Δ1)/cos θ1
Δ0
N
Δ1
N
2
1
θ0 θ1
d
B

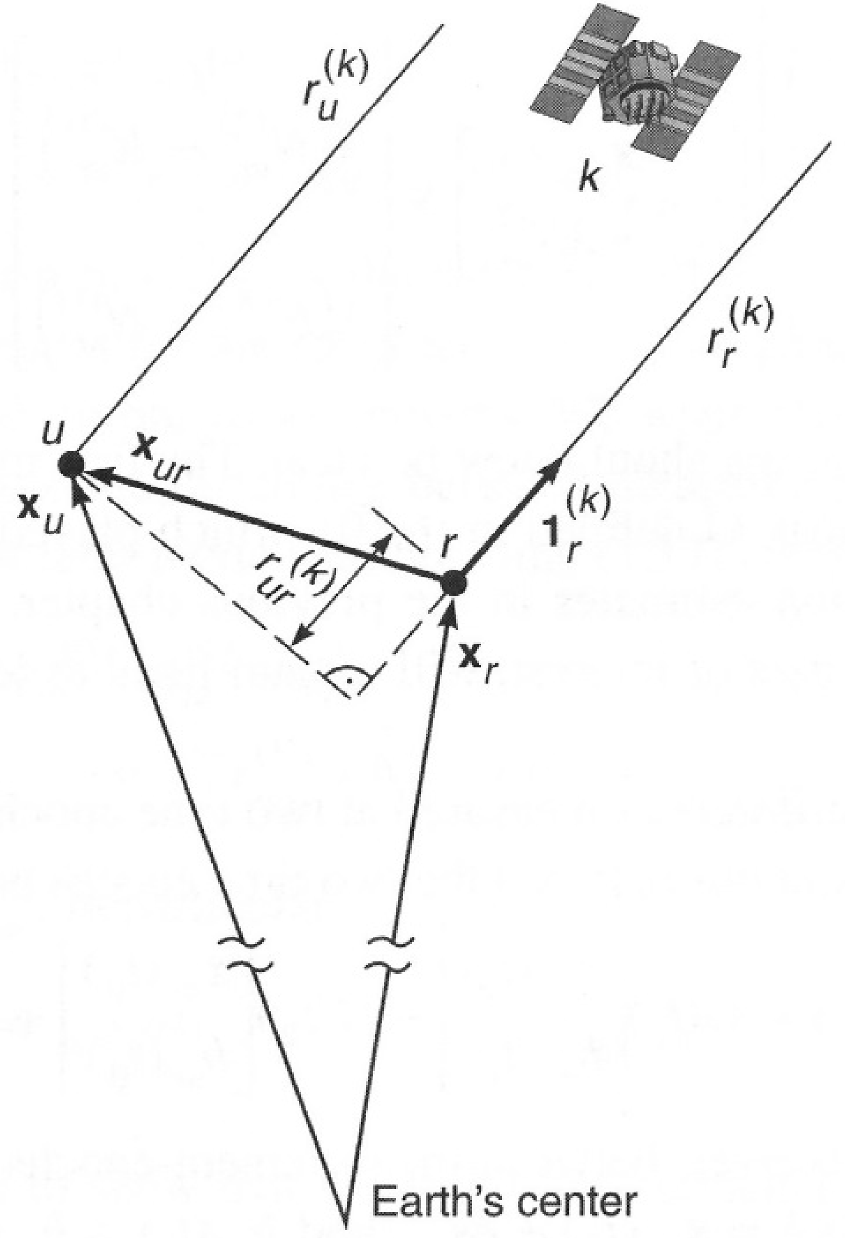


Figure 7.4 Geometry of the single-difference measurements.

phase observable

$$\phi_r^k = \frac{1}{\lambda}\left[r_r^k - I_r^k + T_r^k\right] + \frac{c}{\lambda}\left(dt_r - dt^k\right) + N_r^k + \varepsilon_r^k$$

differencing for short baseline

$$\phi_u^k - \phi_r^k = \frac{1}{\lambda}\left[(r_u^k - r_r^k) - (I_u^k - I_r^k) + (T_u^k - T_r^k)\right] + \frac{c}{\lambda}\left(dt_u - dt_r\right) + \left(N_u^k - N_r^k\right) + \left(\varepsilon_u^k - \varepsilon_r^k\right)$$

$$\phi_{ur}^k = \frac{1}{\lambda} r_{ur}^k + \frac{c}{\lambda} dt_{ur} + N_{ur}^k + \varepsilon_{ur}^k$$

relative position vector in range term

$$r_{ur}^k = r_u^k - r_r^k = -\mathbf{1}_r^k \cdot \mathbf{x}_{ur}$$

$$\mathbf{x}_{ur} = \mathbf{x}_u - \mathbf{x}_r$$

short baseline + differencing ⇒
Sys. Error terms disappear
Abs. → Relative positioning

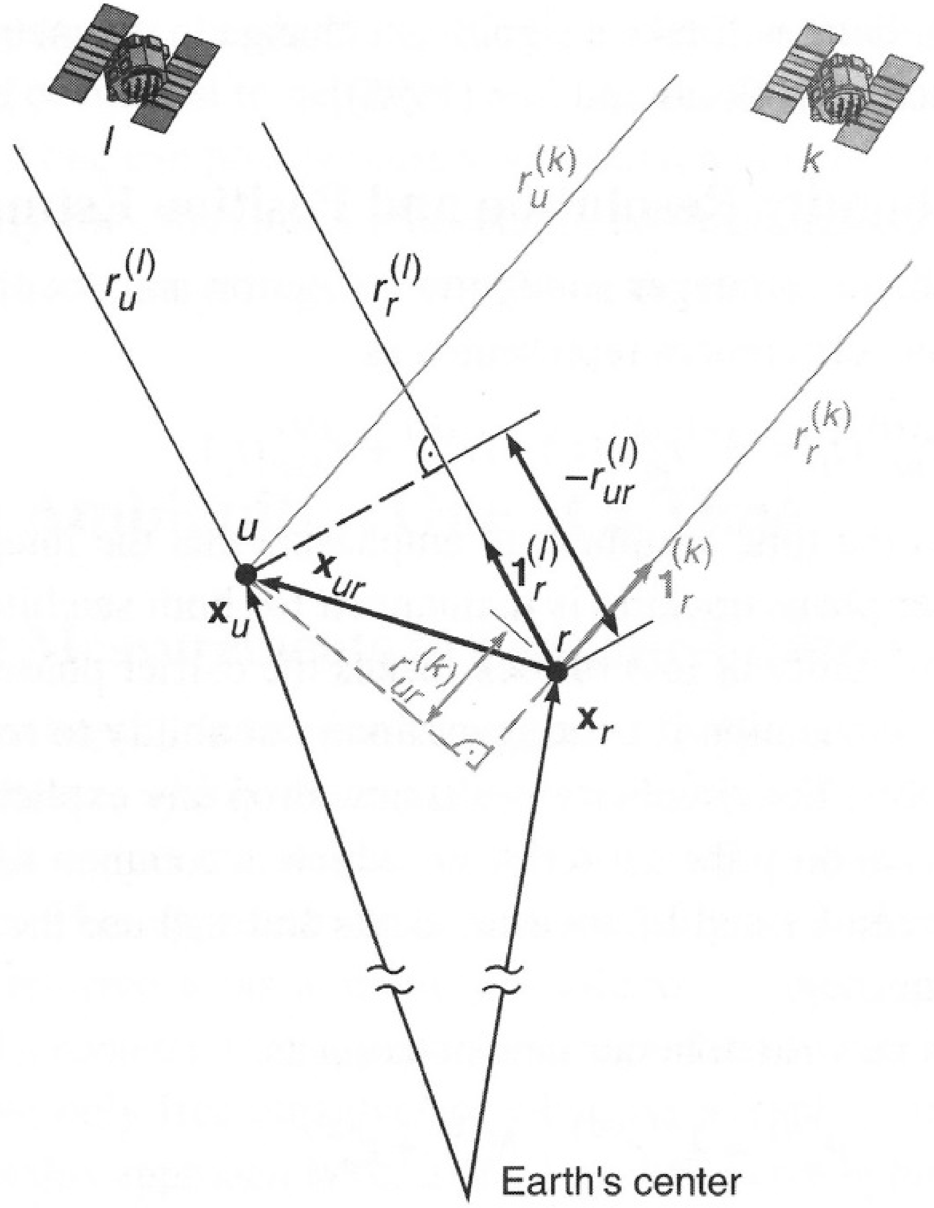


Figure 7.6 Geometry of the double-difference measurements.

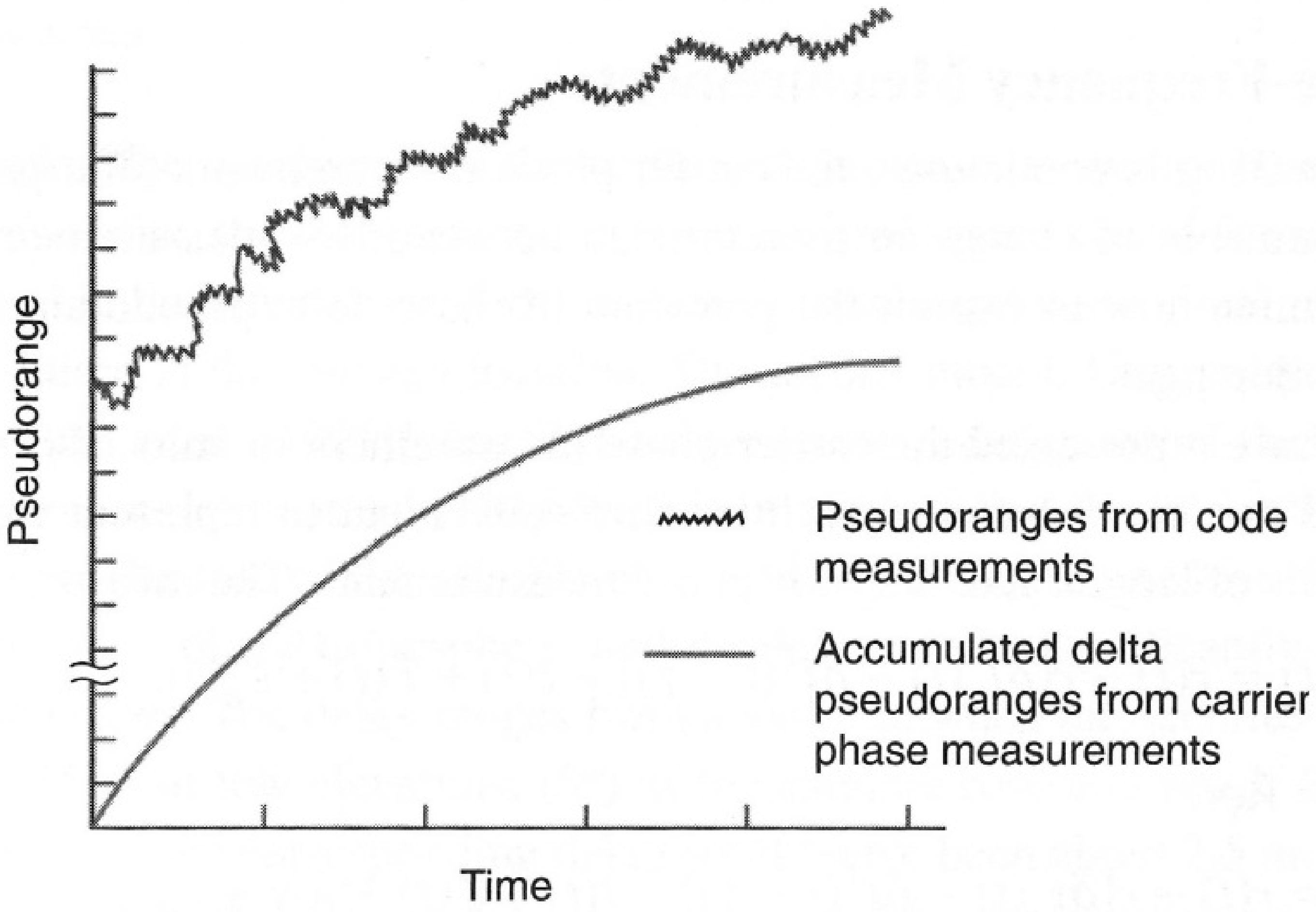


Figure 5.15 A conceptual view of the pseudoranges computed from the code and carrier phase measurements. The code-based measurements are noisy. The carrier-based estimates are precise but ambiguous, and the plot starts arbitrarily at zero value. The carrier phase measurements provide accurate estimates of delta pseudoranges, and can be used to smooth the code-based pseudoranges.

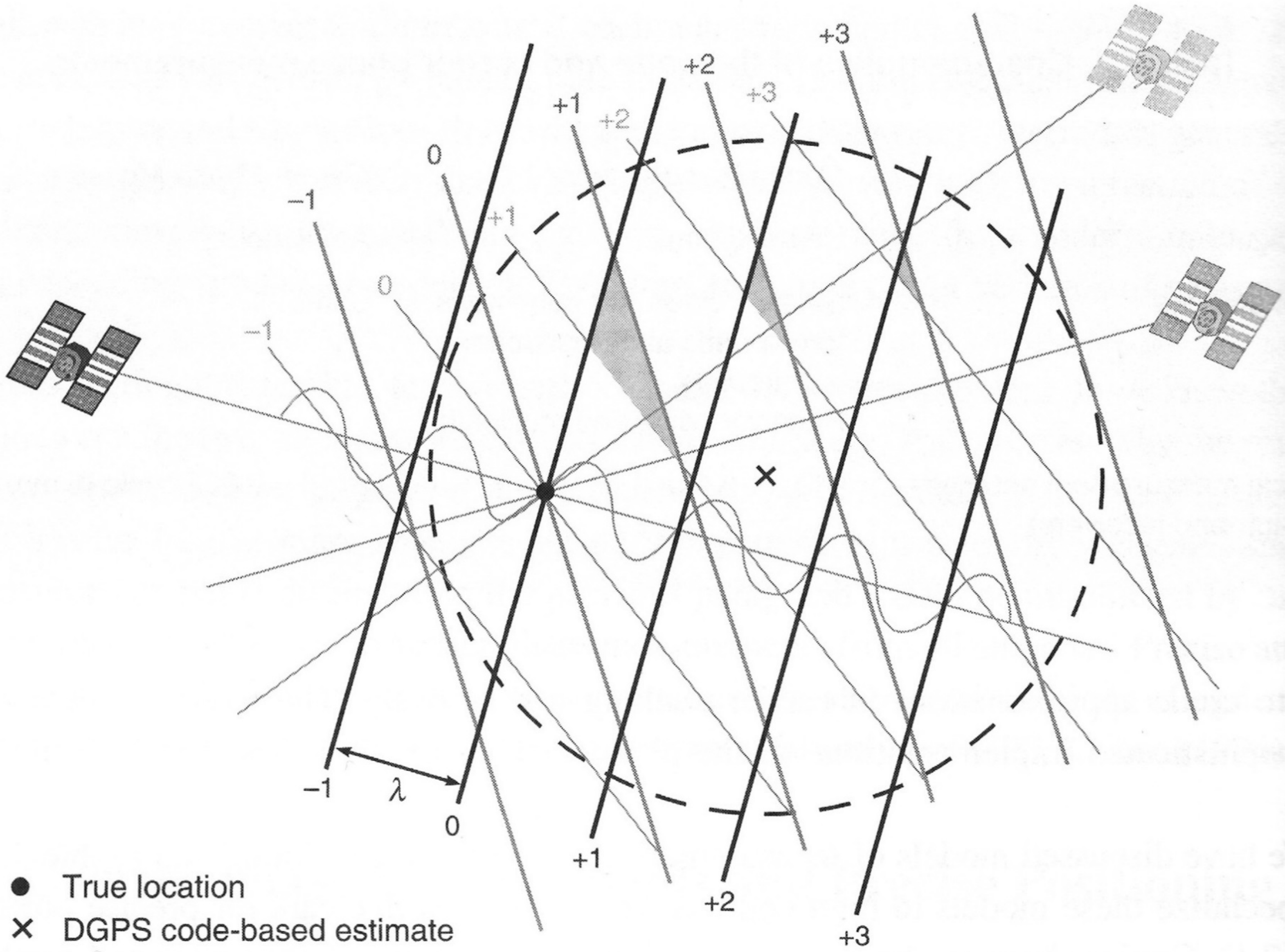
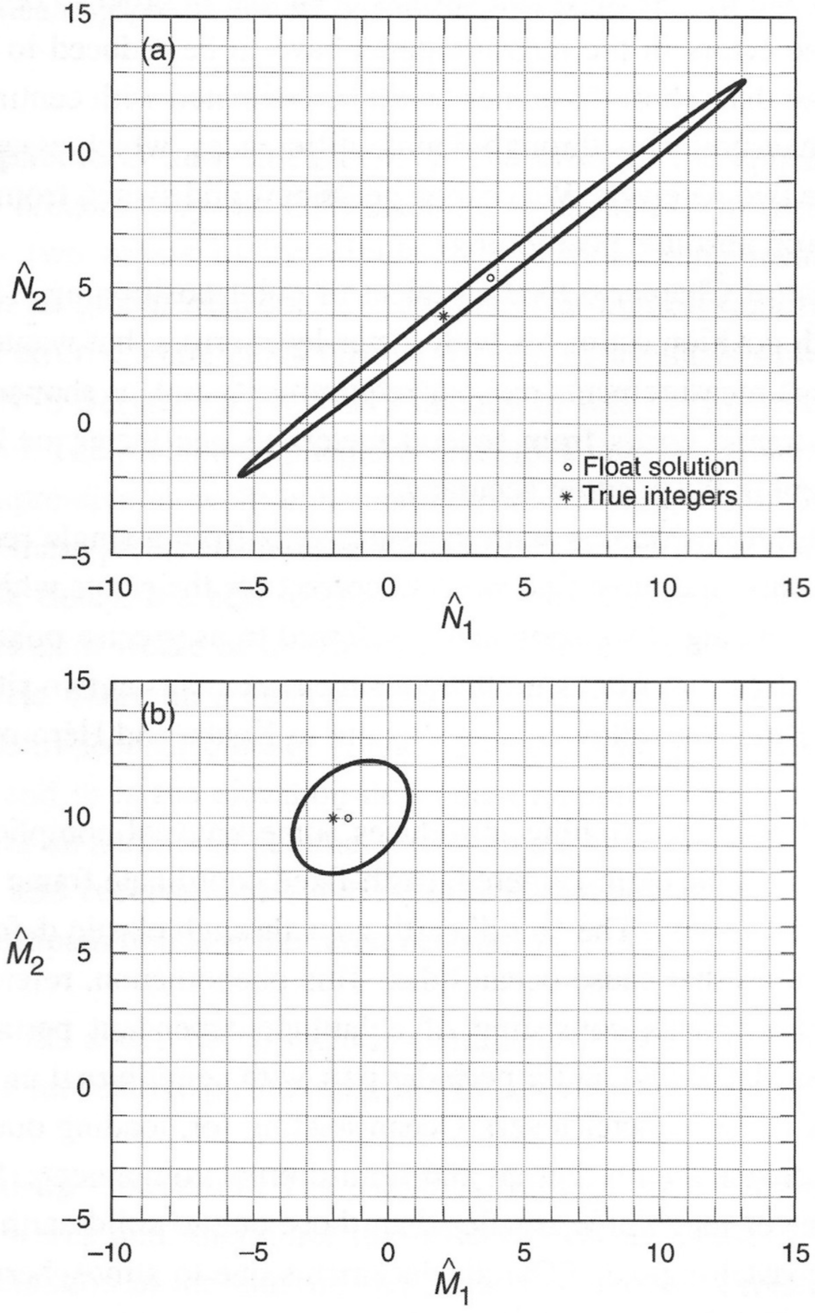
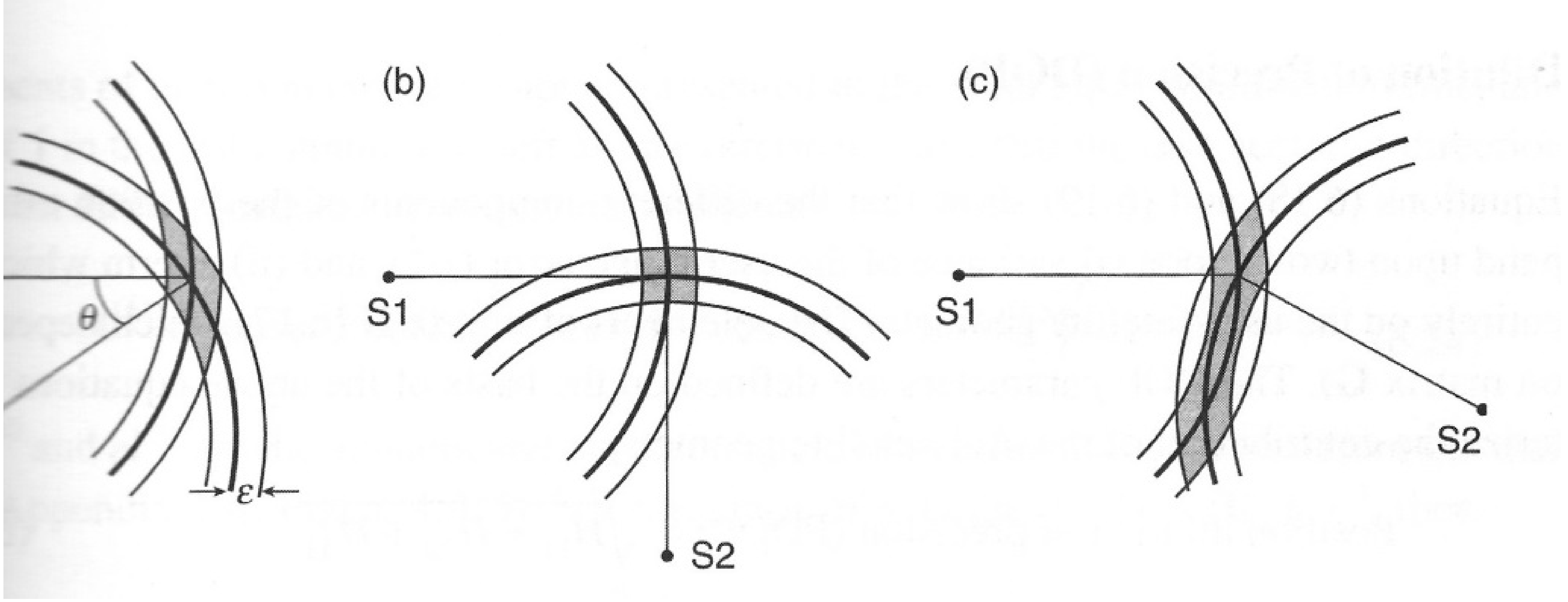


Figure 7.2 Positioning with carrier phase measurements. The user is located at a point where th
wave fronts from the different satellites meet in the observed phase relationship.


(a)
15
10
5
0
−5
$\hat{N}_2$
−10
−5
0
5
10
15
$\hat{N}_1$
○ Float solution
* True integers
(b)
15
10
5
0
−5
$\hat{M}_2$
−10
−5
0
5
10
15
$\hat{M}_1$


θ
ε
(b)
S1
S2
(c)
S1
S2

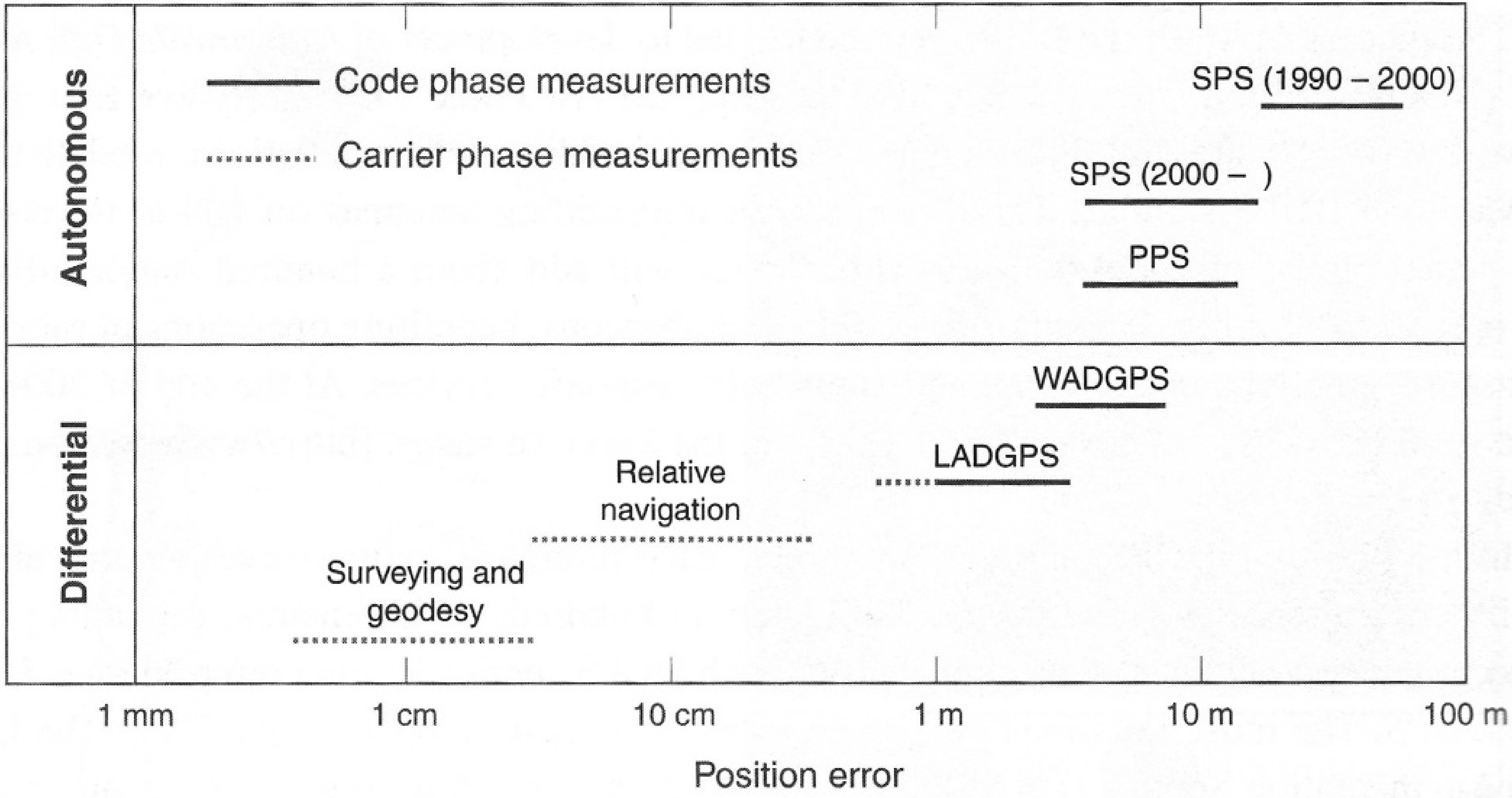
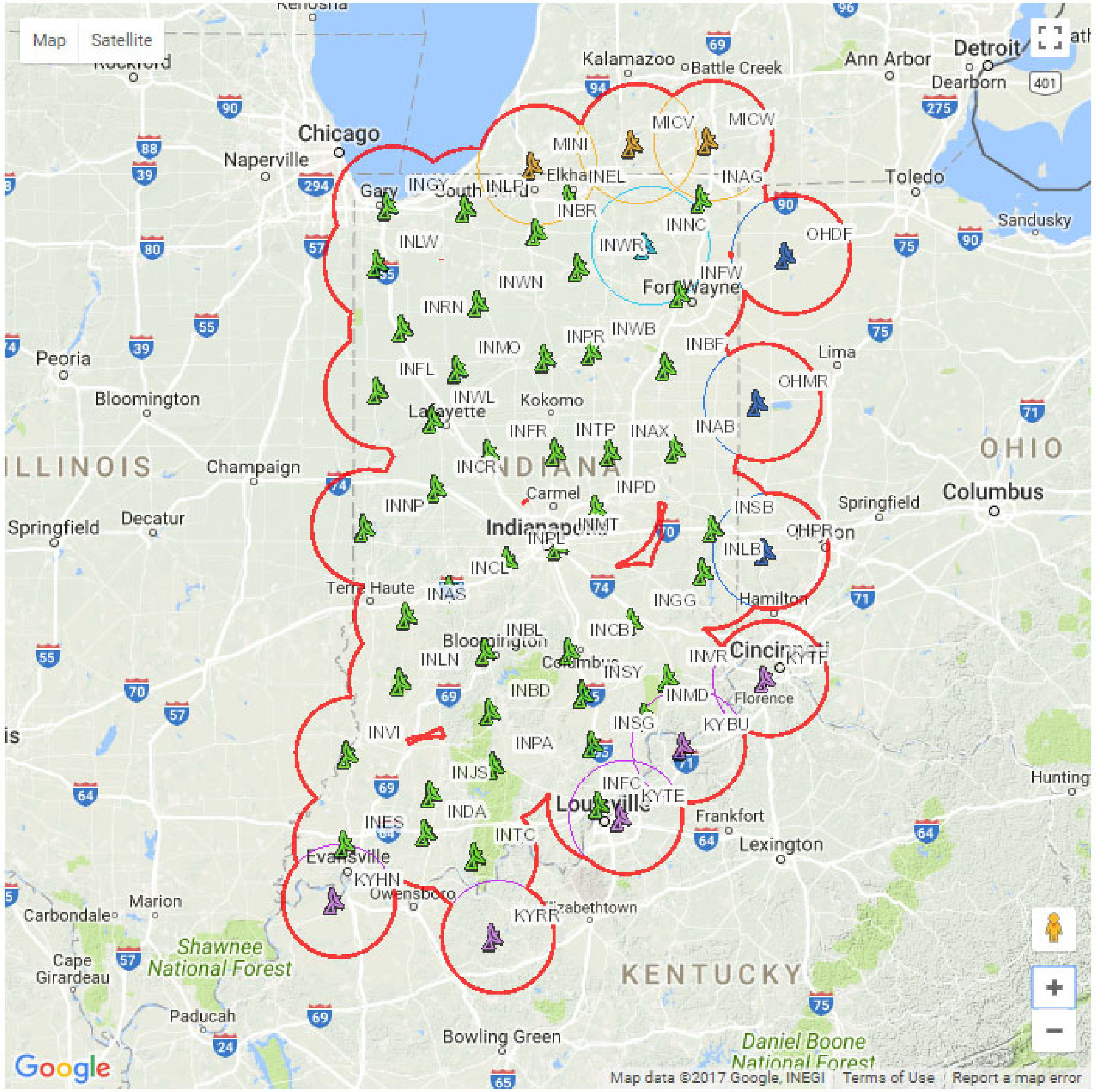


Figure 2.11 A summary of GPS performance in different modes.

InCORS Station Locations

45 Sites across the state operated by INDOT as well as 13 Sites
from Neighboring Partners that are included in the RTN solution.
Outer red buffer is 35km. The 35km buffers around Neighboring Partner
sites depict the additional coverage provided by these sites.
Mouse Click inside any of the 45 State owned (INDOT operated) sites
for information and status of each location.



Indiana Continuously Operating Reference Stations

Allows users to do RTK, real time kinematic without setting up their own base stations, only need a rover and an internet connection to receive differential data.

This has been a big driver for precision Agriculture, and automated blade positioning for earth movers, as well as conventional geomatics.

Fast is fine, but accuracy is everything.

Wyatt Earp

A witty saying proves nothing.

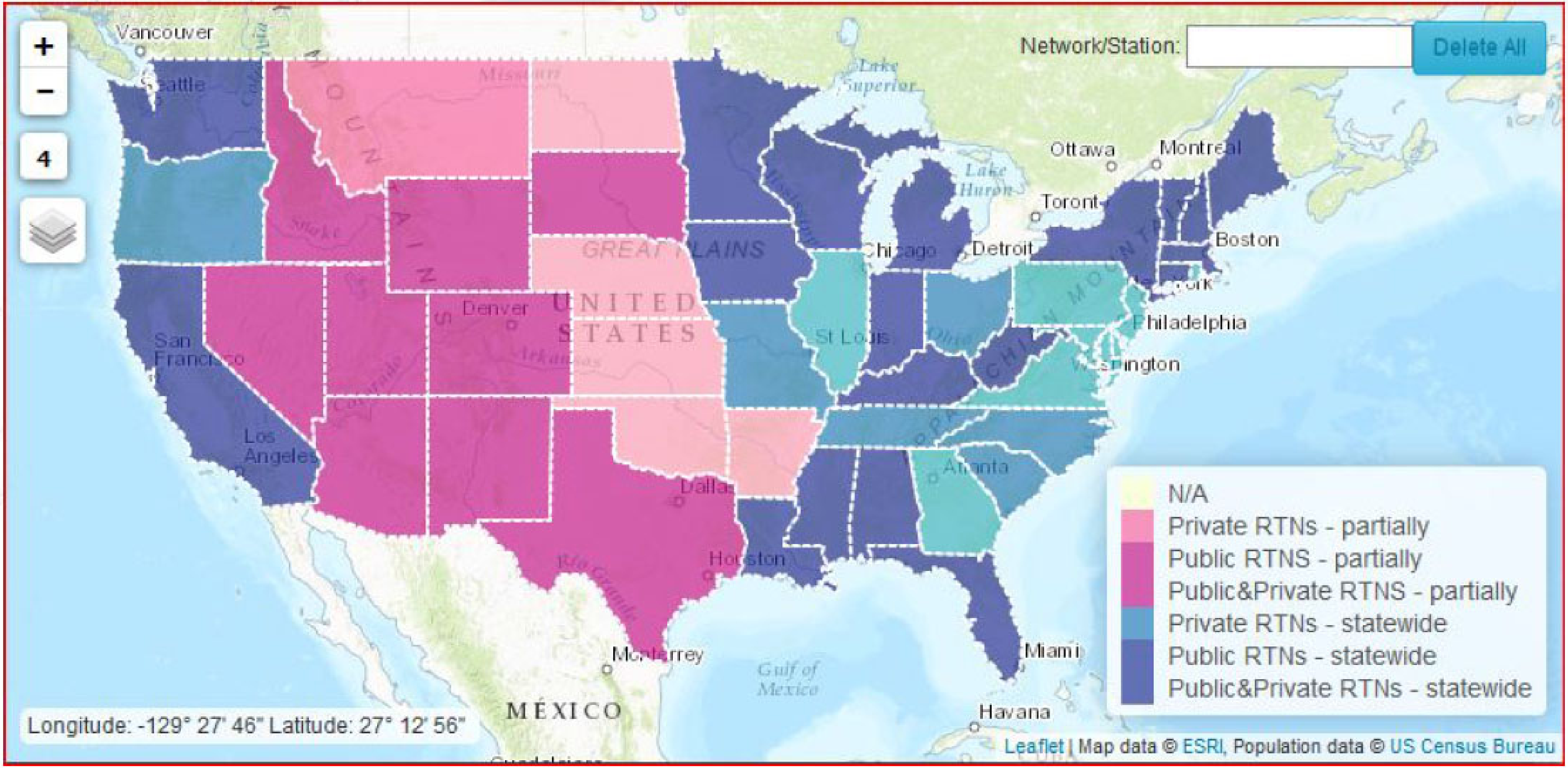
Voltaire

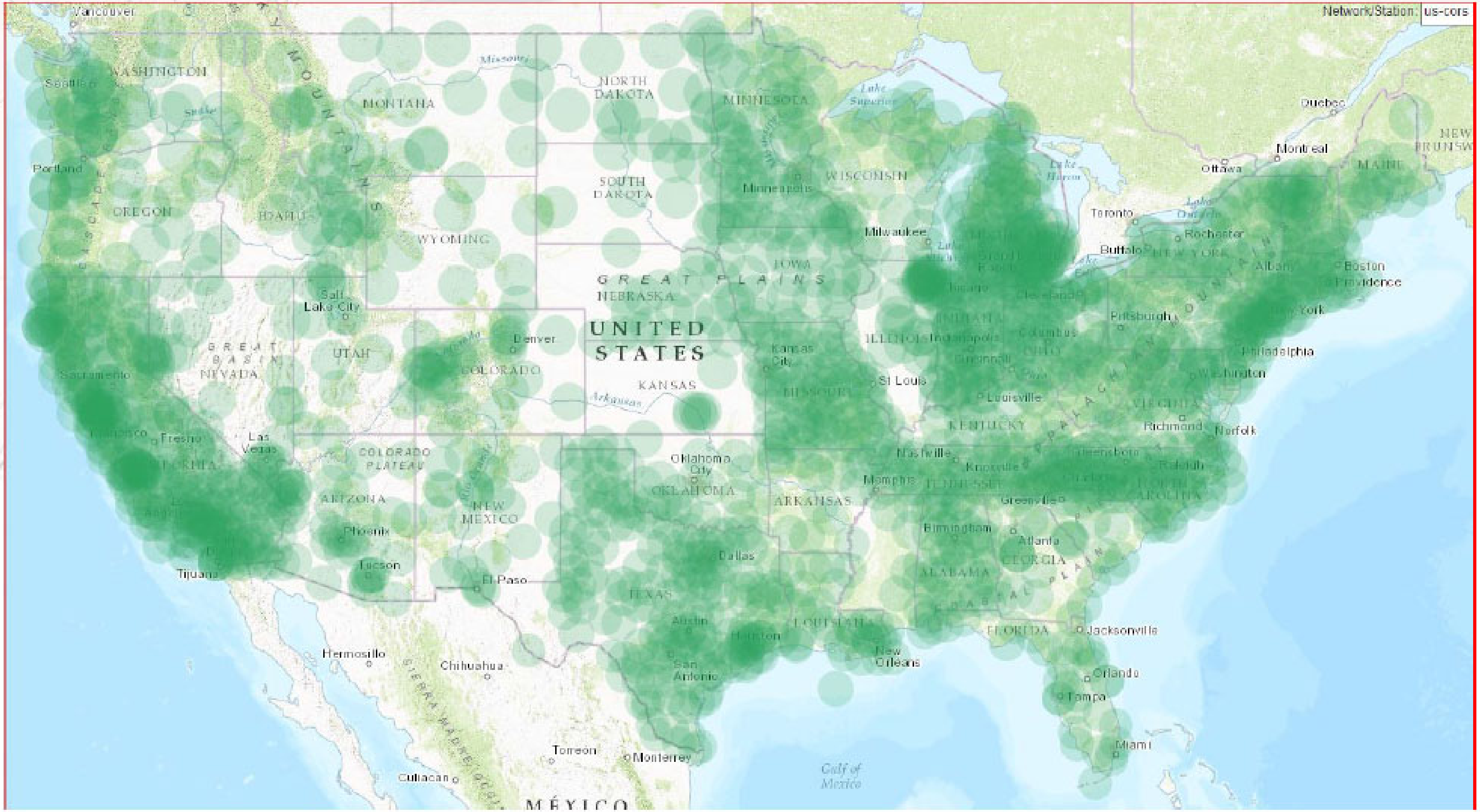
NGS 10-year plan 2008-2018

Ten-Year Milestones (2018):

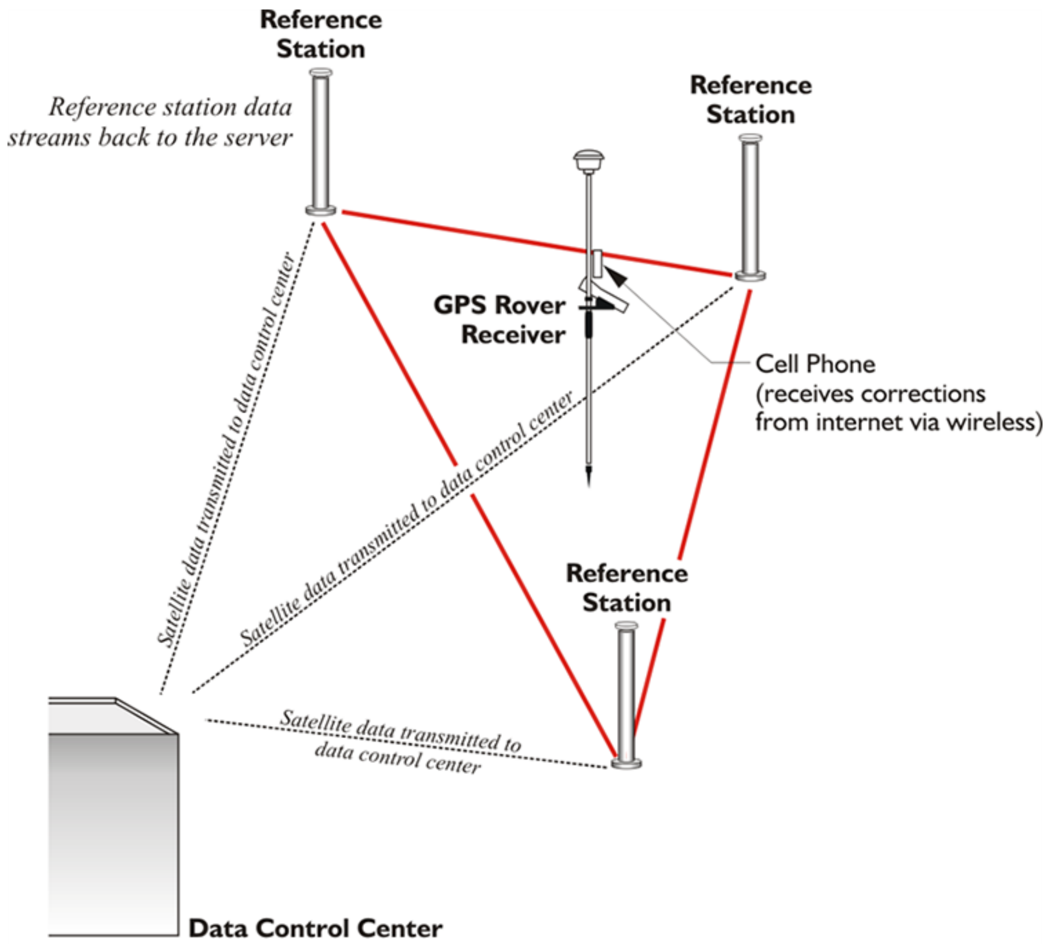
1. NGS provides 1-cm access to the geodetic latitude, longitude and height components of the NSRS for all GPS-exclusive users (with geodetic quality receivers) with *less than 15 minutes* of data anywhere in the United States or its territories.

2. NGS has proof that a gravimetric geoid accurate to 1 cm is computable (or details where and why it is not).


Network/Station:
Delete All
N/A
Private RTNs - partially
Public RTNS - partially
Public&Private RTNS - partially
Private RTNs - statewide
Public RTNs - statewide
Public&Private RTNs - statewide
Longitude: -129° 27' 46" Latitude: 27° 12' 56"
Leaflet | Map data © ESRI, Population data © US Census Bureau



Operational CORS (~1700) with 70km-buffer



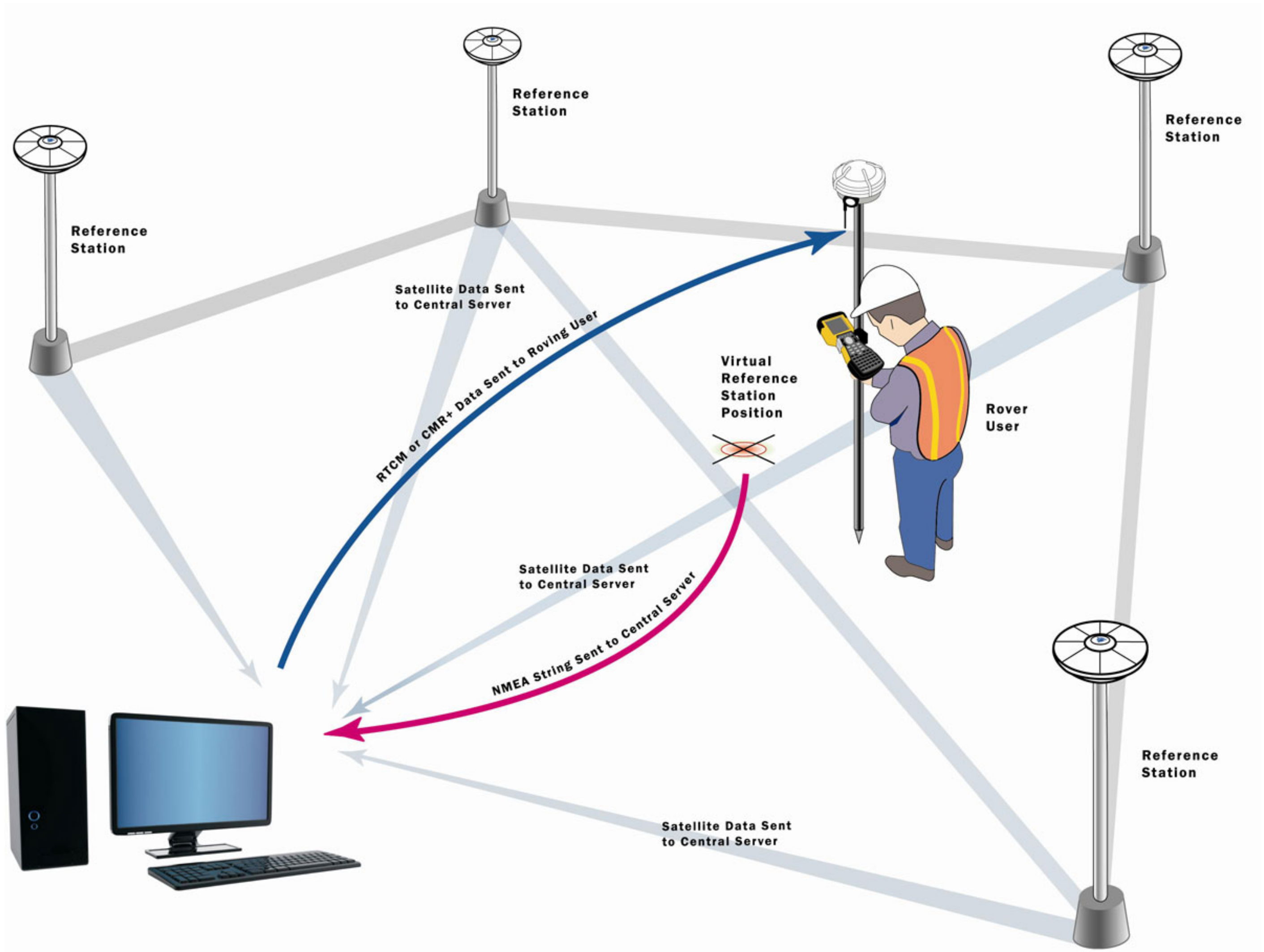


Image courtesy of Trimble