GPS EASY Suite II

easy17—Visualizing Satellite Orbits
easy18—Computing Range and Range Rate Corrections

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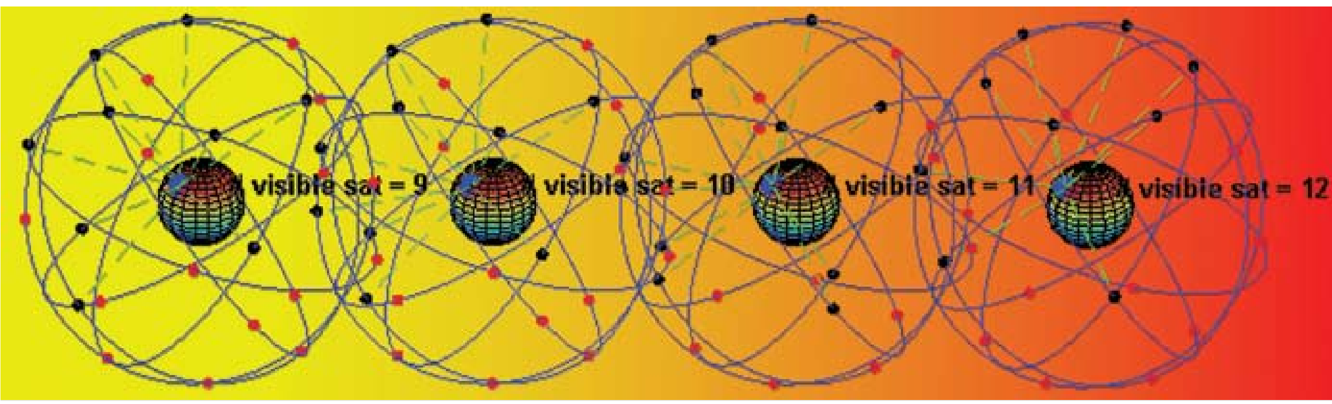


Image of GPS constellation based on public domain file from Wikimedia Commons

In the final two installments in our series, the author describes what GPS orbits would look like from various perspectives and explains how to solve for range and range-rate corrections at a GPS base station.

Newcomers often have difficulties imagining what the satellite orbits actually look like.

We say that the constellation consists of some 30 satellites orbiting in six different planes, all making an angle with the Equator of 55 degrees and rotated 60 degrees compared to the previous plane. **Figure 1** shows the situation as seen from far away in space, in what we call an *inertial frame*.

However, things get less clear if the viewer is on the surface of the rotating Earth. How do the trajectories then look? Very weird is how.

The situation is depicted in **Figure 2**.

Here we use the so-called *Earth Centered Earth Fixed (ECEF) coordinate system*. The ECEF system is in a fixed relationship with the rotating Earth. That is, a given physical point on the surface maintains its coordinates over time, except for possible movements of the crust.

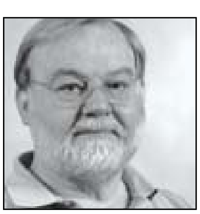
Finally, **Figure 3** shows a curve made up of the *sub-satellite points* of an arbitrary part of an orbit.

The curve is the intersection between the surface of the Earth and the line segment between the satellite and the origin. This sub-satellite curve runs within a symmetric belt on both sides of equator and is limited by northern and southern latitudes equal to the inclination angle of the orbit with the equator.

easy 18

Once I was teaching GPS to control engineers working with air traffic. A need came up for computing range and range rate

Author



Originally graduated as a chartered surveyor, **Kai Borre** obtained his Ph.D. in geodesy from Copenhagen University, and a Doctor of Technology degree from Graz University of Technology. He has been a full professor in geodesy at Aalborg University since 1976. For more than 30 years Borre has conducted research and performed education in the area of satellite based positioning. In 1996 he established the Danish GPS Center and since 2000 has been head of a two-year international M.Sc. program in GPS technology.Borre is a coauthor of the widely used textbooks, *Linear Algebra, Geodesy, and GPS* and *A Software-Defined GPS and Galileo Receiver; Single-Frequency Approach*. Since the early 1990s Borre has published Matlab code for processing of GPS observations, and since 2003 he published Matlab code together with explanatory text, a very successful new pedagogical concept.

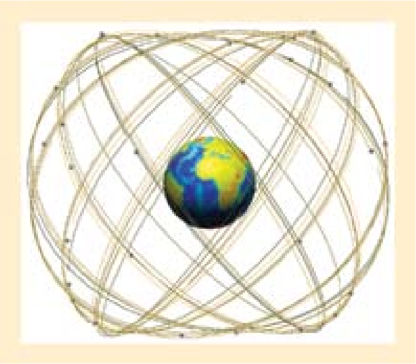


FIGURE 1 **Satellite orbits as seen in inertial frame**

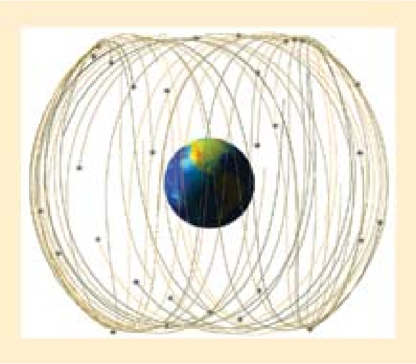


FIGURE 2 **Satellite orbits as seen in Earth Centered Earth Fixed frame**

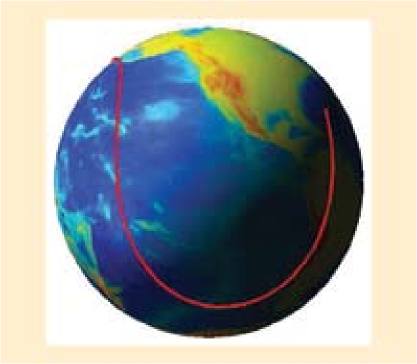


FIGURE 3 **Sub-satellite points for a selected satellite**

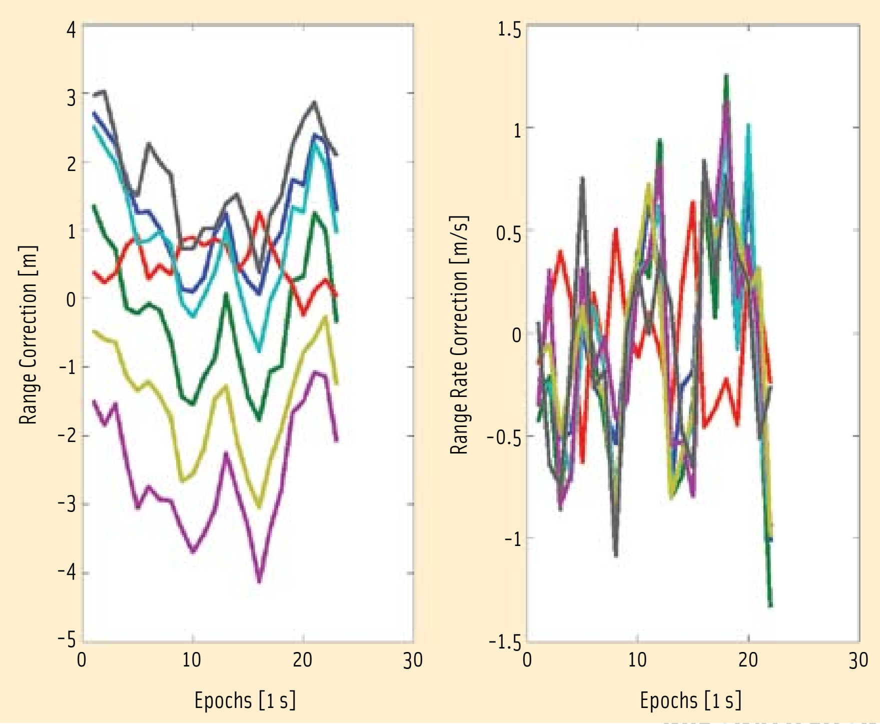


FIGURE 4 **Range and range rate corrections as generated at a base station**

corrections at a base station. Here is the solution.

Let ρ denote the geometric distance between the satellite and the receiver antennas, dt_i denote the receiver clock offset, dt^k the satellite clock offset, and T the tropospheric delay. Then the corrected range is computed as

$$\rho^* = \rho + cdt_i - cdt^k + T$$

and the range correction as

$$d = \rho^* - P_{obs}.$$

Figure 4 shows range and range rate corrections over 23 epochs using September 4, 2001, data.

The receiver clock offset pos(4,:) varies between 1.13×10^5 and 1.15×10^5 through the 23-second period of observations.

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research projects. From 2000 until 2005 Hecker was head of the DLR "Pilot Assistance" Department. Since April 2005 he has been director of the Institute of Flight Guidance of the Technische Universität Braunschweig. He is managing research activities in the areas of air/ground co-operative air traffic management, airborne measurement technologies and services, satellite navigation, human factors in aviation, and safety in air transport systems.

Felix Kneissl is a research associate at the Institute of Geodesy and Navigation (IGN) of the University of the Federal Armed Forces in Munich. He received his diploma in mathematics at the Technical University in Munich (TUM). Since then he

has worked on projects related to GNSS integrity data processing, GNSS signal monitoring, and GNSS user and signal authentication. IG