ECS455: Chapter 4

Multiple Access

4.9 Async. CDMA: Gold codes and GPS

Dr.Prapun Suksompong

www.prapun.com

Office Hours:

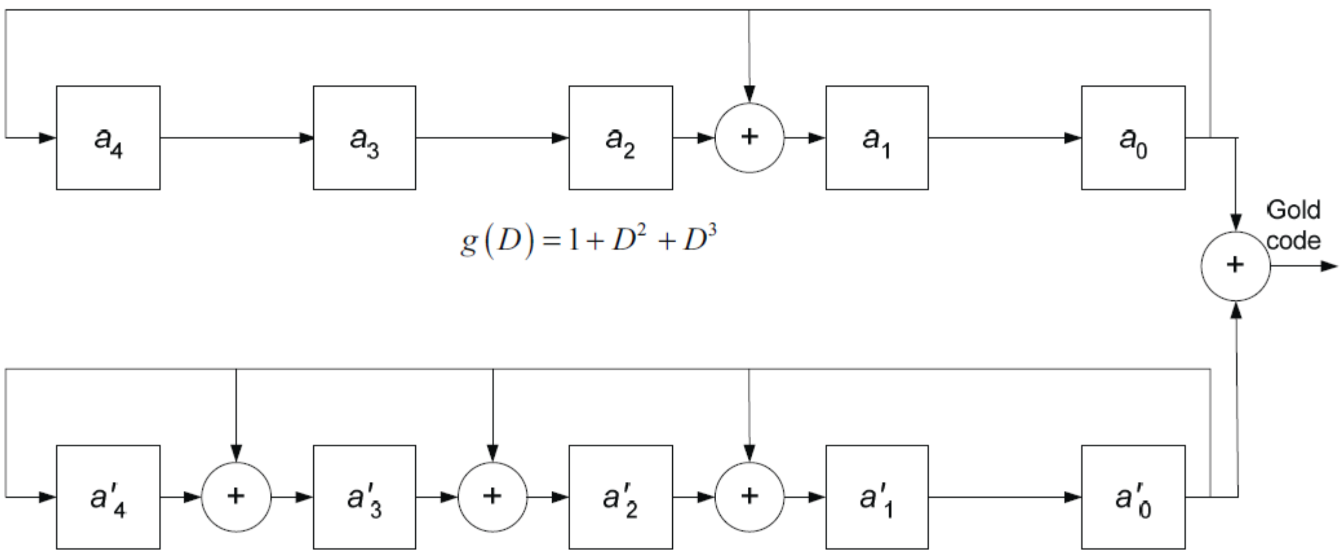
Library (Rangsit)	Mon	16:20-16:50
BKD 3601-7	Wed	9:20-11:20

Asynchronous CDMA Model

- In cellular systems, the design of the **reverse link** (mobile-to-base station) is considerably simplified if the users need not be synchronized.
- It is possible to let the users transmit asynchronously in CDMA.
- Codes assigned to different users need to have **low cross correlation** with each other **independent of the relative delays**
- **Gold codes**

Gold codes

- Gold codes have **worse autocorrelation** properties than maximal-length codes, but **better cross-correlation** properties if properly designed.
- The chip sequences associated with a Gold code are produced by addition of two m-sequences.



$$g(D) = 1 + D^2 + D^3$$

$$g'(D) = 1 + D^2 + D^3 + D^4 + D^5$$

[Ziemer, 2007, Fig. 9]

Orthogonality (a revisit)

- **Downlinks**
  - May use **orthogonal** spreading codes such as Walsh-Hadamard codes
  - Orthogonality can be degraded by multipath fading.
- **Uplinks**
  - Generally use **non-orthogonal** codes due to the **difficulty of user synchronization** and the complexity of maintaining code orthogonality in uplinks with multipath.
  - Little dynamic coordination of users in time or frequency is required
    - Users can be separated by the code properties alone.
- There is a hard limit on how many orthogonal channels (orthogonal codes) can be obtained.
  - For non-orthogonal codes, there is no hard limit.
  - Non-orthogonal codes cause mutual interference between users.
    - The more users, the higher the level of interference
      - Degrade the performance of all the users.
- Non-orthogonal CDMA scheme also requires power control in the uplink to compensate for the near-far effect.

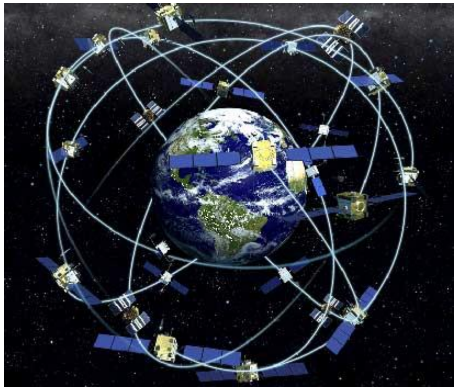
[Goldsmith, p 458]

Review: Near-far Effect

- Arise in the **uplink** because the channel gain between a user's transmitter and the receiver is different for different users.
- Suppose that one user is very **close** to his **base station** or access point, and another user very far away.
  - If both users transmit *at the same power level*, then the **interference from the close user will swamp the signal from the far user**.
- **Power control**
  - Make the *received* signal power of all users to be roughly the same
  - Essentially inverts any attenuation and/or fading on the channel
  - Each interferer must **contribute an equal amount of power**
  - Eliminating the near-far effect

Global Positioning System (GPS)

- Original application in the (US) **military**
- Created in the early 1990s.
- Allow a person to determine the **time** and the person's precise **location** (latitude, longitude, and altitude) anywhere on earth.



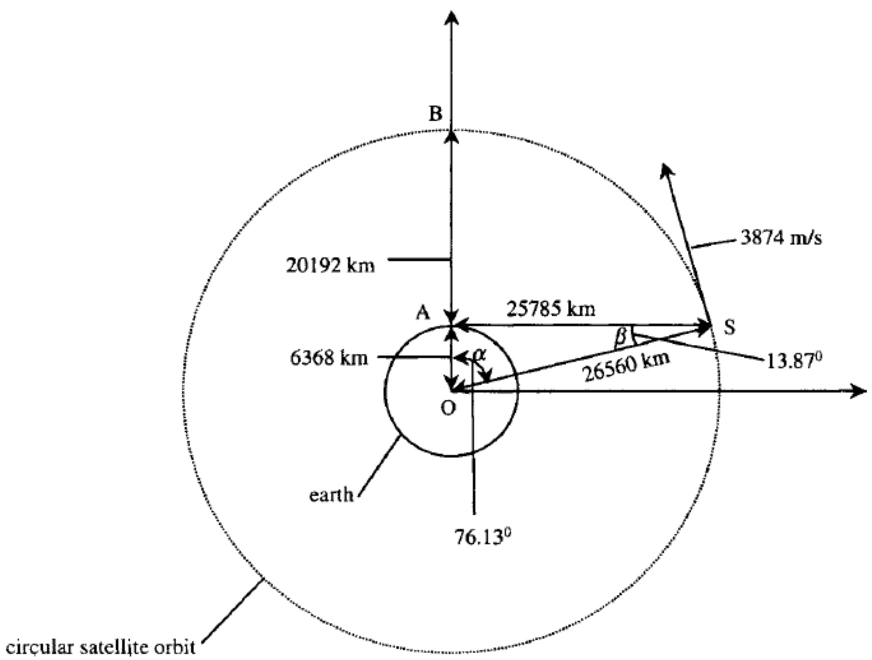
Applications

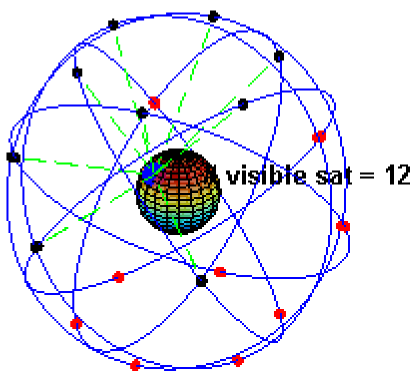
- The potential applications of GPS are so vast that it has been called (with some exaggeration) **the next utility** (similar to gas, water, and electricity).
- Most people probably think of it as the satellite system that allows their satnavs to work,
  but GPS is everywhere these days:
  - it automatically opens train doors at stations;
  - it tags our photos so we'll remember where we took them;
  - it even keeps serves' clocks in sync.
- Its main use, however, is in preventing marital arguments on long car journeys.

[PC Pro, 2011-08, 100 Technologies That Changed The World]

GPS Satellites

- A minimum of 24 GPS satellites are in orbit at 20,200 kilometers (12,600 miles) above the Earth.
- The satellites are spaced so that from any point on Earth, **at least four satellites** will be above the horizon.

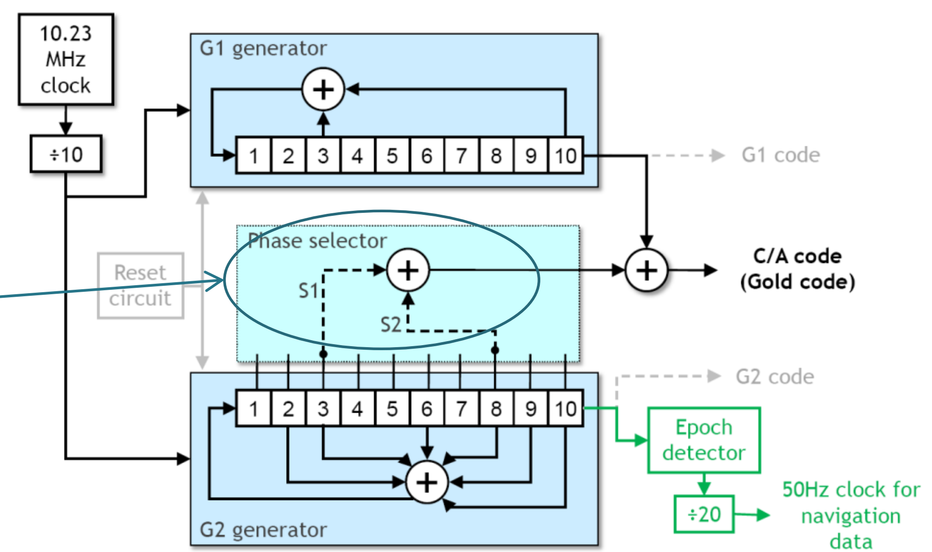




GPS and Gold codes

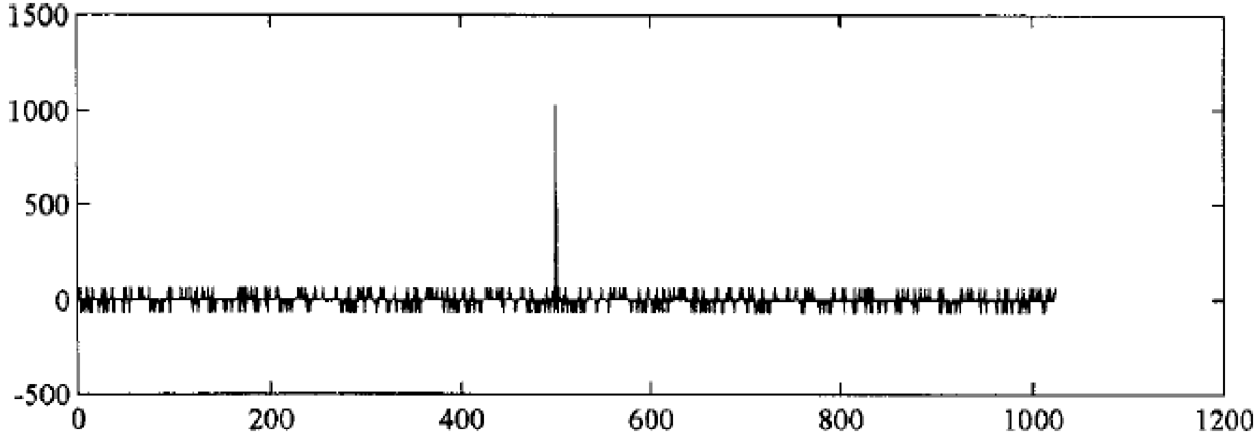
- Gold codes are used to distinguish the signals from different satellites
  - Coarse Acquisition Code (C/A)
  - Standard Positioning Service (SPS)
- The message data is transmitted at 50 bits per second.
- 1023 bits with a period of one millisecond.

Positions of these feedback determine the satellite ID

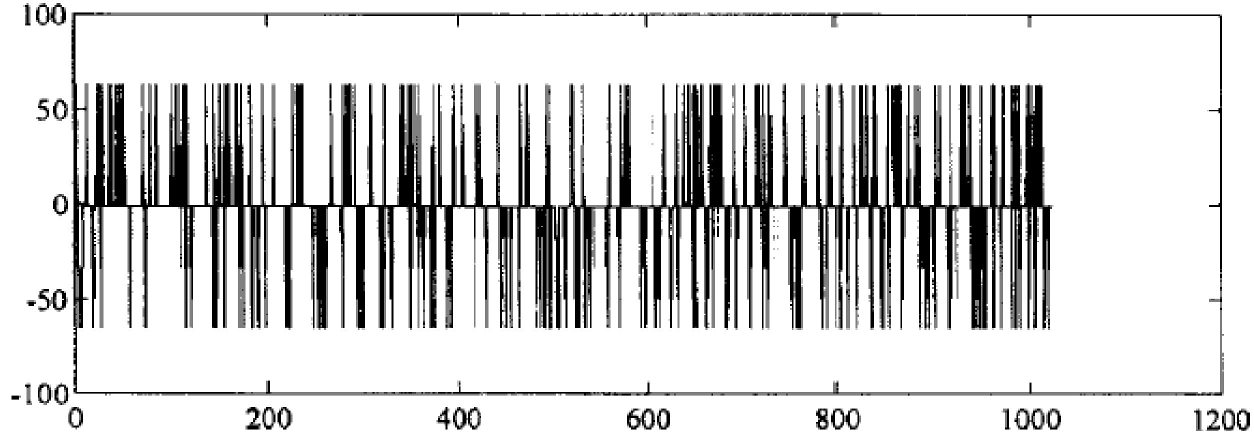


[Plausinaitis]

Auto and cross correlation of C/A code



(a) Autocorrelation of satellite 19.



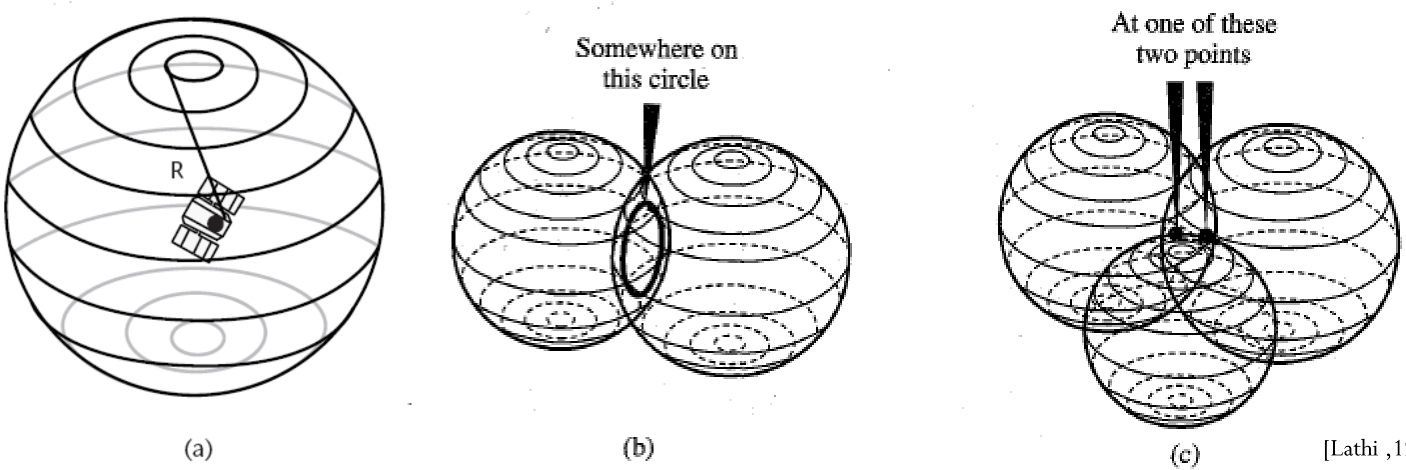
(b) Cross correlation of satellites 19 and 31.

How GPS Works?

- A GPS receiver measuring its **distance from a group of satellites** in space which are acting as precise **reference points**.
- All the satellites have **atomic clocks** of unbelievable precision on board and are synchronized.
- The satellite are continuously transmitting the information about their location and time.
- GPS receiver on the ground is in synchronism with the satellites.
  - Off by an (unknown) amount τ.
  - For now, assume $\tau = 0$.
- By measuring the propagation time, the receiver can compute distance d from that satellite.

GPS-Trilateration

- Intersection of three sphere narrows down the location to just two points.



[Lathi ,1998, Fig. 9.6]

- In practice, there are four unknowns, the coordinates in the three-dimensional space of the user along with τ within the user's receiver.
  - Need a distance measurement from a fourth satellite.