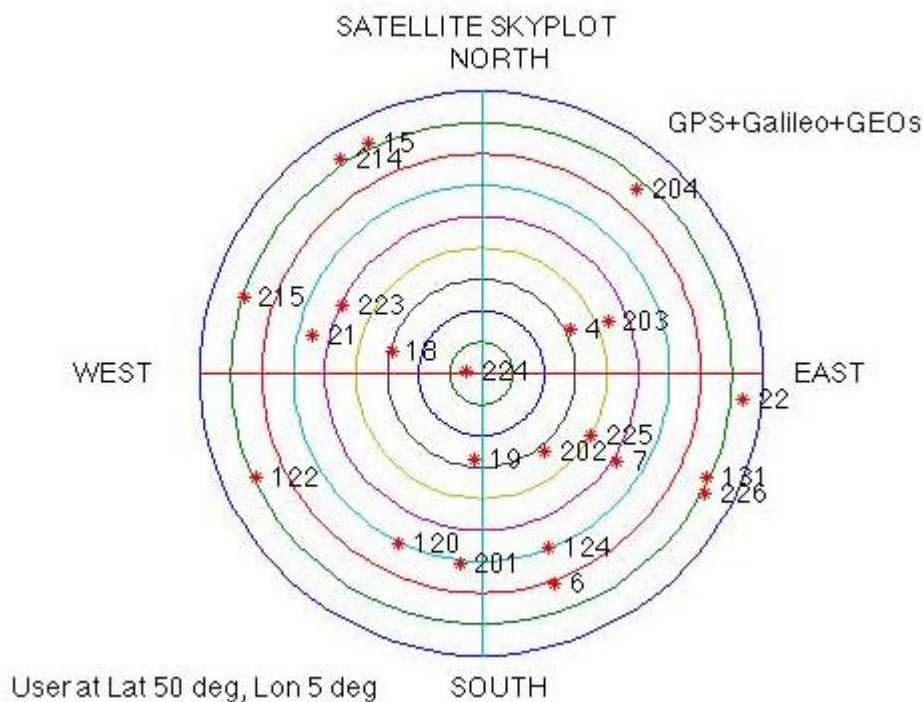# SatNav Toolbox 3.0 for MATLAB

The Satellite Navigation (SatNav) Toolbox for MATLAB was designed specifically for this purpose. The SatNav Toolbox allows one to simulate the satellites, the propagation environment, the receiver measurements and the data processing. The SatNav Toolbox supports the simulation of virtually all satellite navigation applications from stand-alone positioning up through ambiguity resolution for differential carrier-phase applications. Users can simulate constellations like Galileo which have not yet been fielded. With the release of version 3.0, we have added real-data processing via RINEX2 data file support capabilities to the toolbox.

The links below provide examples of analyses that can be performed with the SatNav Toolbox:

- Satellite Skyplots
- Position Solution
- Dilution-of-Precision (DOP) Analysis
- Receiver Autonomous Integrity Monitoring (RAIM) example

To Order the SatNav Toolbox 3.0:

Contact NavtechGPS

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Satellite Skyplots

The SatNav Toolbox provides functions that allow users to produce skyplots of satellite positions for simulated constellations as well as for real constellations (via almanac or ephemeris files). Skyplots provide essentially 'fish-eye' views of the sky. The center of the plot represents a point directly overhead the specified location. The outermost ring corresponds to the horizon.
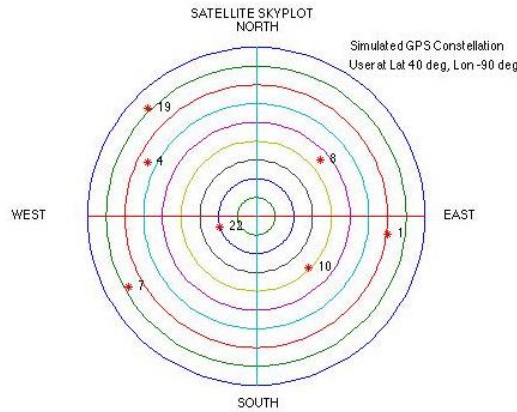

Example programs are also provided to help illustrate how the satellites move across the sky. Here is an example of satellite motion across the sky for a one-hour period for a user at 0 deg latitude (Lat) and 0 deg longitude (Lon):
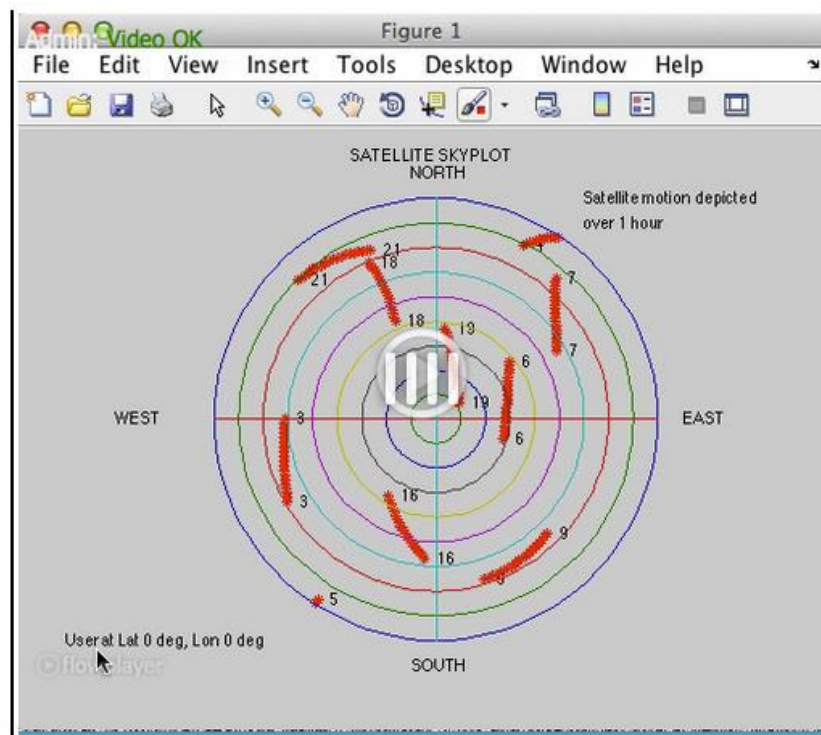

"What happens if we look at the sky over an entire day?"
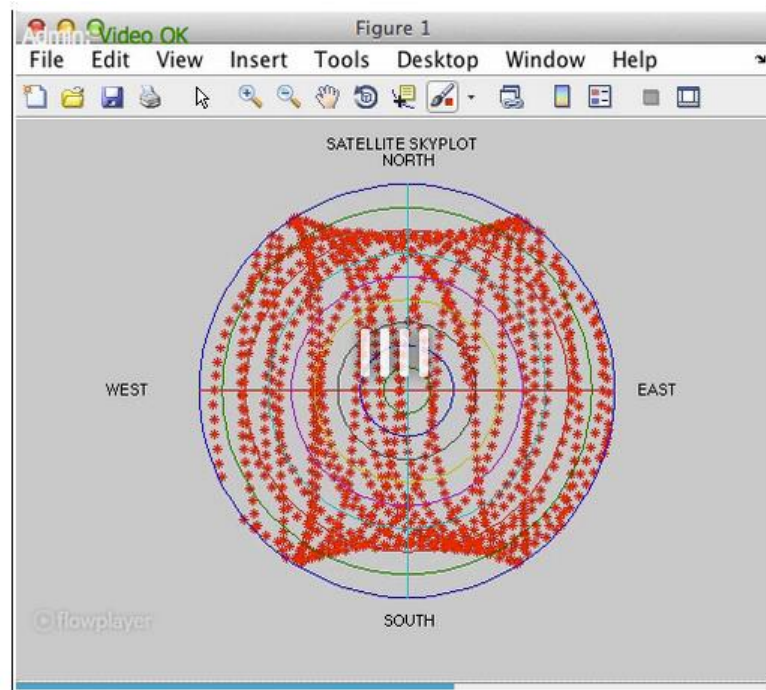
Although satellites appear in most parts of the sky, there are two 'holes' in the sky where no satellites ever appear. This is due to the fact that GPS satellite orbital planes are inclined at 55 degrees with respect to the equator. The effect is more dramatic for a user a mid latitude:
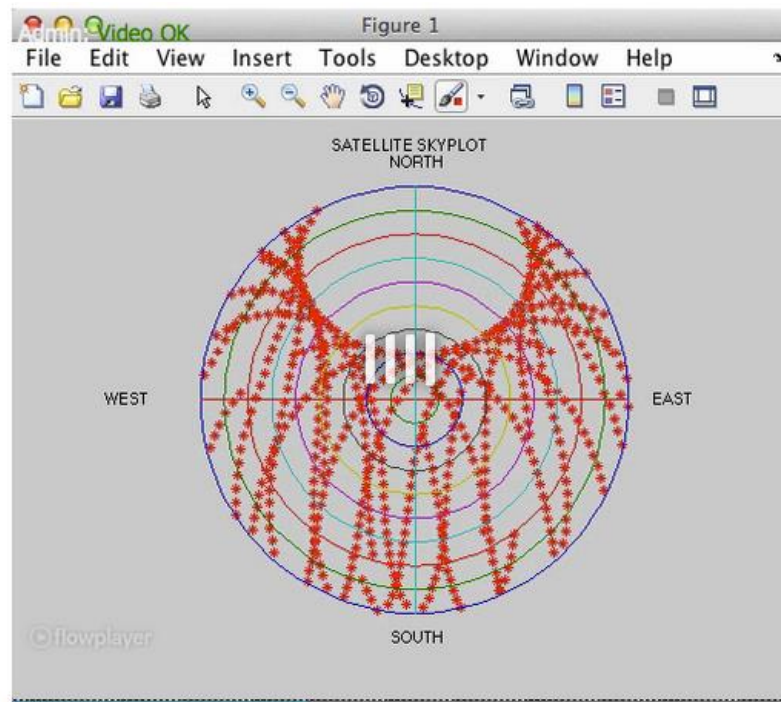
For users in the northern hemisphere there is thus a region in the north direction in which satellites will never appear. If we consider a user very close to the north pole, the 'hole' in satellite coverage is directly overhead:
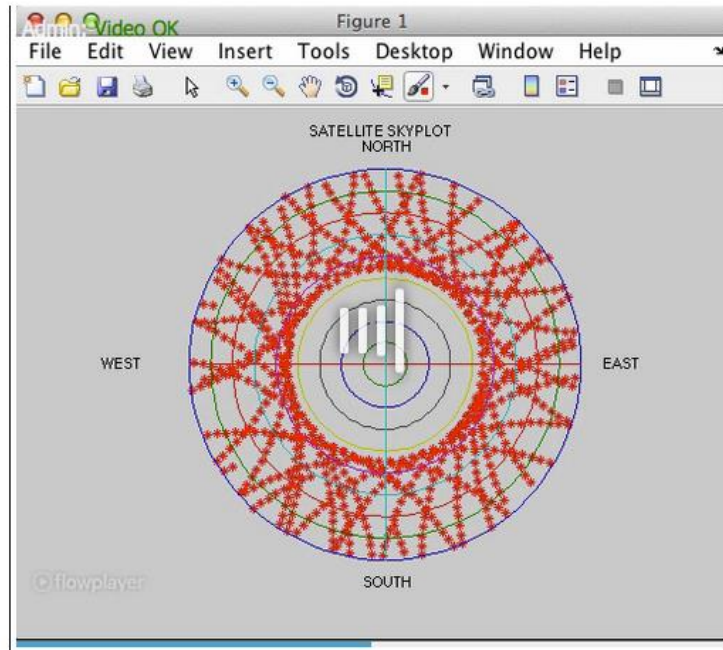
Again, this hole in coverage is due to the 55 degree inclination angle of the satellite orbital planes.

Position Solution

The SatNav Toolbox provides functions and example programs that allow the user to perform position determination based on real pseudorange measurements and broadcast ephemeris data, in RINEX format.

In the example shown here, data was obtained from a continuously operation reference station (CORS) located in Athens, Ohio. Stand-alone (i.e., non-differential) position solutions were calculated using the C/A-code pseudorange measurements. With no tropospheric or ionospheric corrections applied, the horizontal position error is still within +/- 5 meters:
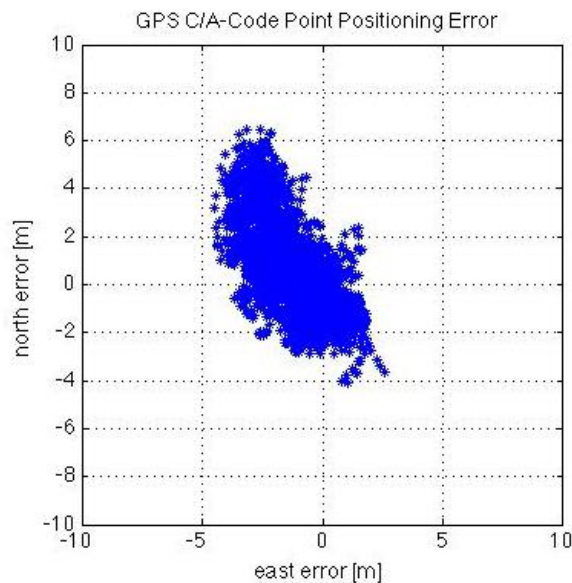

The following plot shows the separate position error components:

GPS C/A-Code Point Positioning Error
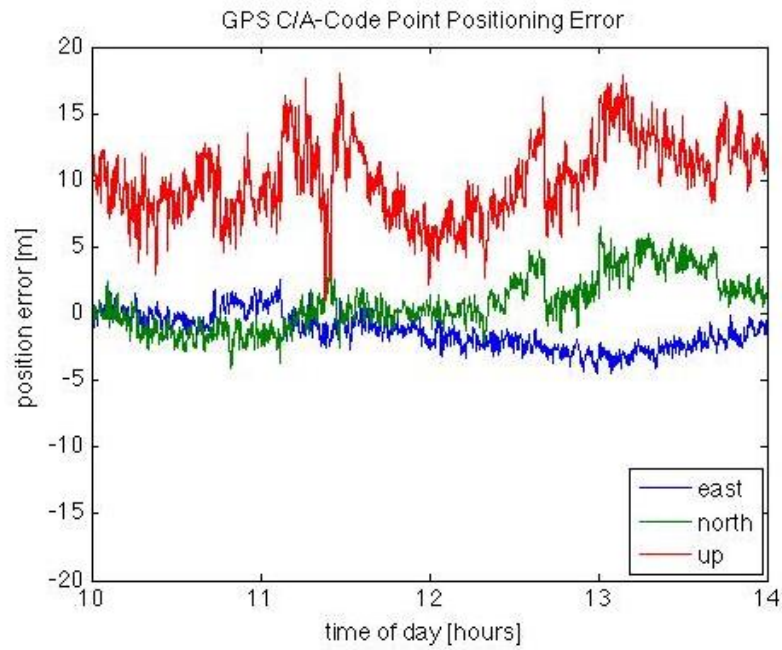
As would be expected, the vertical error is significantly larger than the horizontal error components.

If a simple (i.e., elevation-angle dependent only) tropospheric correction model is applied along with the broadcast ionospheric correction model, the horizontal position error does not seem to improve significantly:

C/A - Tropo and Broadcast Iono Corr. Included
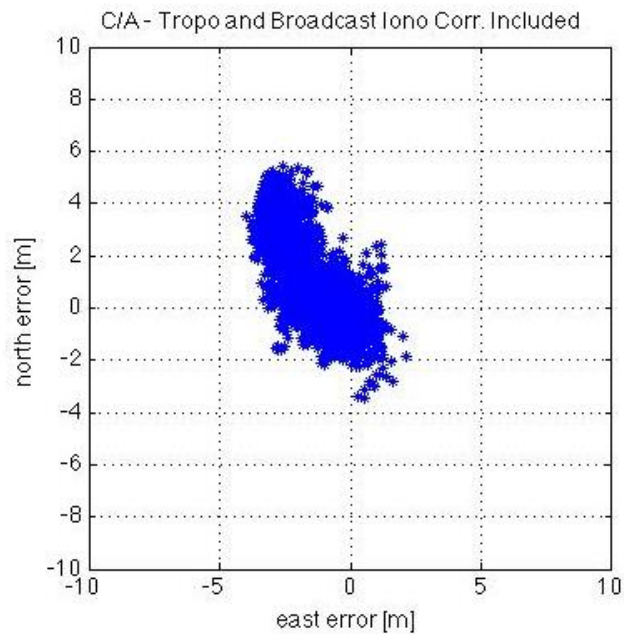
However, examination of the individual components clearly reveals a significant reduction in vertical error:

C/A - Tropo and Broadcast Iono Corr. Included
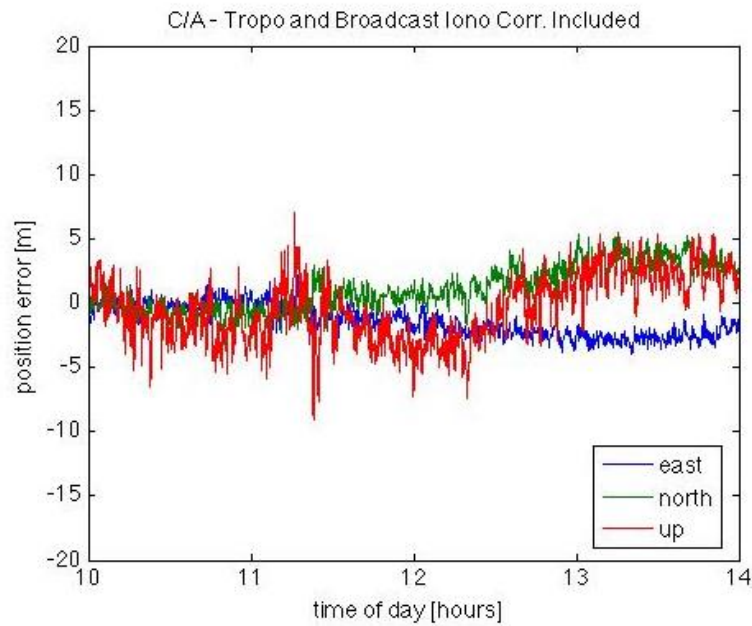
Since the tropospheric and ionospheric errors are composed primarily of biases, the impact is focused on the receiver clock solution and the vertical position error.

Dilution-of-Precision (DOP) Analysis

The SatNav Toolbox allows the user to compute and analyze the effects of dilution-of-precision (DOP). In the example shown here, dual-frequency P(Y)-code pseudorange data was obtained from a continuously operation reference station (CORS) located in Athens, Ohio. Stand-alone (i.e., non-differential) position solutions were calculated with both tropospheric and dual-frequency ionospheric corrections applied. This eliminated the bulk of the bias errors and left primarily noise errors. DOP analysis, strictly speaking, only applies to cases in which the errors on the various measurements are statistically independent (and, ideally, identically distributed).

The following plots illustrate position error components along with scaled DOP values. The DOP values have been scaled for ease of visual comparison with the error plots.


GPS Dual-Freq P-Code
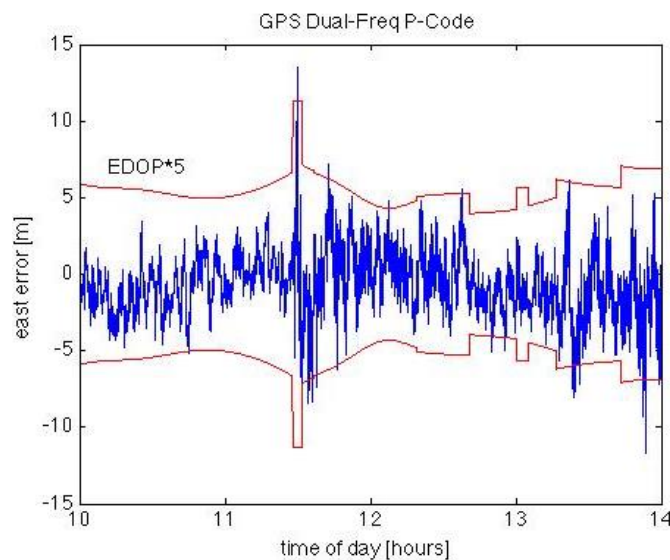
In the east error case, it is observed that error spikes occurring at approximately 11:30 (GPS time) correspond to a spike in the east DOP (EDOP). The correspondence between DOP and error is also clearly evident in the north component:
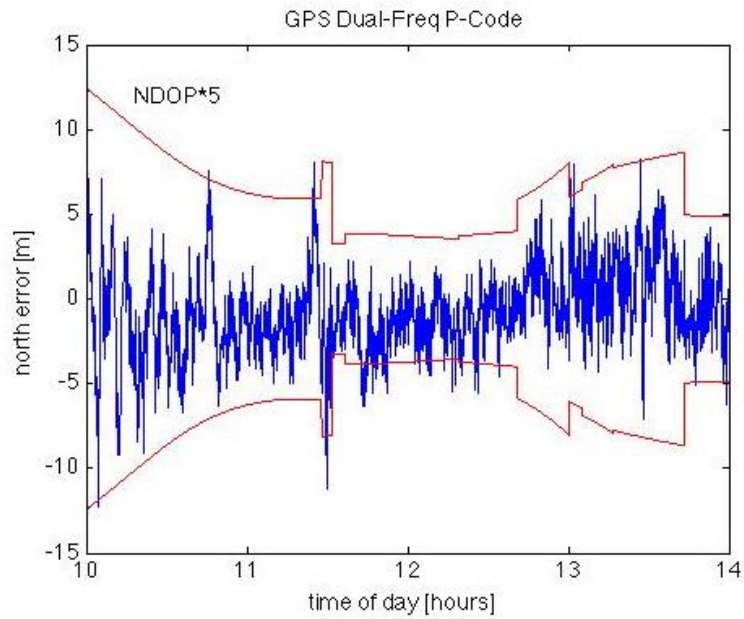
The horizontal error is the root-sum-square of the east and north errors and thus similar behavior is observed:
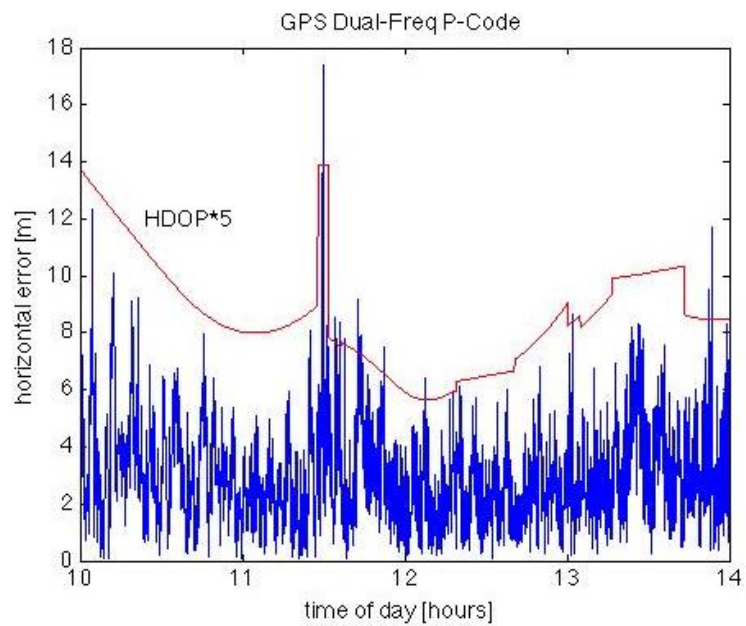
Over the course of the four-hour data collection, significant variations are observed in the vertical error and the VDOP:

GPS Dual-Freq P-Code
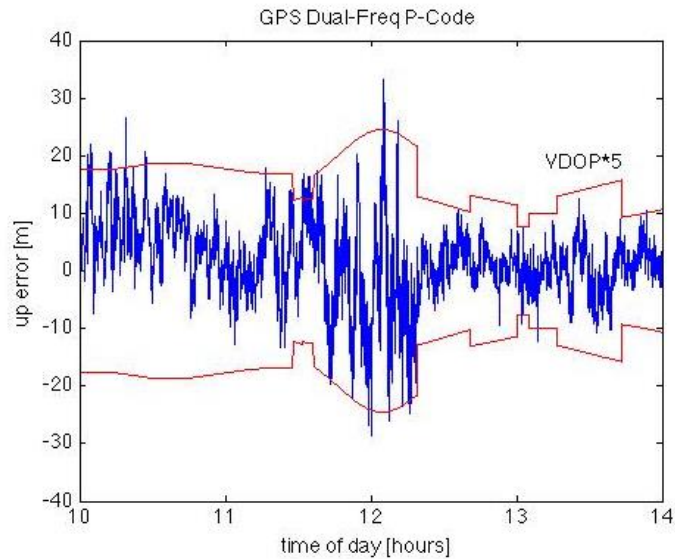
Receiver Autonomous Integrity Monitoring (RAIM) example

The SatNav Toolbox provides functions that allow the user to compute the so-called 'parity vector' which is a test statistic used for fault detection and isolation (FDI). In the world of satellite navigation, FDI is also known as receiver autonomous integrity monitoring (RAIM).

In the example shown here, data was obtained from a continuously operation reference station (CORS) located in Athens, Ohio. Stand-alone (i.e., non-differential) position solutions were calculated using the C/A-code pseudorange measurements. In order to demonstrate the effect of an abnormal error, a slow 'ramp' error of 0.1 meter/second was generated and added to the pseudorange measurements of satellite PRN 28 (which was visible for the entire duration of the data collection).

Over the course of four hours, the induced error has a significant impact on the horizontal position error:

C/A Positioning Err with 0.1 m/s ramp on PRN 28
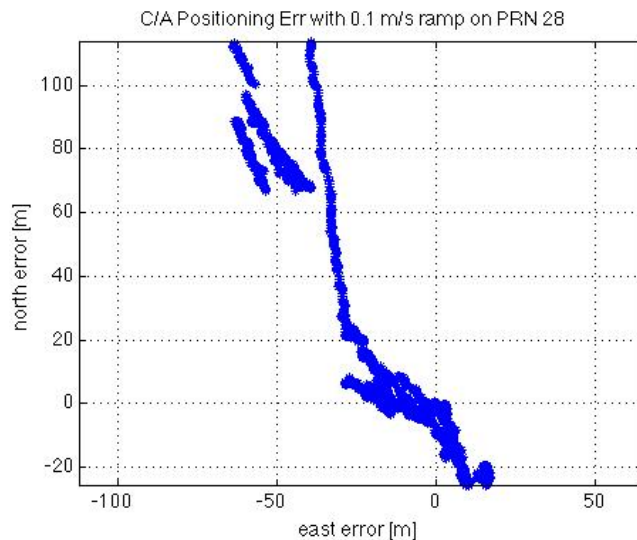
Examination of the individual error components shows the errors to vary significantly as other satellites come into or drop out of the solution:

C/A Positioning Err with 0.1 m/s ramp on PRN 28
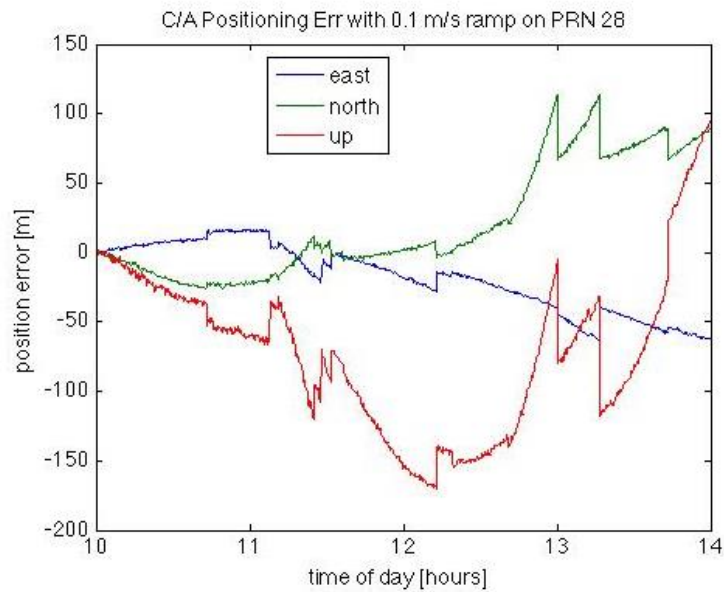
The sudden jumps in the error components are a clearly indication of a constellation change (or, more precisely, a change in the number of satellites used/available in the position solution). If the satellite geometry is favorable, however, the parity vector magnitude can be used as an indication of the position error:

C/A Positioning Err with 0.1 m/s ramp on PRN 28
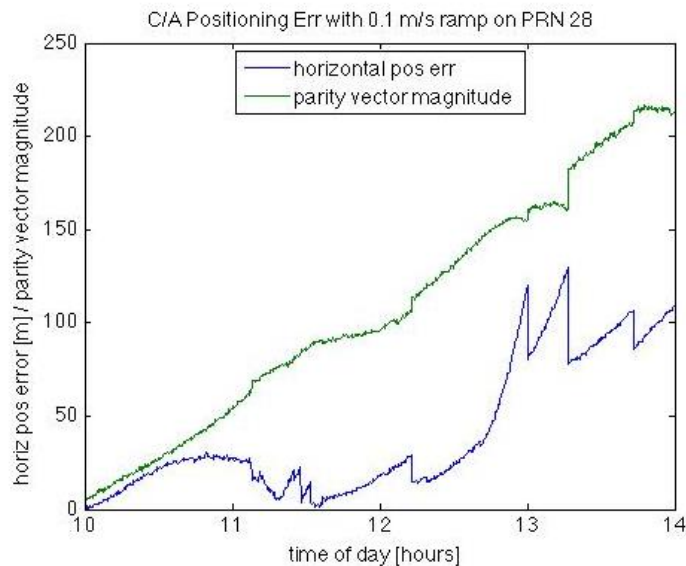
Note that the parity magnitude can be computed in real time by the receiver whereas the actual error is generally unknown. It is known in this example only because the data was obtained from a reference receiver at a surveyed antenna location.

SATNAV TOOLBOX
3.0
FOR MATLAB

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