The satellites broadcast ranging codes and navigation data on two frequencies using a technique called code division multiple access (CDMA); that is, there are only two frequencies in use by the system, called **L1 (1,575.42 MHz) and L2 (1,227.6 MHz).** Each satellite transmits on these frequencies, but with different ranging codes than those employed by other satellites. These codes were selected because they have low cross-correlation properties with respect to one another.

The binary digits 0 and 1 are actually represented by multiplying the electrical signals by either +1 or −1, which is equivalent to leaving the signal unchanged, or flipping the phase of the signal by 180 ^{o}.

There are three types of code on the carrier signals:

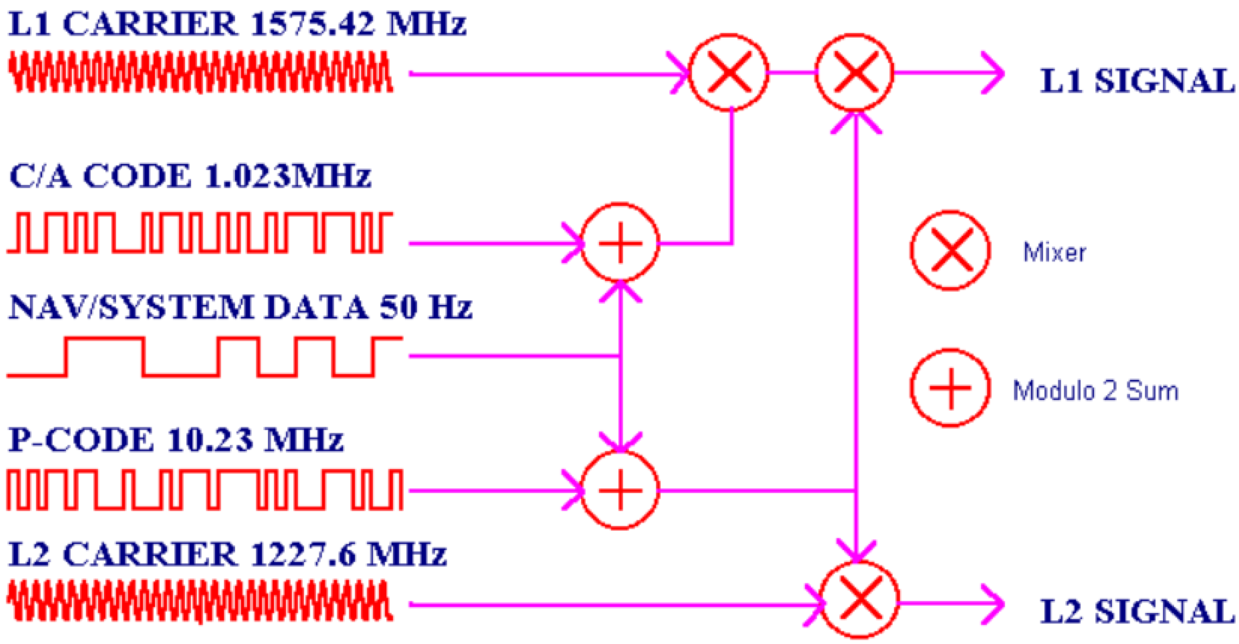
- The C/A code
- The P code
- The Navigation Message

The C/A (“course acquisition”) code can be found on the L1 channel. This is a code sequence which repeats every 1 ms. It is a pseudo-random code, which appears to be random, but is in fact generated by a known algorithm. The carrier can transmit the C/A code at 1.023 Mbps (million bits per second). The “chip length”, or physical distance between binary transitions (between digits +1 and −1), is 293 metres. The basic information that the C/A code contains is the time according to the satellite clock when the signal was transmitted (with an ambiguity of 1 ms, which is easily resolved, since this corresponds to 293 km). Each satellite has a different C/A code, so that they can be uniquely identified.

The P (“precise”) code is identical on both the L1 and L2 channel. Whereas C/A is a courser code appropriate for initially locking onto the signal, the P code is better for more precise positioning. The P code repeats every 267 days. In practice, this code is divided into 7 day segments; each weekly segment is designated a “PRN” number, and is designated to one of the GPS satellites. The carrier can transmit the P code at 10.23 Mbps, with a chip length of 29.3 metres. Again, the basic information is the satellite clock time or transmission, which is identical to the C/A information, except that it has ten times the resolution. Unlike the C/A code, the P code can be encrypted by a process known as “anti-spoofing” , or “A/S” (see below).

The Navigation Message can be found on the L1 channel, being transmitted at a very slow rate of 50 bps. It is a 1500 bit sequence, and therefore takes 30 seconds to transmit. The Navigation Message includes information on the Broadcast Ephemeris (satellite orbital parameters), satellite clock corrections, almanac data (a crude ephemeris for all satellites), ionosphere information, and satellite health status.

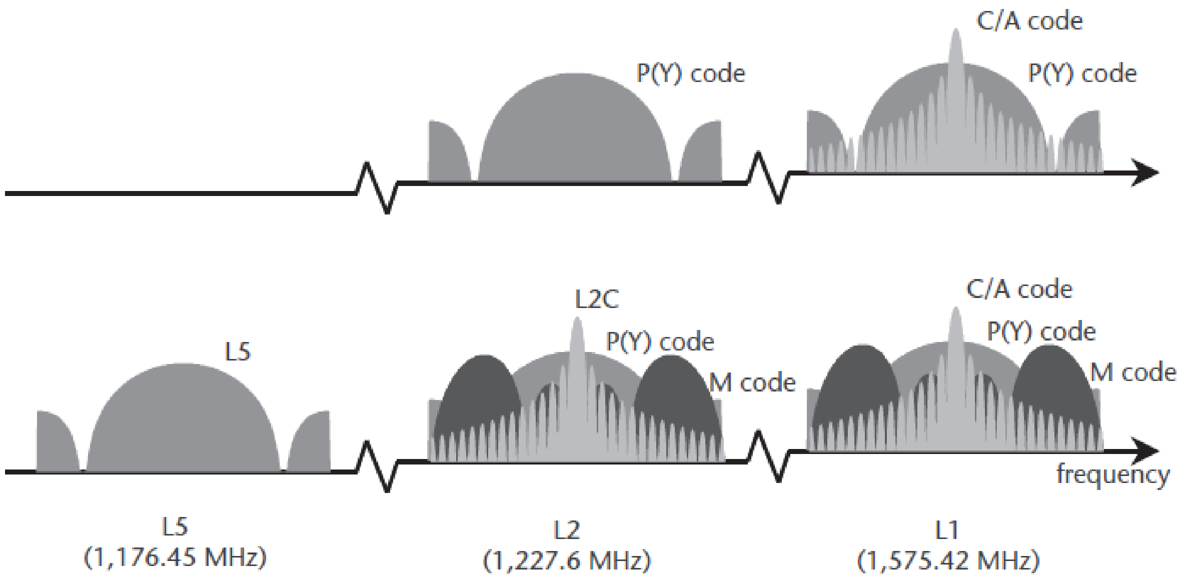
The L5 signal resides in an aeronautical radionavigation service (ARNS) band at 1,176.45 MHz. L5 is intended for safety-of-life use applications. These additional signals will provide SPS users the ability to correct for ionospheric delays by making dual frequency measurements, thereby significantly increasing civil user accuracy. By using the carrier phase of all three signals (L1 C/A, L2C, and L5) and differential processing techniques, very high user accuracy (on the order of millimeters) can be rapidly obtained.



GPS SATELLITE SIGNALS

GPS is a dual-use system. That is, it provides separate services for civil and military users. These are called the Standard Positioning Service (SPS) and the Precise Positioning Service (PPS). The SPS is designated for the civil community, whereas the PPS is intended for U.S. authorized military and select government agency users. Access to the GPS PPS is controlled through cryptography. Initial operating capability (IOC) for GPS was attained in December 1993, when a combination of 24 prototype and production satellites was available and position determination/timing services complied with the associated specified predictable accuracies. GPS reached full operational capability (FOC) in early 1995, when the entire 24 production satellite constellation was in place and extensive testing of the ground control segment and its interactions with the constellation was completed. Descriptions of the SPS and PPS services are presented in the following sections.

During the mid to late 1990s, a new military signal called M code was developed for the PPS. This signal will be transmitted on both L1 and L2 and is spectrally separated from the GPS civil signals in those bands. The spectral separation permits the use of noninterfering higher power M code modes that increase resistance to interference. Furthermore, M code will provide robust acquisition, increased accuracy, and increased security over the legacy P(Y) code.



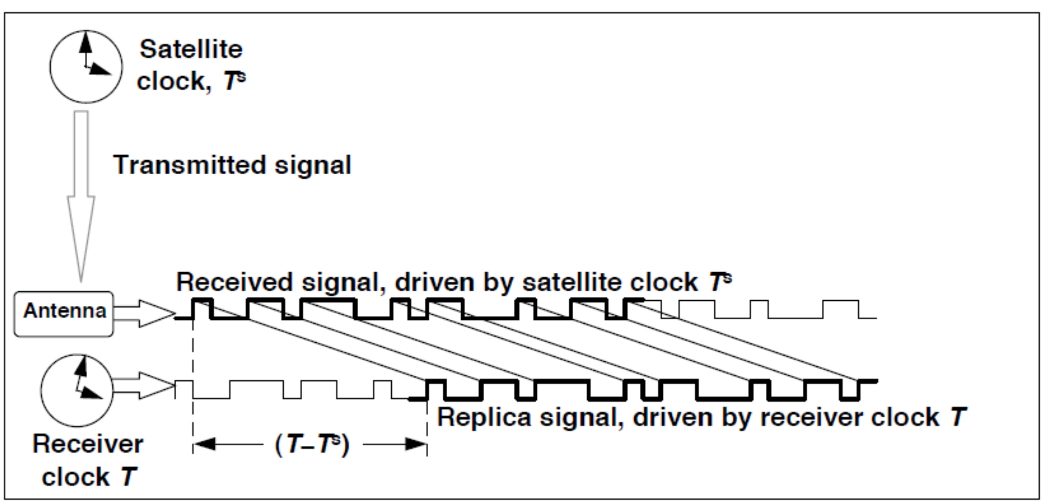
GPS signal evolution.

PSEUDORANGE OBSERVATION EQUATIONS

Receivers record data at regular, specified intervals (say, every 30 seconds, as instructed by the receiver user). It is the reading of the receiver clock time T, which is used to say exactly when the measurement is sampled. Therefore, the value of T at a measurement epoch is known exactly, and is written to the data file along with the observation. (What is not known, is the true time of measurement). The actual observation to satellite s can be writted:

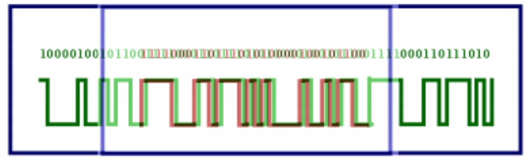
$$P^S = (T - T^S)\, c$$

where T is the known reading of the receiver clock when signal is received, T^S is the reading of the satellite clock when the signal was transmitted, and c is the speed of light (in a vacuum) = 299792458 m/s.

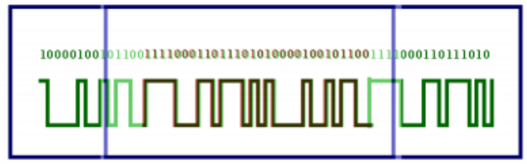


A schematic diagram showing how the GPS pseudorange observation is related to the satellite and receiver clocks.

A Short Repeating PRN Code Sample



Partial Correlation of Identical Receiver and Satellite PRN Codes



Full Correlation (Code-Phase Lock) of Receiver and Satellite PRN Codes

Receiver generates a copy of the (known) code and correlates with the received code

Calculation of User Position

In order to determine user position in three dimensions (x_u, y_u, z_u) and the offset t_u, pseudorange measurements are made to four satellites resulting in the system of equations

$$\rho_j = \left\| \mathbf{s}_j - \mathbf{u} \right\| + ct_u \qquad (2)$$

where j ranges from 1 to 4 and references the satellites. Equation (2.   ) can be expanded into the following set of equations in the unknowns x_u, y_u, z_u, and t_u:

$$\rho_1 = \sqrt{(x_1 - x_u)^2 + (y_1 - y_u)^2 + (z_1 - z_u)^2} + ct_u$$

$$\rho_2 = \sqrt{(x_2 - x_u)^2 + (y_2 - y_u)^2 + (z_2 - z_u)^2} + ct_u$$

$$\rho_3 = \sqrt{(x_3 - x_u)^2 + (y_3 - y_u)^2 + (z_3 - z_u)^2} + ct_u$$

$$\rho_4 = \sqrt{(x_4 - x_u)^2 + (y_4 - y_u)^2 + (z_4 - z_u)^2} + ct_u$$

where x_j, y_j, and z_j denote the jth satellite's position in three dimensions.