Access Scheme in Satellite Networking (1)

Lecture 12

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A PRE-ASSIGNED/DEDICATED SYSTEM

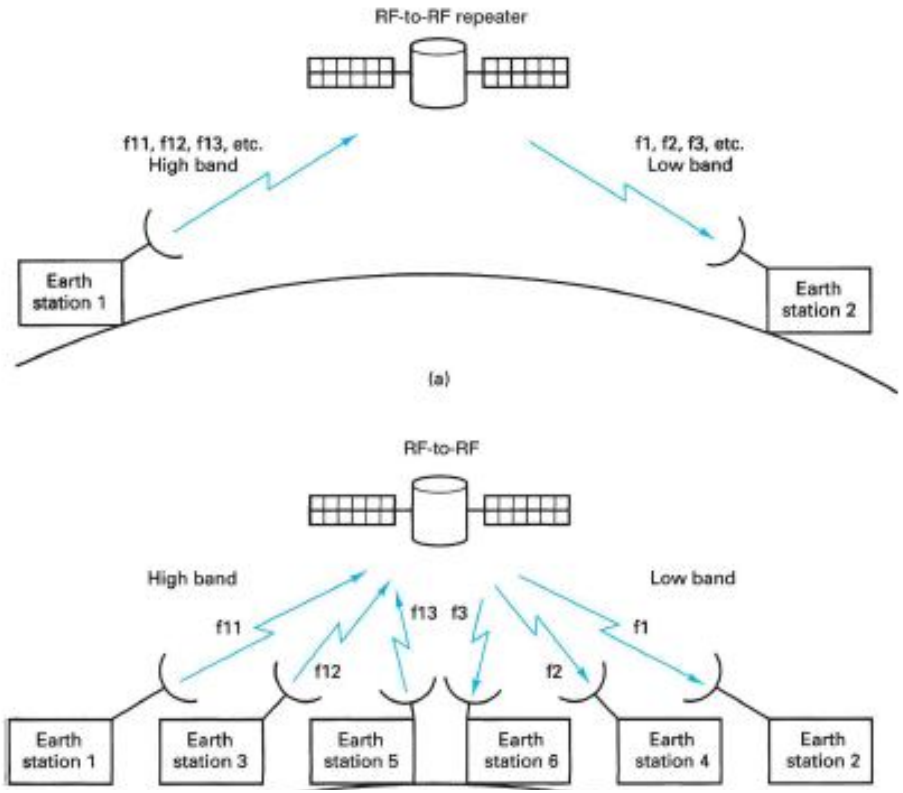


FIGURE 15-1 Fixed-frequency earth station satellite system: (a) single link; (b) multiple link

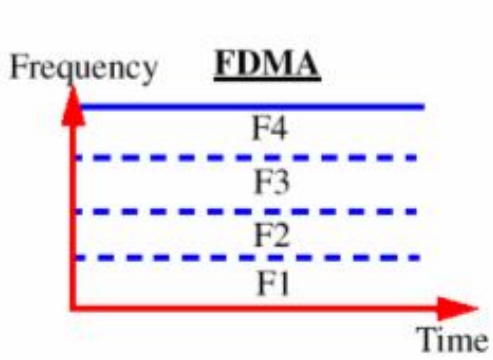
- Each earth station requires two dedicated pairs of Tx/Rx frequencies to communicate with any other station
- As many communication partners, same number of transponders (RF-RF duplex translator/repeater)
- Transponder BW 36 MHz which is mostly wasted

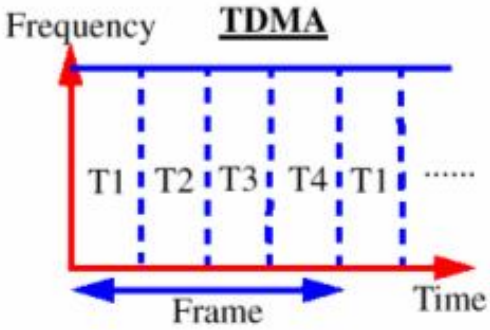
TWO TYPES OF DUPLEXING

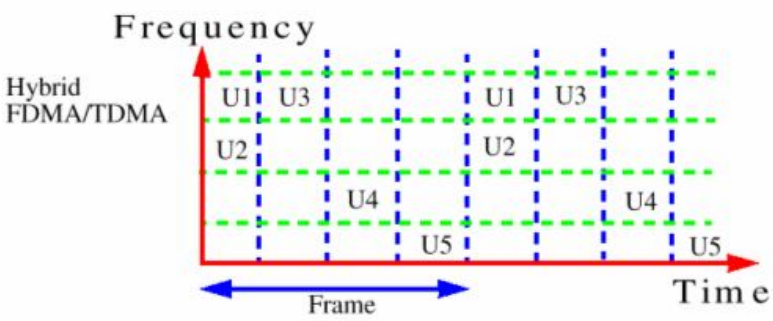
- A Duplex Link allows simultaneous transmission of information in both directions
  - **Frequency Division Duplex (FDD)** – **two frequency channels for each up/down link i.e. one frequency channel for Tx and other for Rx**
  - **Time Division Duplex (TDD)** – **a single frequency channel shared by both Tx and Rx**

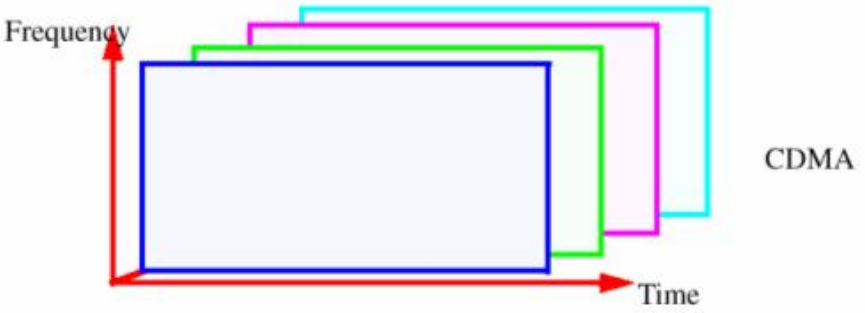
THREE MULTIPLE ACCESS TECHNIQUES

- Satellite Multiple Accessing/Destination means more than one users/earth s tations can access to one or more Radio Channels (Transponders) on board
  - **FDMA**
  - **TDMA**
  - **CDMA**
    - **FH - CDMA**
    - **DS - CDMA**







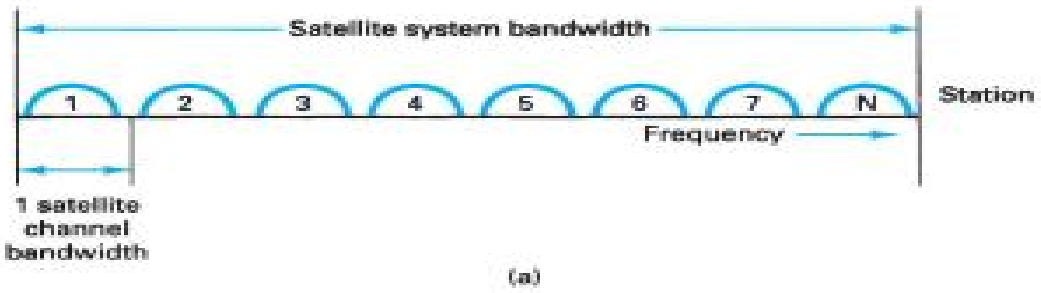


CATEGORIZATION OF MA TECHNIQUES

- **Narrow-band Systems –** Total system BW is divided into a large number of narrow-band radio channels
  - **FDMA/FDD –** Each user is assigned two narrow-band radio channels, one for up-link and other for down-link
  - **TDMA –** When each narrow-band radio channel is divided into number of time slots, and each user is assigned two time slots, one for Tx and other for Rx.
    - **Hybrid TDMA/FDMA or TDMA/FDD –** when two slots (same position in time) of the user are allocated in two different narrow-band radio channels
    - **TDMA/TDD –** when two slots of the user are allocated in the same narrow-b and radio channel
- **Wide-band Systems –** Total spectrum/BW is shared by all users all the time
  - **Wide-band TDMA**, each user is allocated two time slots to use the entire spectrum. **TDMA/FDD and TDMA/TDD** both configurations are possible.
  - **Wide-band CDMA,** entire spectrum is used by each user all the time but with use of orthogonal codes. **CDMA/FDD and CDMA/TDMA** both configurations are possible.

FREQUENCY DIVISION MULTIPLE ACCESS (FDMA) - THE CONCEPT

- Given **Radio Spectrum (RF BW) is divided into a large number of narrow-band radio channels called sub-divisions**
- Each sub-division has its own sub-carrier called IF Carrier
- A **control mechanism** is required to ensure that each user/earth station uses only its own assigned sub-division at any time
- **SCPC** - a system where each sub-division carries only one 4-kHz voice channel
- **MCPC** - a system where several speech/voice band channels are frequency-division multiplexed to form a group, super-group or even master-group
- **FDM/FM/FAMA** - a system using a fixed MCPC format over a long period of time
- **DAMA** - a system that allows all users continuous and equal access to the entire transponder BW by assigning carrier frequencies on a temporary basis as per demand



(a)

FDMA - Examples

- **Intelsat IV and V** used FDMA/FM/FAMA system
- **SPADE DAMA** Satellite System – SPADE ES Tx

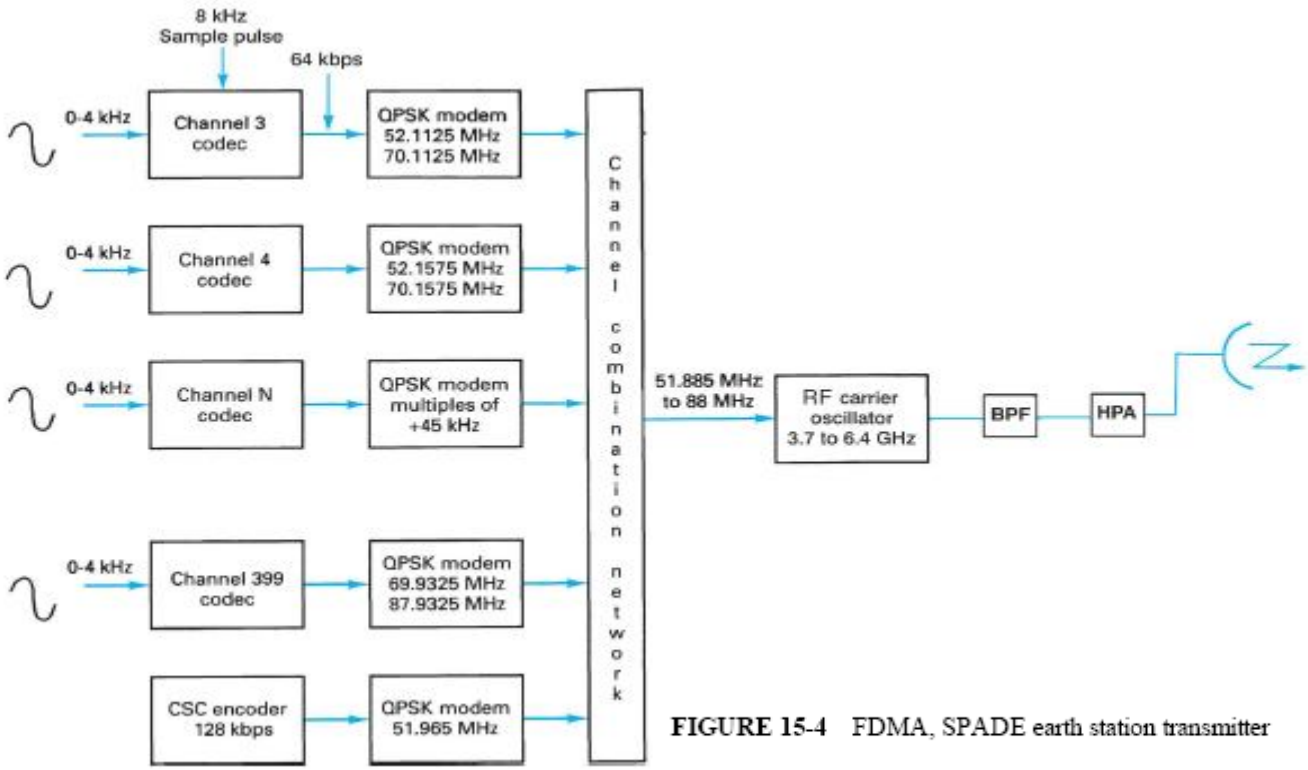


FIGURE 15-4 FDMA, SPADE earth station transmitter

FDMA - Examples

- **SPADE DAMA** Satellite System – Carrier Frequency Assignment

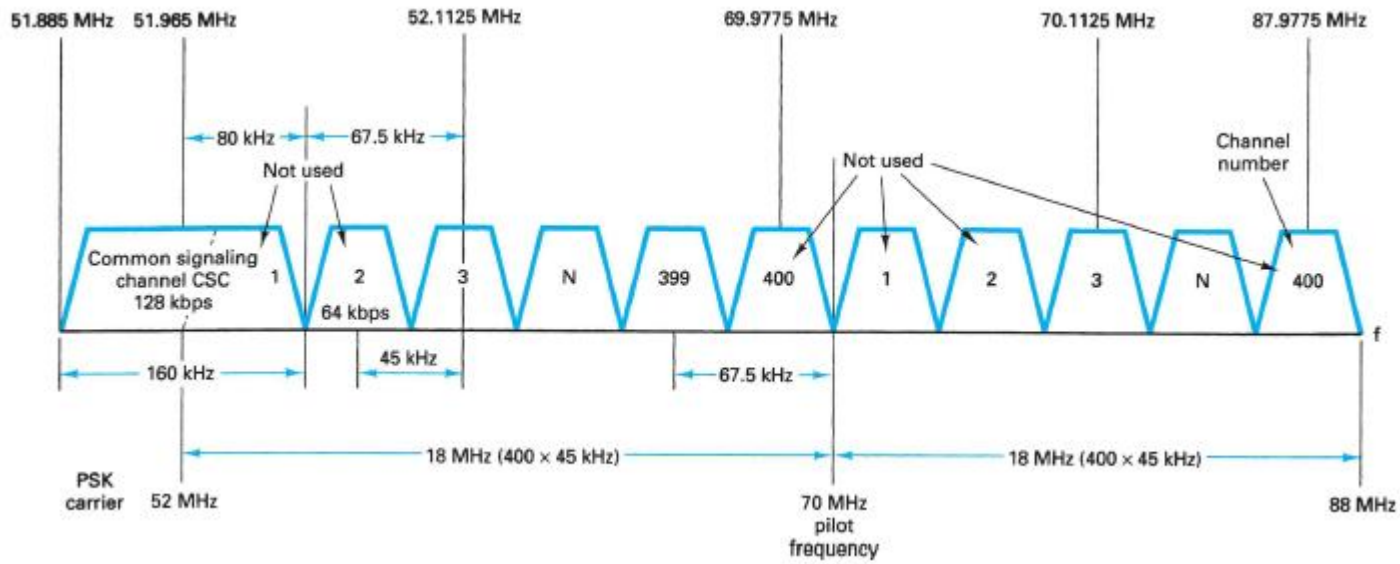
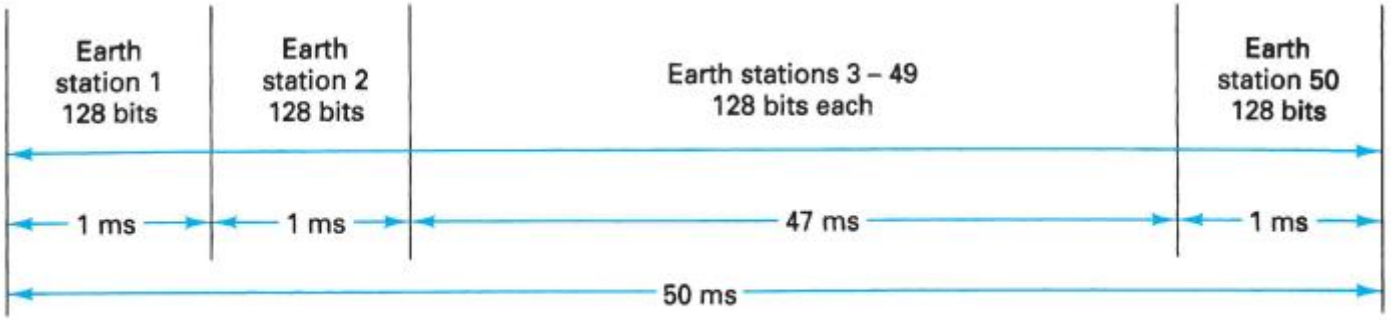


FIGURE 15-5 Carrier frequency assignments for the *Intelsat* single-channel-per-carrier PCM multiple-access demand-assignment equipment (SPADE)

FDMA - Examples

- **SPADE DAMA** Satellite System – Frame Structure of Common Signaling Channel (CSC)

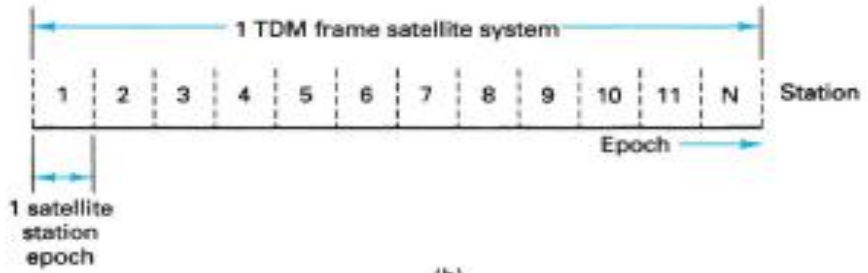


128 bits/1ms × 1000 ms/1s = 128 kbps or 6400 bits/frame × 1 frame/50 ms = 128 kbps

FIGURE 15-6 FDMA, SPADE common signaling channel (CSC)

TIME DIVISION MULTIPLE ACCESS (TDMA) -

The Basic Concept



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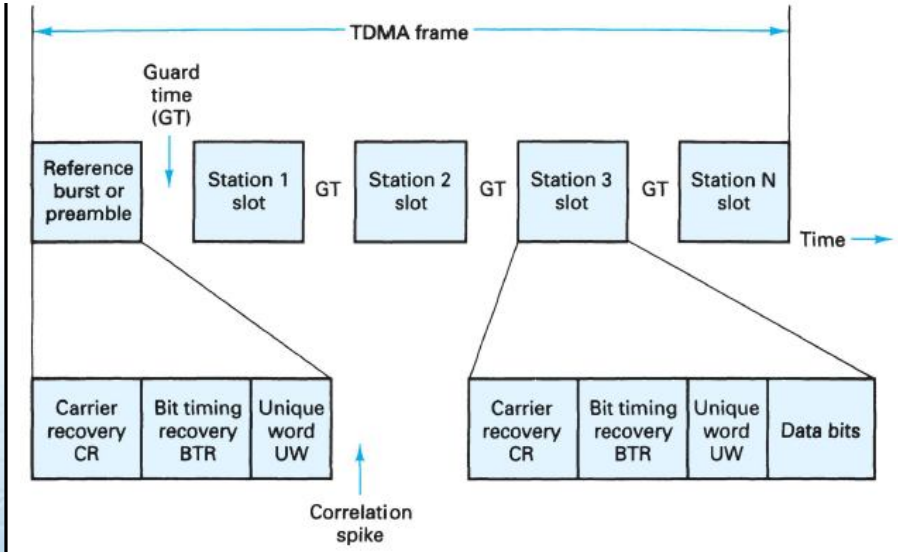
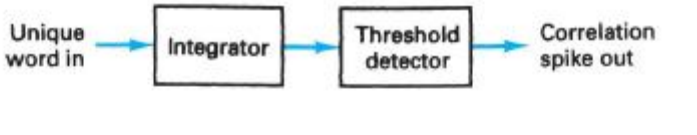
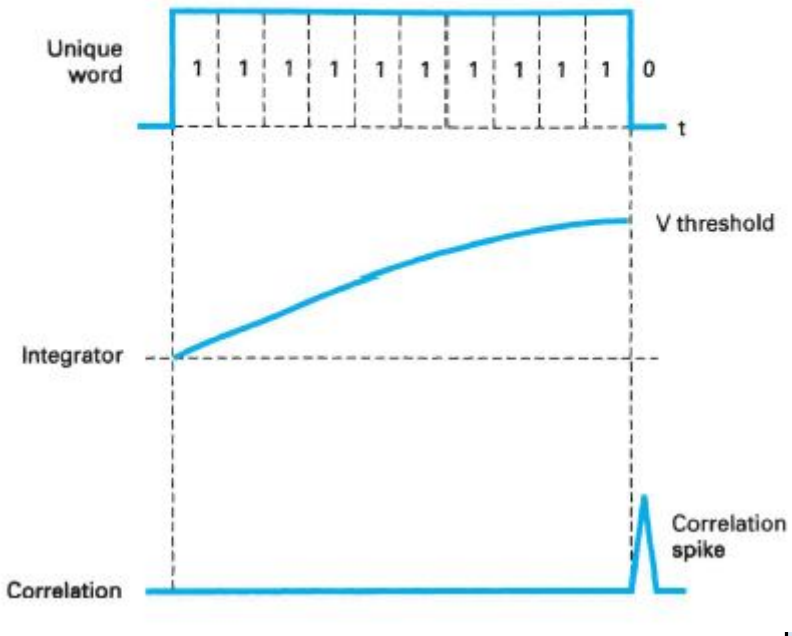
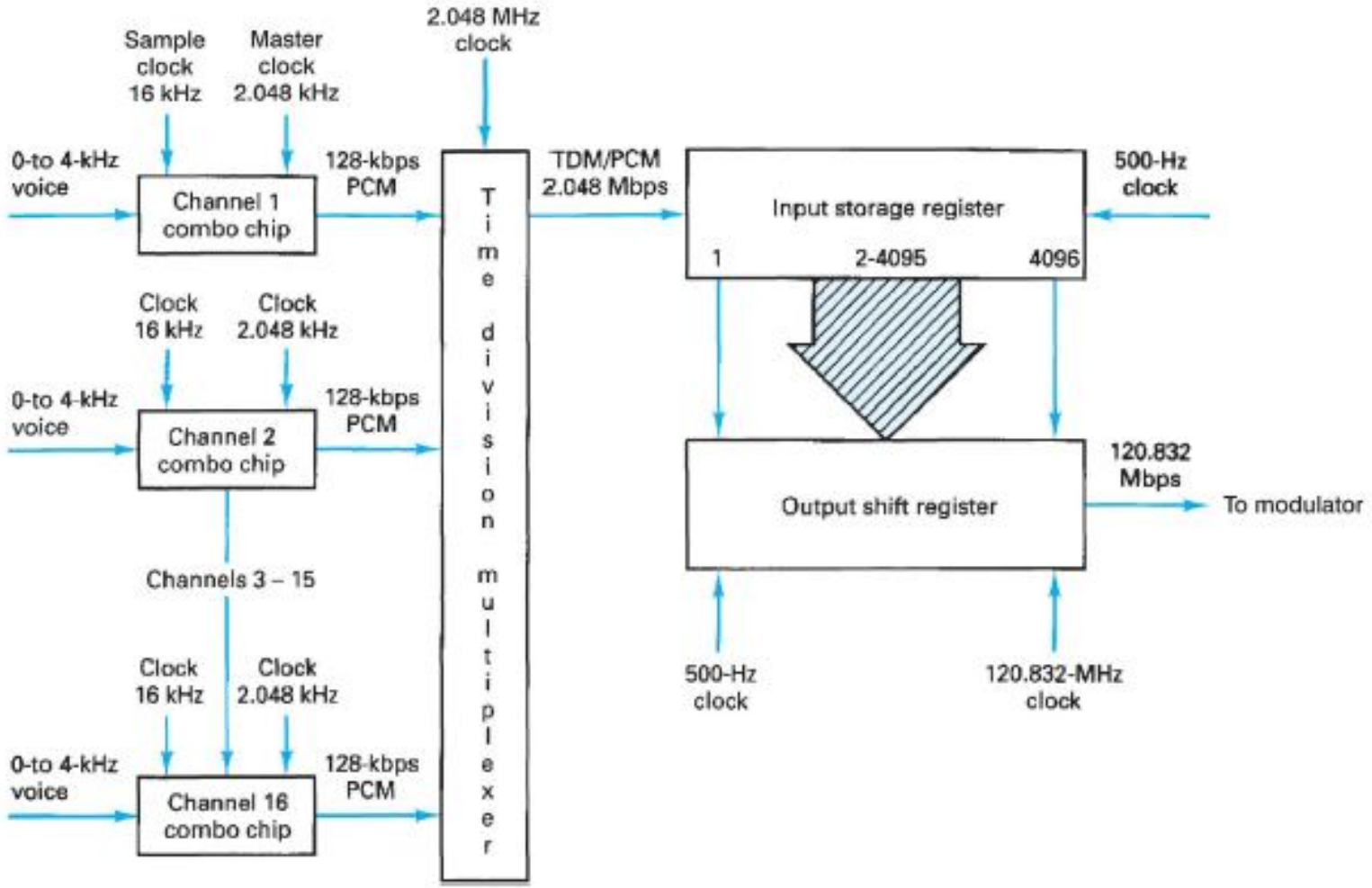


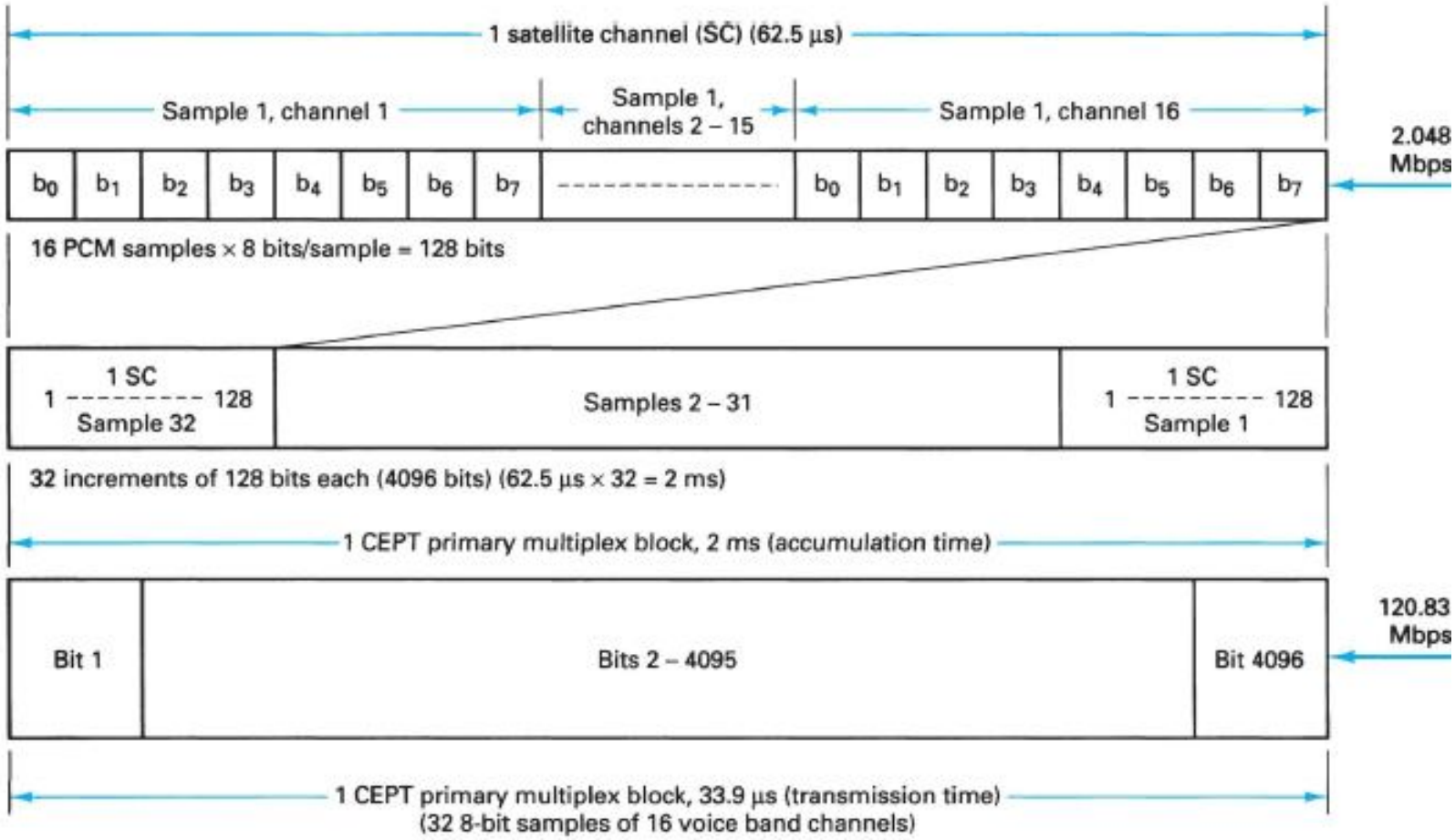




TIME DIVISION MULTIPLE ACCESS (TDMA)



TIME DIVISION MULTIPLE ACCESS (TDMA

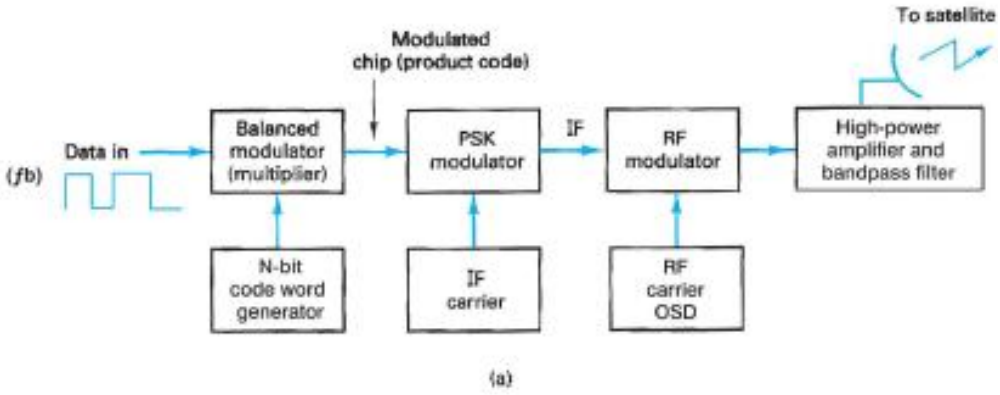


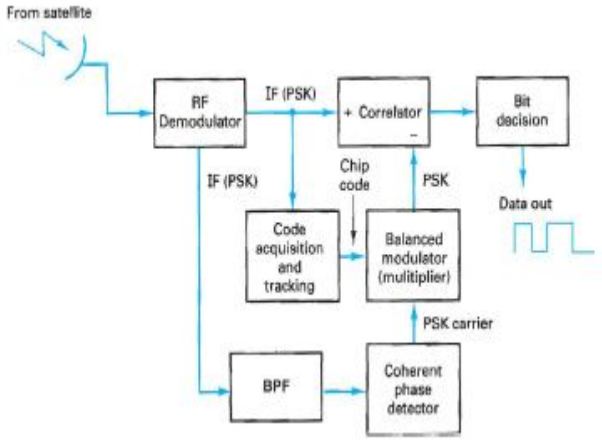
FDMA and TDMA – A Comparison

- **In TDMA,** only one carrier from any of several Earth Stations is present at Satellite at any time
- **FDMA** requires each Earth Station capable of transmitting and receiving on multitude of carrier frequencies (FDMA/DAMA)
- TDMA is more amenable to digital transmission (storage, processing, rate-conversion etc.) than FDMA
- TDMA requires precise synchronization

THREE MULTIPLE ACCESS TECHNIQUES

- **Code Division Multiple Access (CDMA) - The Concept**
  - **No restrictions on any user/earth station on time and frequency slots usages, rather any user can use allocated BW or all system BW at any time, however, using a special chip code to spread its low - bandwidth signal over the entire allocated spectrum… Spread Spectrum Multiple Access**





2.2.1.1 FDMA systems:

- Use **low bit rates** -> simple low cost electronics.
- Low bit rates -> **large symbol time** as compared to avg. delay spread -> no intersymbol interference -> thus little or no equalization is required.
- It is a **continuous transmission** system and so a small number of bits are needed for overhead (synchronization and framing).
- Involves **narrowband filters** that cannot be realized in VLSI -> high cost.
- Requires **guard bands** between the frequency bands to reduce adjacent channel interference.
- Fixed bit rate per channel, **no flexibility in bit rate** (i.e., cannot support bursts or variable bit rate traffic).
- Because it uses **FDD**, transmitter and receiver operate at the same time, more costly design.

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2.2.1.2 TDMA systems:

- Permits **flexible bit rates** (i.e., multiple time slots can be assigned to a user, e.g., if each time slot translates to 32Kbps, then a 64Kbps user gets assigned 2 slots per frame).
- Can support **bursts or varible bit rate** traffic if number of slots assigned to a user can be changed frame by frame (e.g., 2 slots in frame 1, 3 slots in frame 2, 1 slot in frame 3, 0 slots in frame 4, etc.).
- No **guard bands** required for wideband system.
- No **narrowband filters** required for wideband system -> can be implemented using VLSI
- The **high bit rates** of wideband systems will require complex equalization.
- Because of burst mode of operation requires a large number of **overhead bits** for synchronization and framing.
- If **TDD** is used it reduces the cost of the system as transmitter and receiver operate in different time slots. (Note that FDD can use staggered time slots so that simultaneous transmission and reception is not necessary).

- **Guard time** (extra bits) required in each slot to accommodate time inaccuracies because of clock instability
- Electronics must operate at high bit rates -> **high power consumption** -> shortens battery life. Also more expensive.
- Complex signal processing required to be able to **synchronize** within a short slot time.

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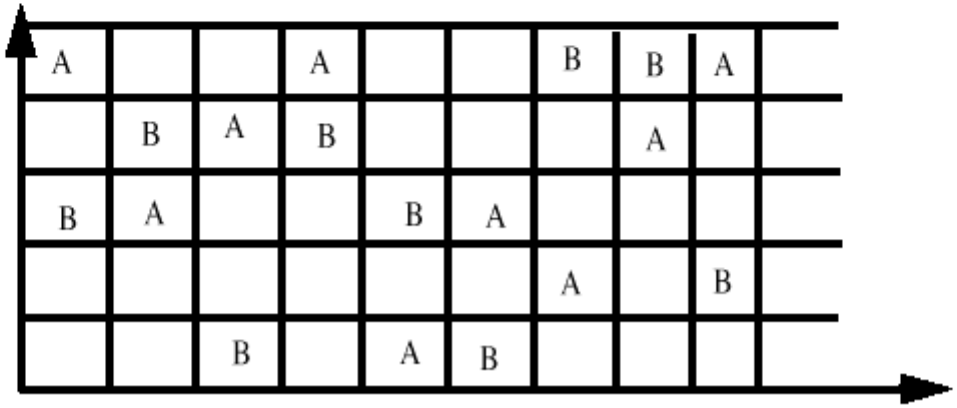
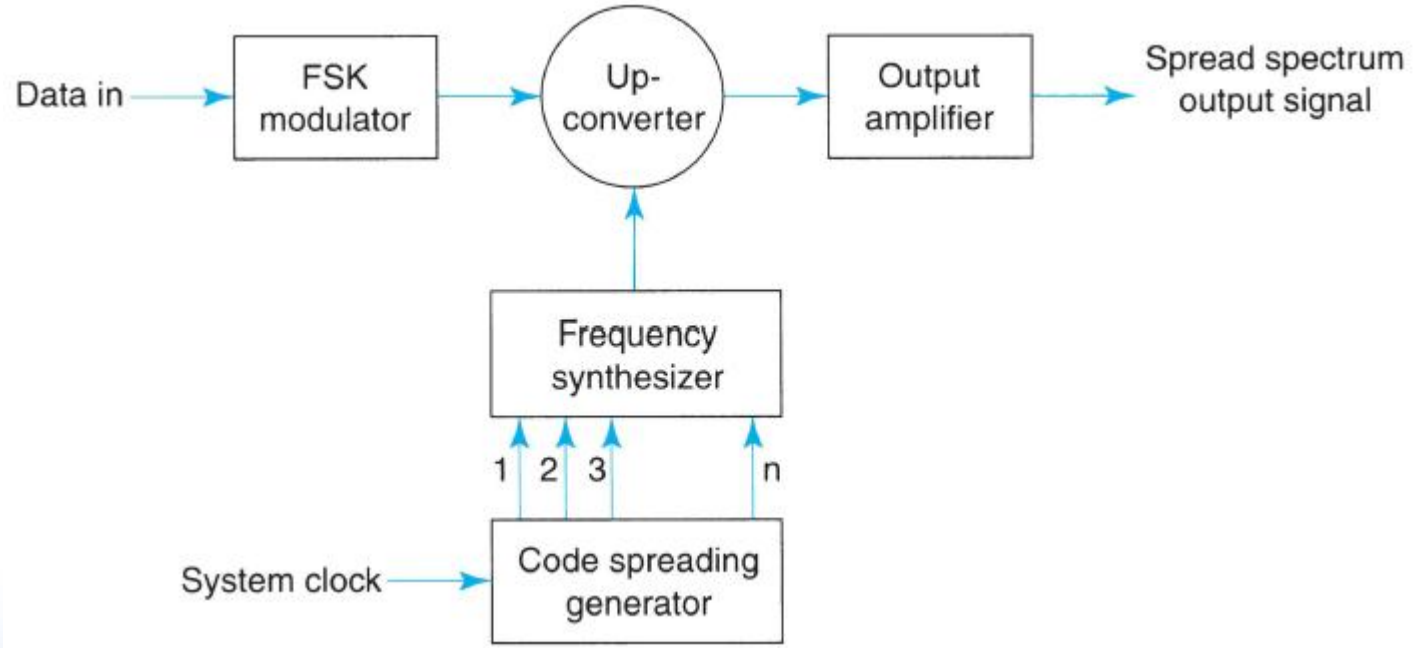
2.2.1.3 CDMA systems

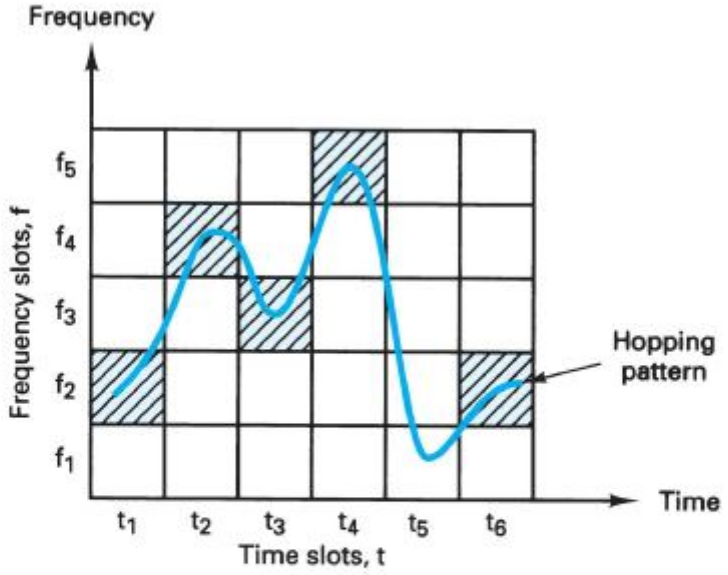
- **Two** types exist:
  - Direct Sequence CDMA (DS-CDMA)
  - Frequency hopping CDMA (FH-CDMA)
- **1. FH-CDMA** is based on a narrowband FDM system in which an individual user's transmission is spread out over a number of channels over time (the channel choice is varied in a pseudorandom fashion). If the carrier is changed every symbol then it is referred to as a fast FH system, if it is changed every few symbols it is a slow FH system.

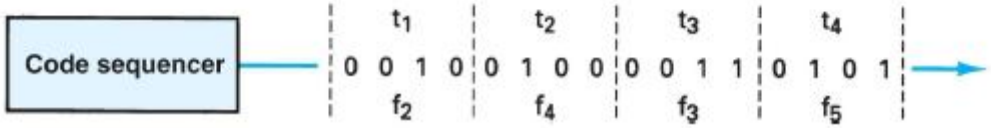


FH-Spread Spectrum



FH-Spread Spectrum

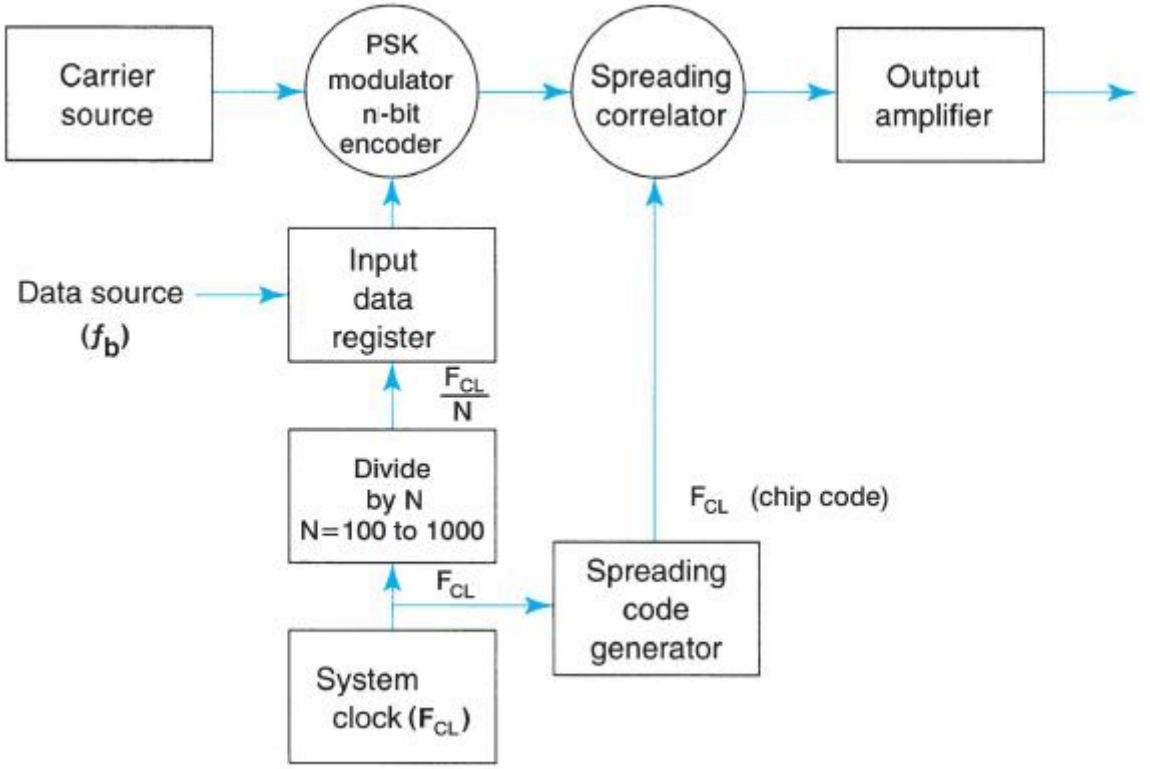




- **2. DS-CDMA** spreads the narrowband user signal (Rbps) over the full spectrum by multiplying it by a very wide bandwidth signal (W). This is done by taking every bit and in the user stream and replacing it with a pseudonoise (PN) code (a longer bit sequence called the chip rate). The codes are orthogonal (or approx. orthogonal).
  - This results in a processing gain G = W/R (chips/bit). The higher G the better the system performance as the lower the interference. G^2 indicates the number of possible codes. Not all of the codes are orthogonal.

CDMA

❖ DS-Spread Spectrum



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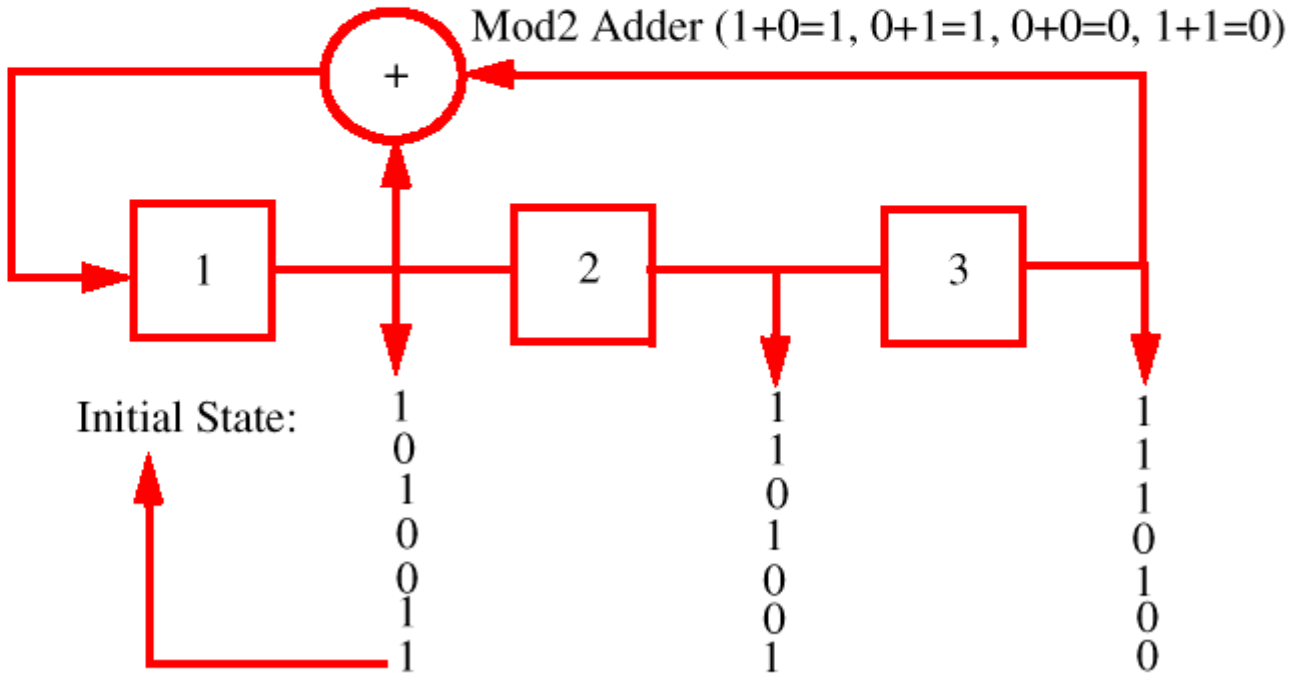
2.2.2 DS-CDMA

- An m-bit PN generator generates $N=2^m - 1$ different codes.
- Out of these codes only "m" codes are orthogonal -> zero cross correlation.
- For example a 3 bit shift register circuit shown below generates N=7 codes.



2.2.2.1 Orthogonal Codes

- A pair of codes is said to be orthogonal if the cross correlation is zero.
- For two m-bit codes: $x_1,x_2,x_3,...,x_m$ and $y_1,y_2,y_3,...,y_m$:

$$R_{xy}(0) = \sum_{1(i=\ )}^{m} x_i \cdot y_i = 0$$

- For example: x = 0011 and y = 0110. Replace 0 with -1, 1 stays as is. Then:

x = -1 -1 1 1

y = -1 1 1 -1

$R_{xy}(0) = 1 -1 +1 -1 = 0$

- CDMA has a **soft capacity**. The more users the more codes that are used. However as more codes are used the S/I ratio will drop and the BER will go up of all users.
- CDMA requires tight **power control** as it suffers for far-near effect. In other words, a user close to the base station transmitting with the same power as a user farther away will drown the latter's signal. All signals must have more less equal power at the receiver.
- **Rake receivers** can be used to improve signal reception. Time delayed versions (a chip or more delayed) of the signal (multipath signals) can be collected and used to make bit level decisions.
- **Soft handoffs** can be used. Mobiles can switch base stations without switching carriers. Two base stations receive the mobile signal and the mobile is receiving from two base stations (one of the rake receivers is used to listen to other signals).
- **Burst transmission** - reduces interference
- Electronics must operate at high bit rates -> **high power consumption** -> shortens battery life. Also more expensive. However, transmitter turns off in between bursts conserving energy.