5

GNSS Receiver Operation Overview

5.1 Receiver Channels

The signal processing for satellite navigation systems is based on a channelized structure. This is true for both GPS and Galileo. This chapter provides an overview of the concept of a receiver channel and the processing that occurs. In later chapters the specifics of the signal and data processing are outlined.

Figure 5.1 gives an overview of a channel. Before allocating a channel to a satellite, the receiver must know which satellites are currently visible. There are two common ways of finding the initially visible satellites. One is referred to as *warm start* and the other is referred to as *cold start*.

Warm start In a warm start, the receiver combines information in the stored almanac data and the last position computed by the receiver. The almanac data is used to compute coarse positions of all satellites at the actual time. These positions are then combined with the receiver position in an algorithm computing which satellites should be visible. The warm start has at least two downsides. If the receiver has been moved far away since it was turned off (e.g., to another continent), the receiver position cannot be trusted and the found satellites do not match the actual visible satellites. Another case is that the almanac data can be outdated, so they cannot provide good satellite positions. In either case, the receiver has to make a cold start.

Cold start In a cold start, the receiver does not rely on any stored information. Instead it starts from scratch searching for satellites. The method of searching is referred to as acquisition and it is described in the following section.

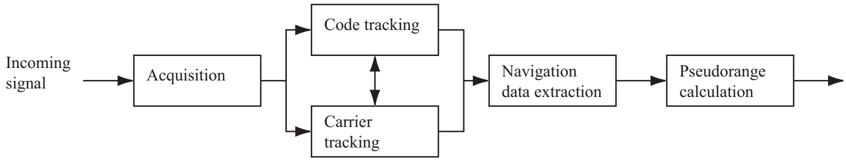

FIGURE 5.1. One receiver channel. The acquisition gives rough estimates of signal parameters. These parameters are refined by the two tracking blocks. After tracking, the navigation data can be extracted and pseudoranges can be computed.

An acquisition search through all possible satellites is quite time-consuming. That is, in fact, the reason why a warm start is preferred if possible.

5.1.1 Acquisition

The purpose of acquisition is to identify all satellites visible to the user. If a satellite is visible, the acquisition must determine the following two properties of the signal:

Frequency The frequency of the signal from a specific satellite can differ from its nominal value. In case of downconversion, the nominal frequency of the GPS signal on L1 corresponds to the IF. However, the signals are affected by the relative motion of the satellite, causing a Doppler effect. The Doppler frequency shift can—in the case of maximum velocity of the satellite combined with a very high user velocity—approach values as high as 10 kHz; see Tsui (2000), page 39. For a stationary receiver on Earth, the Doppler frequency shift will never exceed 5 kHz.

Code Phase The code phase denotes the point in the current data block where the C/A code begins. If a data block of 1 ms is examined, the data include an entire C/A code and thus one beginning of a C/A code.

Many different methods have been used: they are all in one way or another based on the GPS signal properties. The C/A code correlation properties are especially important; see Section 2.3.4.

The received signal s is a combination of signals from all n visible satellites

$$s(t) = s^1(t) + s^2(t) + \cdots + s^n(t). \tag{5.1}$$

When acquiring satellite k, the incoming signal s is multiplied with the local generated C/A code corresponding to the satellite k. The cross correlation between C/A codes for different satellites implies that signals from other satellites are nearly removed by this procedure. To avoid removing the desired signal component, the locally generated C/A code must be properly aligned in time, that is, have the correct code phase.

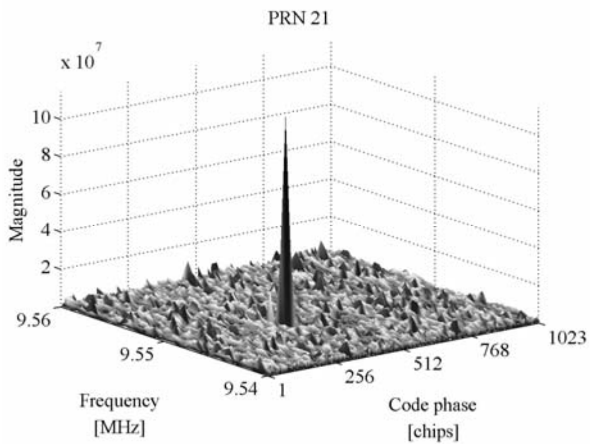

FIGURE 5.2. Acquisition plot for PRN 21. Signals originating from PRN 21 are present in the received signal. This is seen from the significant peak in the acquisition plot. The peak location is related to a C/A code phase and a frequency of the signal.

After multiplication with the locally generated code, the signal must be mixed with a locally generated carrier wave. This is done to remove the carrier wave of the received signal. To remove the carrier wave from the signal, the frequency of the locally generated signal must be close to the signal carrier frequency. As mentioned earlier, the frequency can change up to ± 10 kHz from the nominal frequency, so different frequencies within this area must be tested. To identify whether or not a satellite is visible, it is sufficient to search the frequency in steps of 500 Hz resulting in 41 different frequencies in case of a fast-moving receiver and 21 in case of a static receiver; see Akos (1997), page 85.

After mixing with the locally generated carrier wave, all signal components are squared and summed providing a numerical value.

The acquisition procedure works as a search procedure. For each of the different frequencies 1023 different code phases are tried. When all possibilities for code phase and frequency are tried, a search for the maximum value is performed. If the maximum value exceeds a determined threshold, the satellite is acquired with the corresponding frequency and phase shift. Figure 5.2 shows a typical acquisition plot performed for a visible satellite. The plot shows a significant peak, which indicates high correlation.

Figure 5.3 shows a typical acquisition plot, performed for a satellite that is not currently visible at the GPS receiver. In this plot, all values are nearly identical, indicating low correlation.

5.1.2 Tracking

The main purpose of tracking is to refine the coarse values of code phase and frequency and to keep track of these as the signal properties change over time.

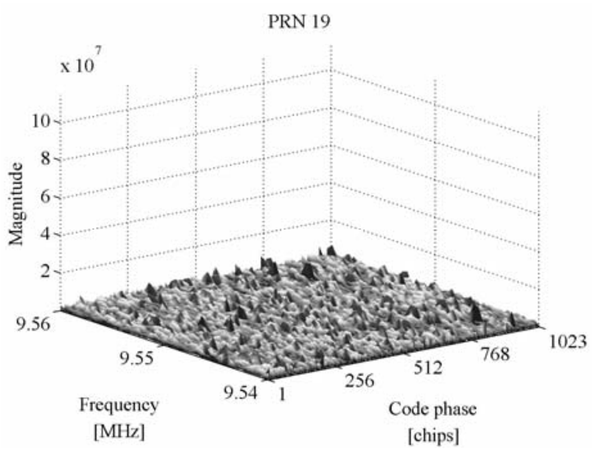

FIGURE 5.3. Acquisition plot for PRN 19. Signals originating from PRN 19 are clearly not present in the received signal as there is no sign of a peak in the acquisition plot.

The accuracy of the final value of the code phase is connected to the accuracy of the pseudorange computed later on. The tracking contains two parts, code tracking and carrier frequency/phase tracking:

Code tracking The code tracking is most often implemented as a delay lock loop (DLL) where three local codes (replicas) are generated and correlated with the incoming signal. These three replicas are referred to as the early, prompt, and late replica, respectively. The three codes are often separated by a half-chip length.

Carrier frequency/phase tracking The other part of the tracking is the carrier wave tracking. This tracking can be done in two ways: either by tracking the phase of the signal or by tracking the frequency.

The tracking is running continuously to follow the changes in frequency as a function of time. If the receiver loses track of a satellite, a new acquisition must be performed for that particular satellite.

5.1.3 Navigation Data Extraction

When the signals are properly tracked, the C/A code and the carrier wave can be removed from the signal, only leaving the navigation data bits. The value of a data bit is found by integrating over a navigation bit period of 20 ms. After reading about 30 s of data, the beginning of a subframe must be found in order to find the time when the data was transmitted from the satellite.

When the time of transmission is found, the ephemeris data for the satellite must be decoded. This is used later on to compute the position of the satellite at the time of transmission.

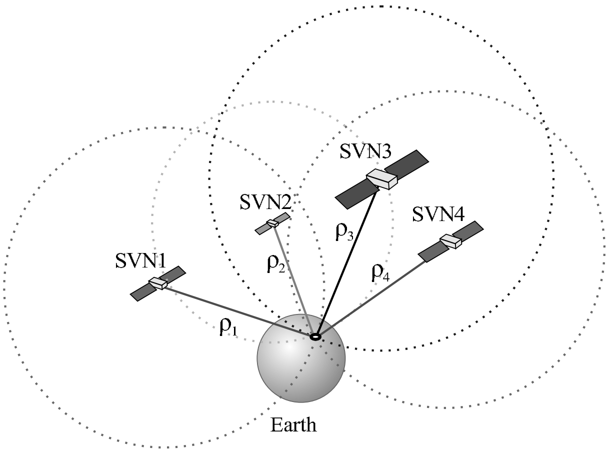

FIGURE 5.4. The basic principle of GNSS positioning. With known position of four satellites SVNi and signal travel distance ρ_i, the user position can be computed.

The last thing to do before making position computations is to compute pseudoranges. The pseudoranges are computed based on the time of transmission from the satellite and the time of arrival at the receiver. The time of arrival is based on the beginning of the subframe.

5.2 Computation of Position

The final task of the receiver is to compute a user position. The position is computed from pseudoranges and satellite positions found from ephemeris data. Figure 5.4 gives an impression of the method of position computation using GPS.

Section 8.5 gives a detailed description of the computational algorithm.