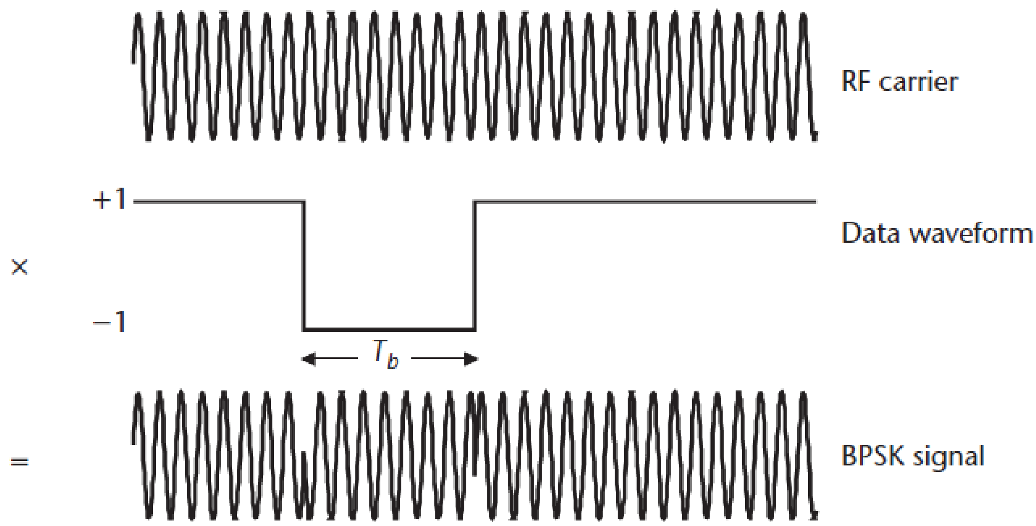
GPS Satellite Signal Characteristics

This lecture examines the properties of the GPS satellite signals, including frequency assignment, modulation format, navigation data, and the generation of PRN codes.

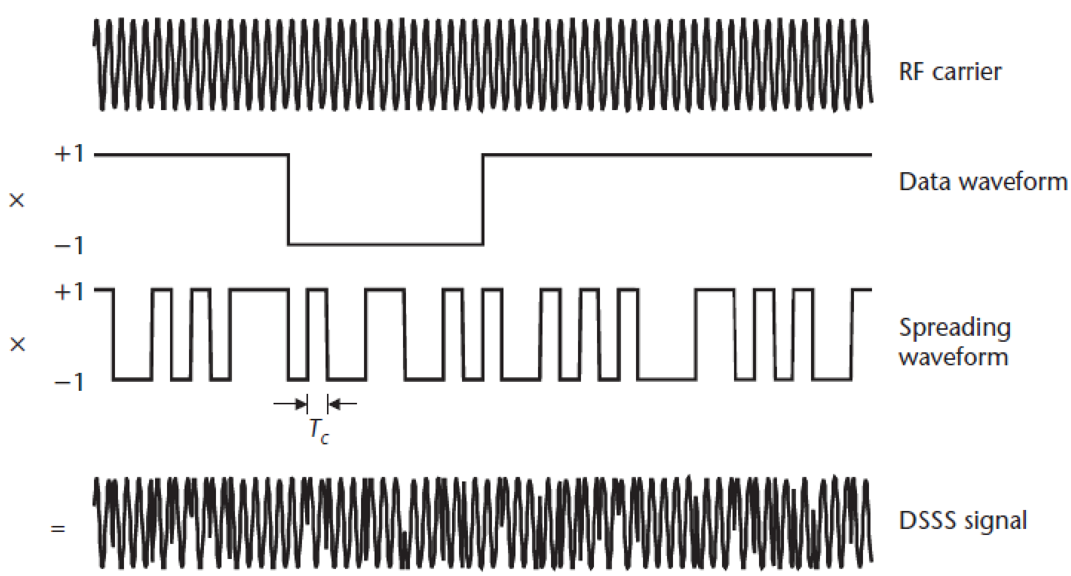
1. Modulation Types

Binary phase shift keying **(BPSK)** is a simple digital signaling scheme in which an RF carrier is either transmitted "as is" or with a 180º phase shift over successive intervals in time depending on whether a digital 0 or 1 is being conveyed.



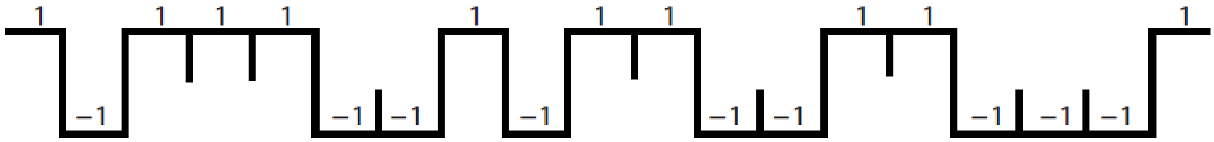
BPSK modulation.

Direct sequence spread spectrum **(DSSS)** is an extension of BPSK or other phase shift keyed modulation used by GPS and other satellite navigation systems. DSSS signaling adds a third component, referred to as a *spreading* or PRN waveform (pseudorandom noise), which is similar to the data waveform but at a much higher symbol rate. This PRN waveform is completely known, at least to the intended receivers.



DSSS modulation.

GPS satellite transmissions utilize direct sequence spread spectrum (DSSS) modulation. DSSS provides the structure for the transmission of ranging signals and essential navigation data, such as satellite ephemerides and satellite health. The ranging signals are PRN codes that binary phase shift key (BPSK) modulate the satellite carrier frequencies. These codes look like and have spectral properties similar to random binary sequences but are actually deterministic.



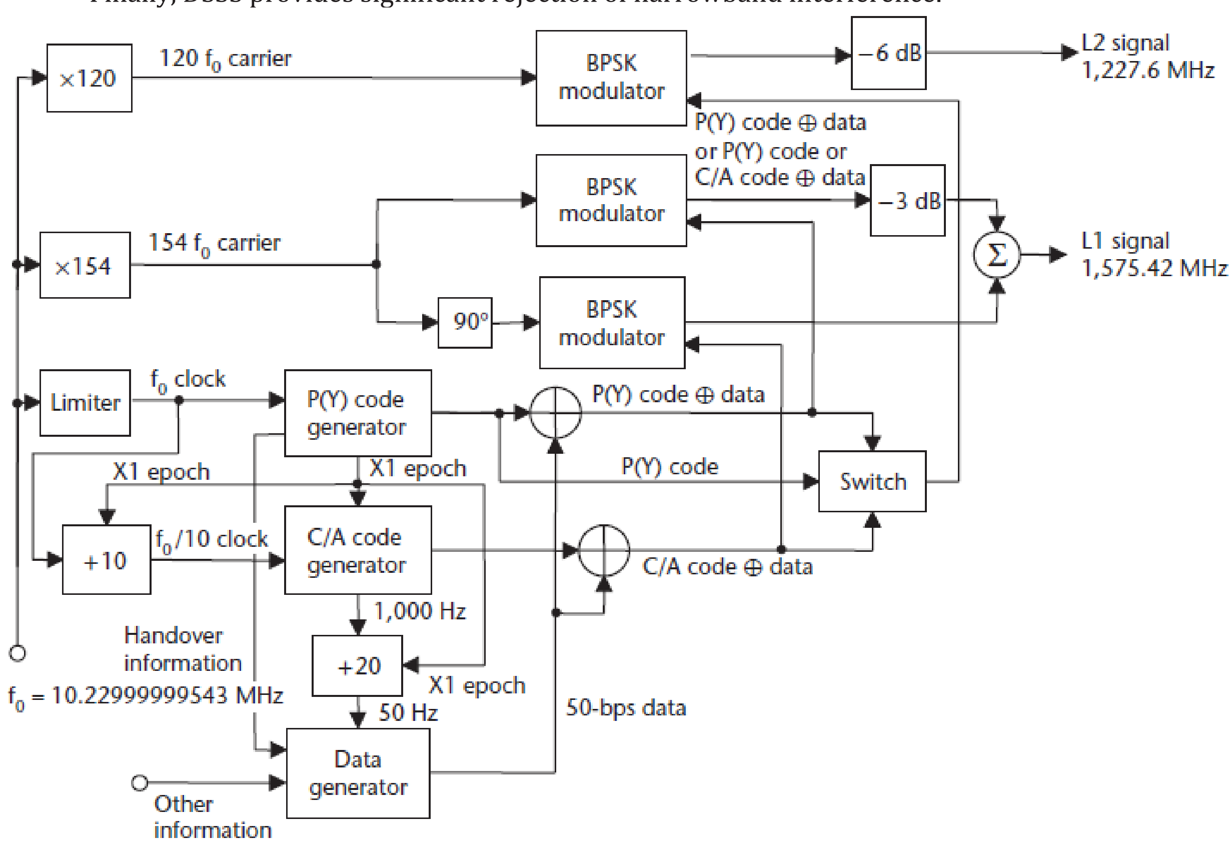
PRN ranging code.

Each GPS satellite broadcasted two types of PRN ranging codes: a “short” coarse/acquisition (C/A)-code and a “long” precision (P)-code.

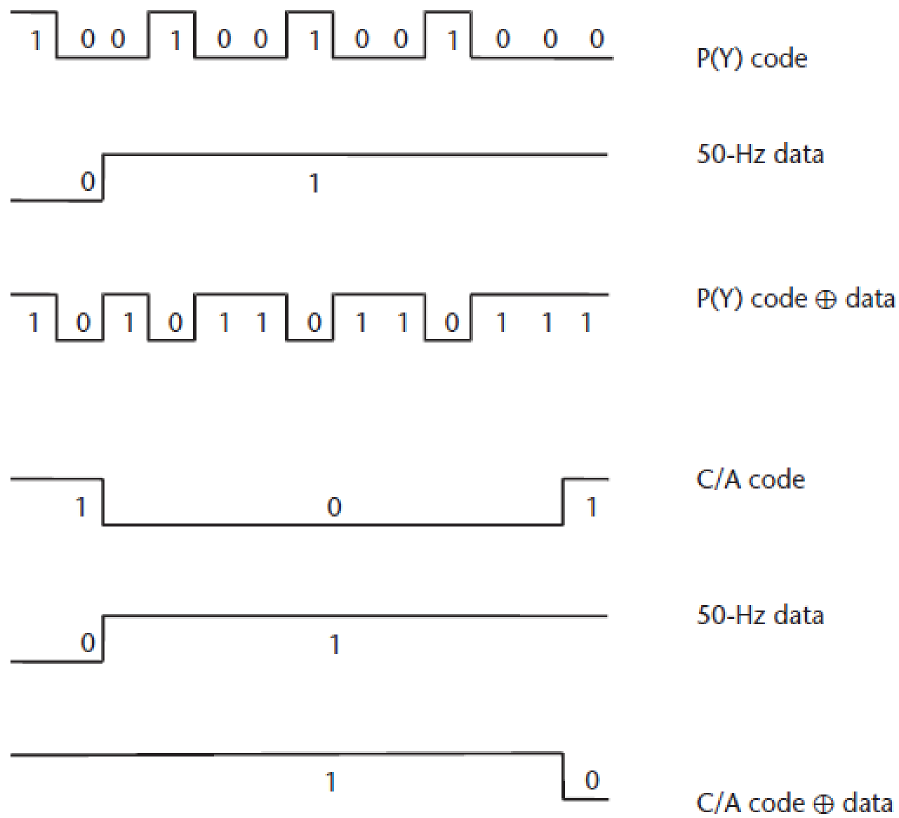
Presently, the P-code is encrypted. This encrypted code is denoted as the Y-code. The Y-code is accessible only to PPS users through cryptography.

There are three primary reasons why DSSS waveforms are employed for satellite navigation.

- First and most importantly, the frequent phase inversions in the signal introduced by the PRN waveform enable precise ranging by the receiver.
- Second, the use of different PRN sequences from a well-designed set enables multiple satellites to transmit signals simultaneously and at the same frequency.
- A receiver can distinguish among these signals, based on their different codes. For this reason, the transmission of multiple DSSS signals having different spreading sequences on a common carrier frequency is referred to as *code division multiple access* (CDMA).
- Finally, DSSS provides significant rejection of narrowband interference.



Legacy GPS satellite signal structure.



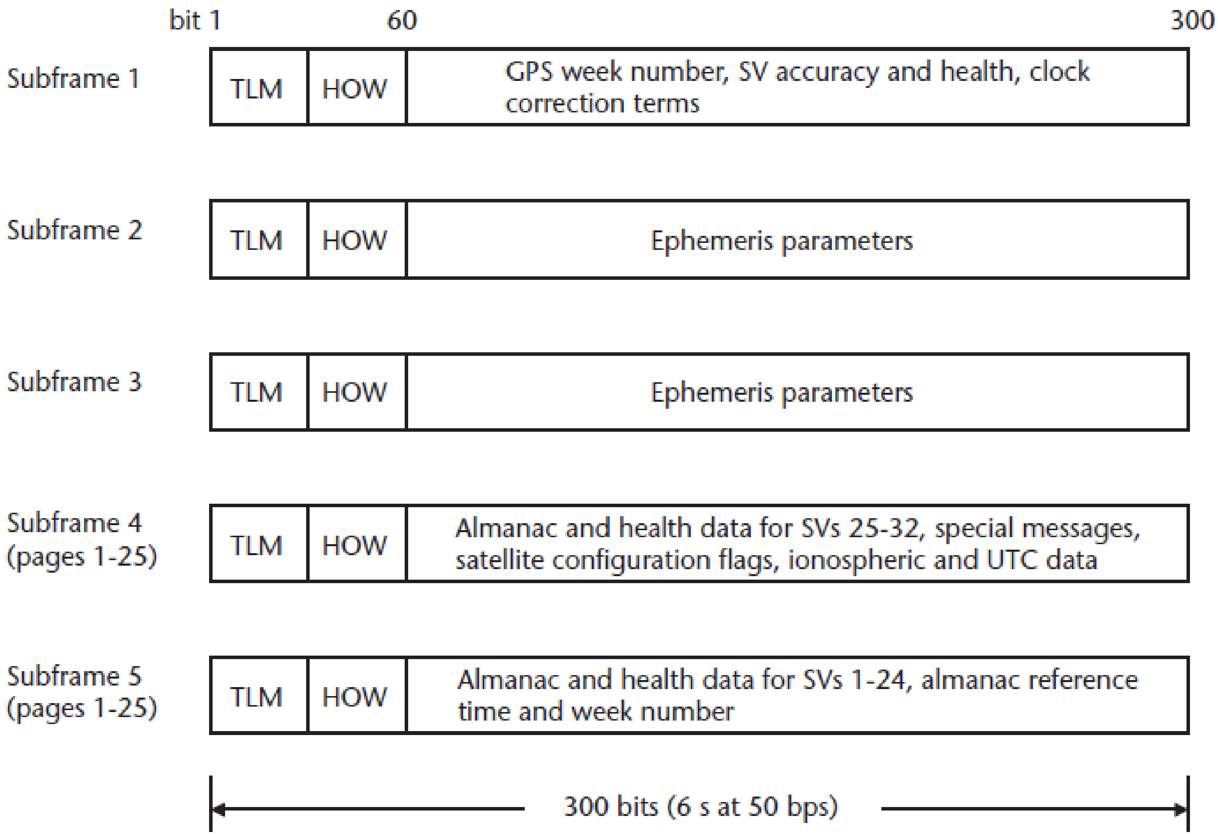
GPS code mixing with data.

Navigation Message Format

The GPS navigation message is transmitted in five 300-bit subframes. Each subframe is itself composed of ten 30-bit words. The last 6 bits in each word of the navigation message are used for parity checking to provide the user equipment with a capability to detect bit errors during demodulation. A Hamming code is employed. The five subframes are transmitted in order beginning with subframe 1. Subframes 4 and 5 consist of 25 pages each, so that the first time through the five subframes, page 1 of subframes 4 and 5 are broadcast. In the next cycle through the five subframes, page 2 of subframes 4 and 5 are broadcast and so on.

The first two words of each subframe (bits 1–60) contain telemetry (TLM) data and a handover word (HOW). The TLM word is the first of the 10 words in each subframe and includes a fixed preamble, a fixed 8-bit pattern **10001011 that never changes.** This pattern is included to assist the user equipment in locating the beginning of each subframe. Each TLM word also includes 14 bits of data that are only meaningful to authorized users.

The HOW, so-named because it allows the user equipment to "handover" from C/A code tracking to P(Y) code tracking, provides the GPS time-of-week (TOW) modulo 6 seconds corresponding to the leading edge of the following subframe. The HOW also provides two flag bits, one that indicates whether anti-spoofing is activated, and one that serves as an alert indicator. If the alert flag is set, it indicates that the signal accuracy may be poor and should be processed at the user's own risk. Finally, the HOW provides the subframe number (1–5).



Navigation message format.

Subframe 1 provides the GPS transmission week number, which is the number of weeks modulo 1,024 that have elapsed since January 5, 1980. The first rollover of the GPS week number occurred on August 22, 1999. The next rollover will occur in April 2019. Subframe 1 also provides the satellite clock correction and time of clock.

Subframes 2 and 3 include the osculating Keplerian orbital elements. that allow the user equipment to precisely determine the location of the satellite.

Pages 2–5 and 7–10 of **subframe 4** and pages 1–24 of **subframe 5** contain almanac data (coarse orbital elements that allow the user equipment to determine approximate positions of other satellites to assist acquisition) for SVs 1–32.

Page 13 of **subframe 4** includes the Navigation message correction table (NMCT) range corrections. Page 18 of **subframe 4** includes ionospheric correction parameters for single-frequency users and parameters so that user equipment can relate UTC to GPS system time. Page 25 of **subframes 4 and 5** provide configuration and health flags for SVs 1–32. The data payloads of the remaining pages of subframes 4 and 5 are currently reserved.