Global Positioning System

(GPS) Lectures

References

1- L.F.Wiederholt, "GPS SYSTEM SEGMENTS " lecturer. 2012

2- E. Calais," The Global Positioning System" Purdue University - EAS Department, Civil 3273 – ecalais@purdue.edu

3- Elliott D. Kaplan," Understanding GPS Principles and Applications" © 2006 ARTECH HOUSE, INC. 685 Canton Street, Norwood, MA

Lecture (3) GPS

11. GPS Satellite Signal Structure

The satellites transmit ranging signals on two band frequencies, L1 and L2, as shown in figure (9);

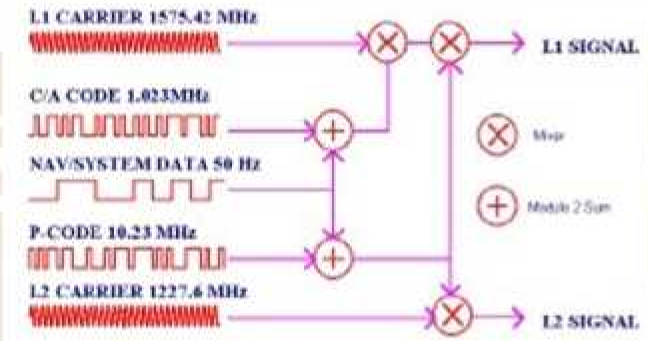


Figure (9): GPS Satellite Signals

- The L1 = 1575.42 MHz has Coarse/Acquisition (C/A) code and P-code.
- The L2 = 1227.60 MHz has P-code.
- Wavelengths L1 ~190 mm; L2 ~244 mm

While, a *navigation message* is superimposed on both the P-code and the C/A-code. Navigation Message consisting of data bits that describe the GPS satellite orbits, clock corrections, and other system parameters.

Navigation Data message:

The following summarizes the important information about the navigation data message, as shown in figure (10):

1) 50 bits/second rate (much slower than code or carrier) navigation data transmitted by the satellites are formatted into *30-bit words and 20 ms in duration.*
2) The words are grouped into sub-frames of 10 words that are 300 bits in length and 6 s in duration.
3) Frames consist of 5 sub-frames. 30 s in duration each frames (1500 bits each frame).
4) A super-frame consists of 25 frames and has duration of 12.5 min.
5) *HOW transmitted every sub-frame?*

Each satellite transmits its independent information such as

1) Clock corrections and ionospheric delay model in sub-frame #1
2) Ephemeris data in sub-frames #2 and #3
3) Messages and almanac in sub-frames #4 and #5 for all satellites information in the constellation

The following figure (10) illustrates the format of the data message:

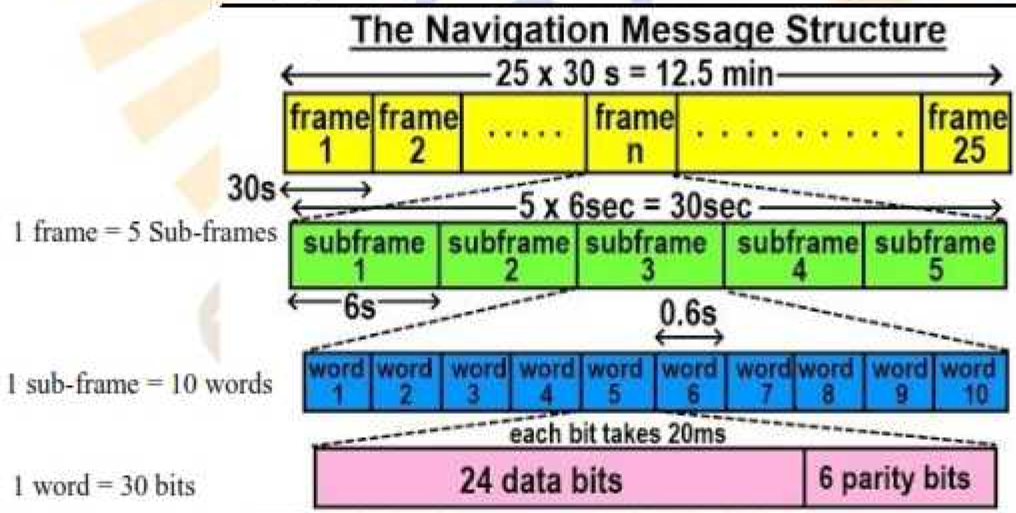


Figure (10): Navigation message structure.

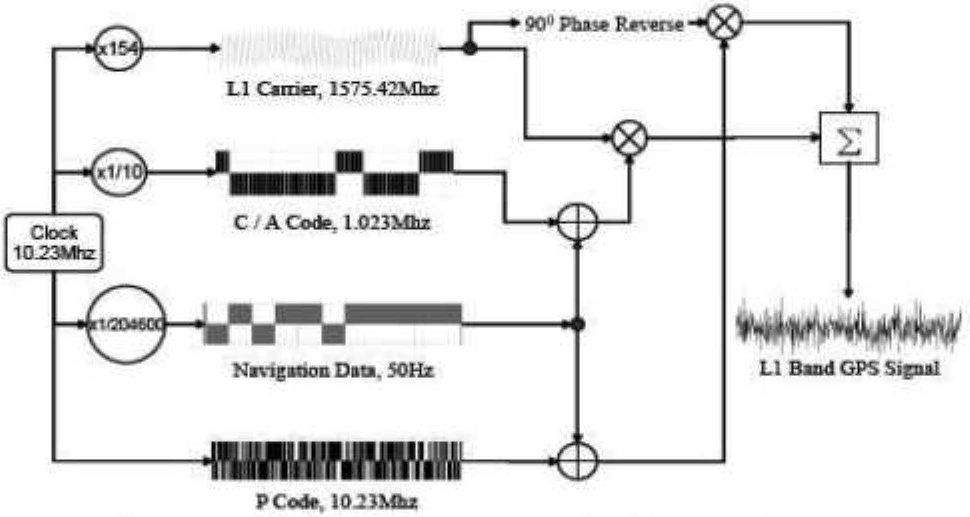
Specifics of GPS signal

Figure (11) depicss a general schematic to generate a L1 band signal as represented by the equation shown in the figure (11) for C/A code.

- The ***atomic clocks*** aboard the GPS satellites produce a fundamental frequency $f_o = 10.23\ MHz$
- Two frequencies are derived from the atomic clock:

$$L1 = (f_o * 154) = 10.23 * 154 = 1.57542\ \text{GHz}$$
$$L2 = (f_o * 120) = 10.23 * 120 = 1.22760\ \text{GHz}$$

- L1 and L2 are the two carrier frequencies used to transmit timing information by GPS satellite.

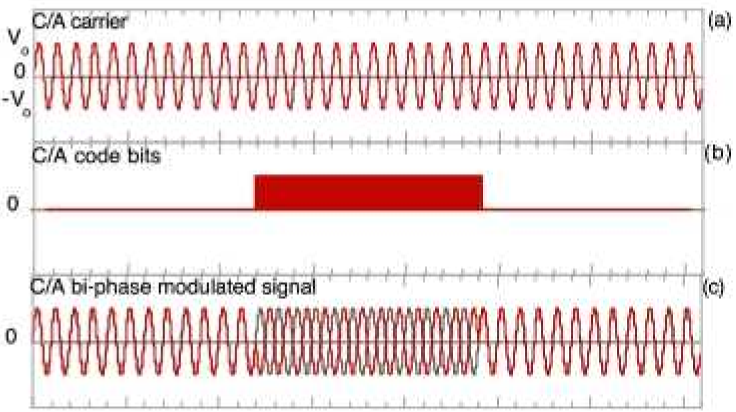


$$r_i(t) = \sqrt{2P_i(t)} \cdot CA(t - \tau_i(t)) \cdot D(t - \tau_i(t)) \cdot \cos\left(2\pi\left(f_L + \delta f_{L,i}(t)\right)t + \phi_i(t)\right) + n_i(t)$$

Figure (11): Schematic showing the generation of L1 band GPS signal.
The equation is the mathematical representation of C/A code in L1 band.

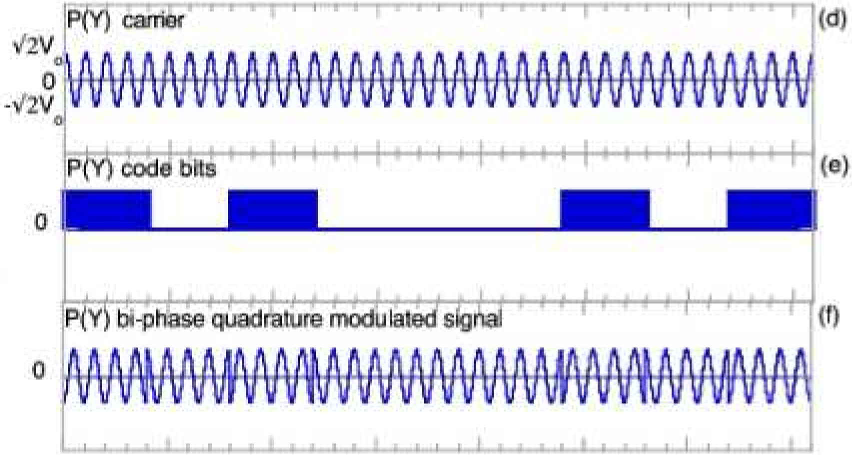
- There are sets of *phase reversals* on the L1 signal:
  C/A code at rate of 1.023 MHz and the P(Y) code add 90° *out of phase* at a rate of 10.23 MHz.
- There are sets of phase reversals on the L1 signal:
  - C/A code at Chip rate (rate at which phase might change) 1.023 MHz. and
  - Precise positioning code (P code) at a rate of 10.23 MHz
  - Y-code [Anti-Spoofing (AS) code] also 10.23 MHz derived by multiplying P-code by ~20KHz code (highly classified)
- Code lengths:
  - C/A code is 1023 bits long
  - P-code is 37 weeks long (2x1014bits in code)
  - Only one P-code, satellites use different weeks from same code (P-code repeats each week)
  - As far as we know Y-code never repeats (again classified)
- Data message: Implemented by changing sign of code at rate of 50 bits/second (low data rate).
- 10.23 MHz is fundamental frequency in GPS.
- The following graphics show schematically the construction of the GPS signal

CA Code Modulation

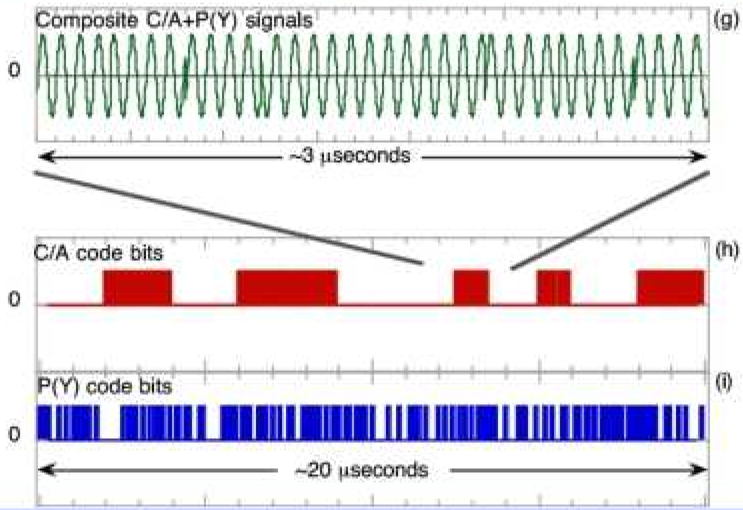


P-Code generation

(P-code rate should 10 times higher than C/A code)



Composite: Sum of C/A and P code



12. Software GPS Receiver Architecture.

The architecture of software GPS receivers is shown in figure (12), it includes RF front end implemented by hardware and GPS signal processing by software. In RF front end, after RF GPS signal is collected by the antenna, it is filtered by a band pass filter (BPF) to reduce band noise. Then a low noise amplifier (LNA) with low noise figure is used to amplify the GPS signal to required power. Here the noise figure should be as low as possible, because the signal is very weak and buried in noise. As RF GPS signal frequency is 1575.42MHz, it must be down converted by mixers to intermediate frequency (IF) for the sampling operation by ADC. At last, analog IF GPS signal is transformed to digital IF signal in ADC for base band signal processing.

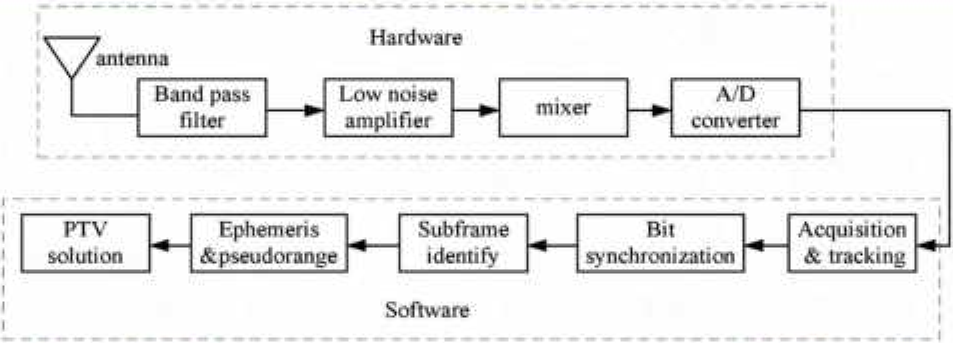


Figure (12): Architecture of software GPS receivers

13. GPS Signal Acquisition

The quantized IF signal to GPS base band processor can be expressed as

$$r(t) = AD(t-\tau^D)C(t-\tau)\cos(2\pi(f_{IF}+f_d)t+\theta)+\eta(t)$$

Where A is signal amplitude,

D and τ^D are navigation data of *50b/s* and its delay,

C represents spreading C/A code with a period of 1ms and rate of 1.023MHz,

τ is C/A code phase delay,

f_{IF} is intermediate frequency,

f_d is carrier Doppler shift,

θ is carrier initial phase,

$\eta(t)$ is noise.