

# Multiple Access Techniques

# Multiple Access Types

- Multiple access scheme allows many users to share satellite's resource (Capacity).
- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

# FDMA

- It is the simplest and most established technique employed in satellite communications.
- The available transponder bandwidth is divided into channels and then assigned to users. The users are separated in the frequency domain. FDMA assign particular frequency slices to different wireless terminals.
- Types:
  - Single Channel per Carrier (SCPC)
  - Multiple Channel per Carrier (MCPC)

# FDMA

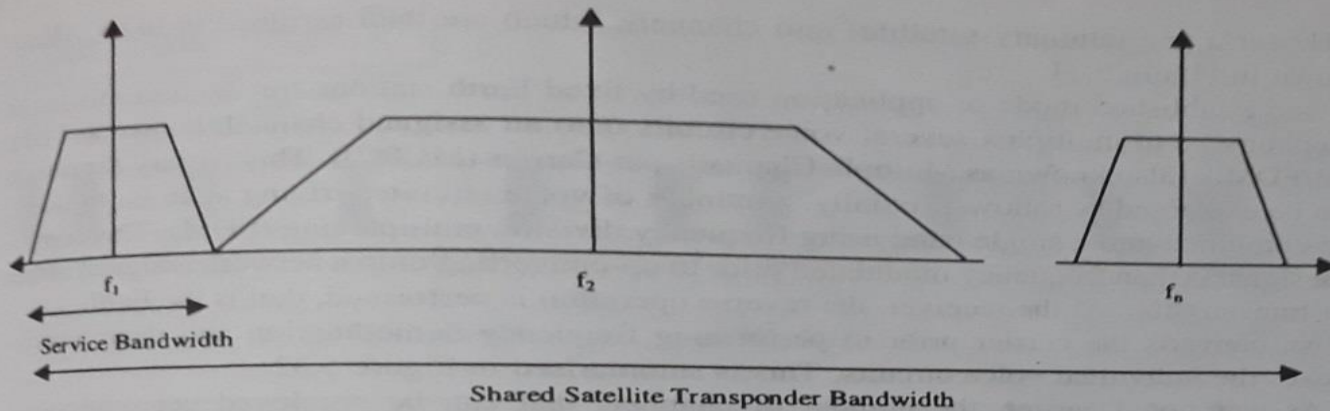
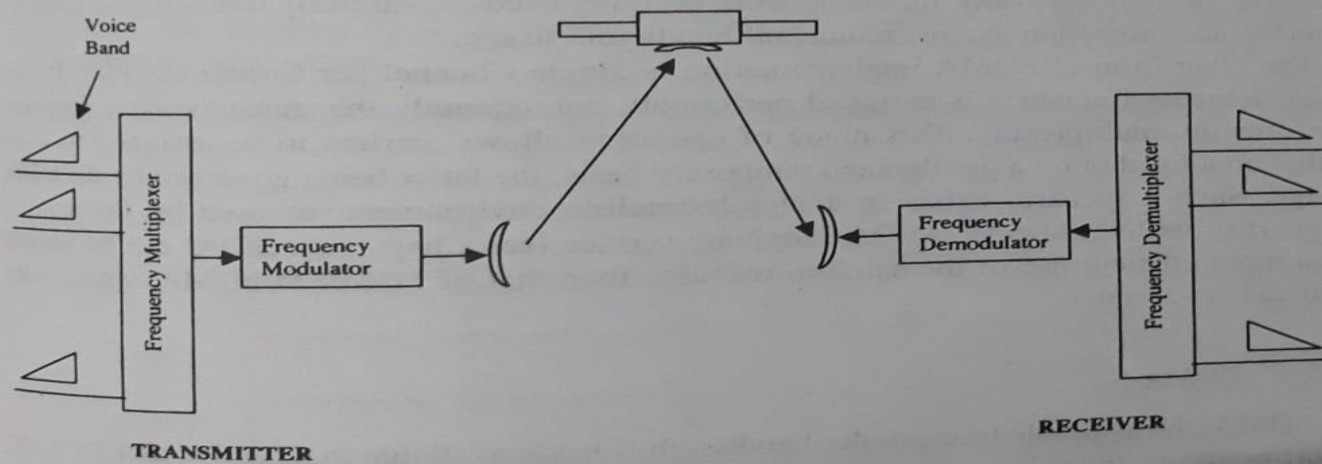


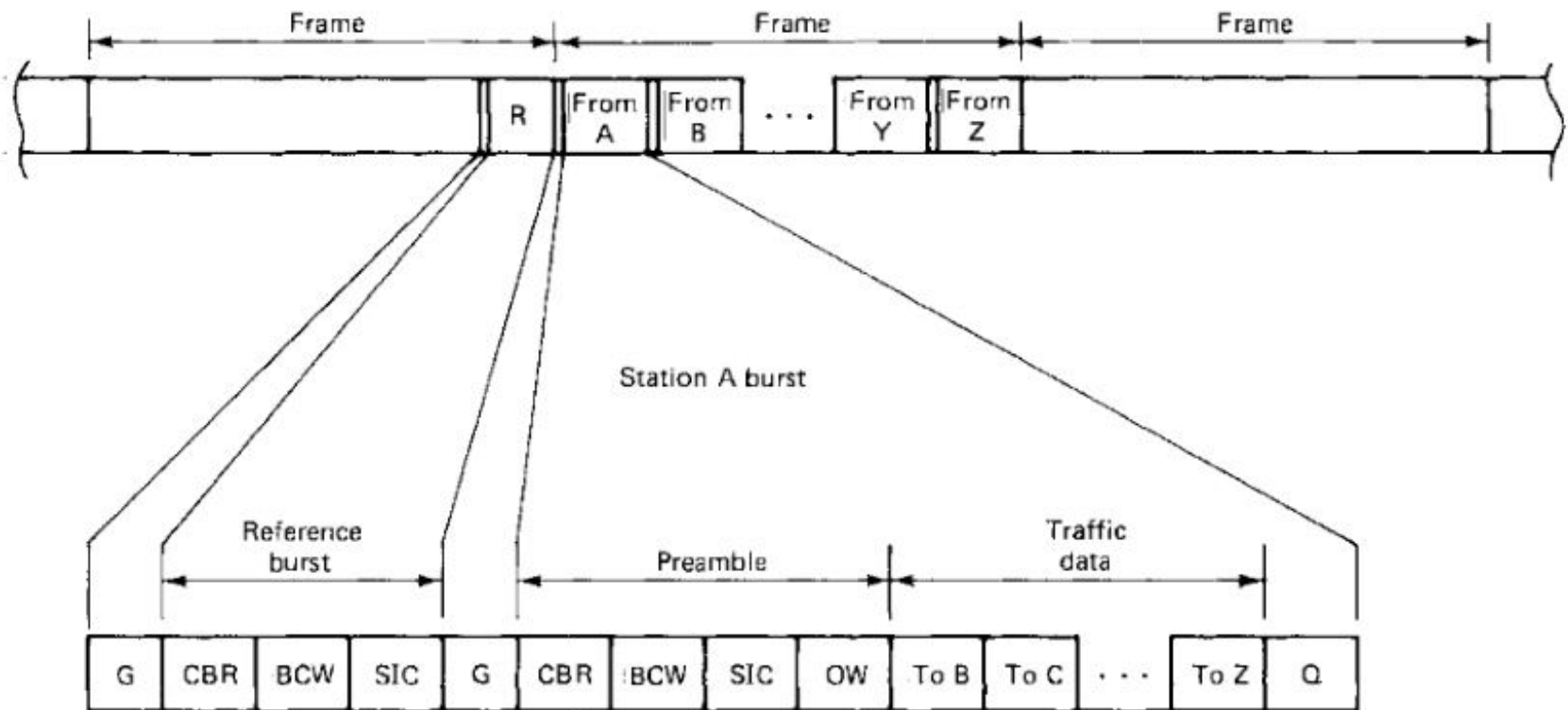
Figure 5.31 Multi-carrier usage of shared transponder bandwidth.



# TDMA

- The available transponder bandwidth is made available to an active user for a very short period of time, known as burst. In TDMA the users are separated in time domain. TDMA assign particular time slices to different wireless terminals.
- In the short period of time data are rapidly transmitted.
- The total available transponder bandwidth is shared with other users during different time slots.
- Reference burst is used to ensure that each user transmits within a specific time slot. Reference burst is made up of three parts namely, i. Carrier and Bit Timing Recovery, ii. Unique Word and iii. Control Information.

# TDMA Frame Structure



Legend:

G – guard time

CBR — carrier and bit-timing recovery

BCW – burst code word (also known as a unique word or UW)

SIC – station identification code

**Q – postamble**

# CDMA

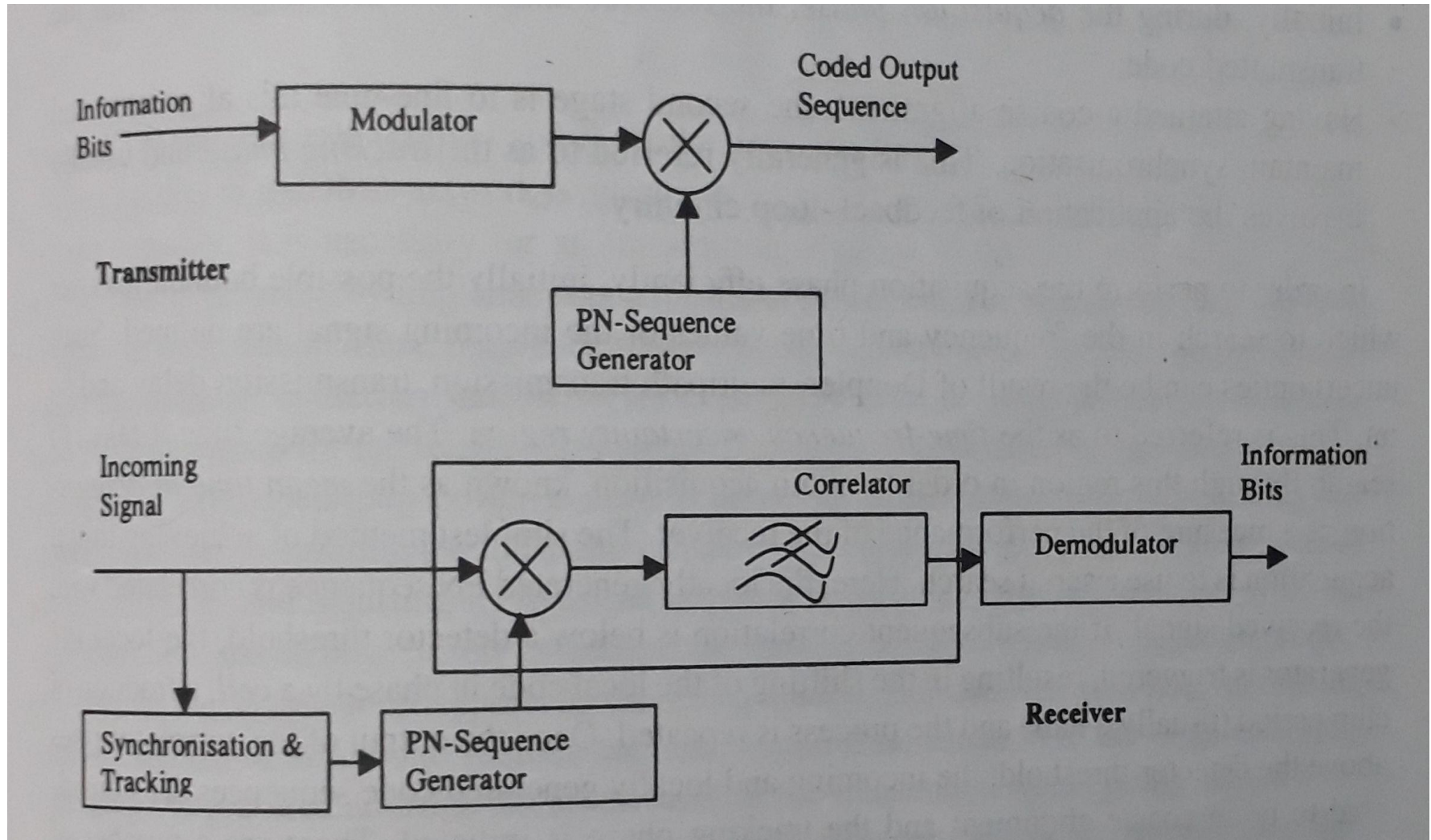
- CDMA is a digital wireless technology that was pioneered and commercially developed by QUALCOMM in 1995.
- In CDMA the total available bandwidth is made accessible to all active users at the same time. This is achieved with a unique code known only to the transmitter and receiver.
- Code generation is achieved by using a linear feedback multi-stage shift register and a modulo 2 adder. The output produces a code sequence with noise like properties termed as pseudo noise.
- CDMA techniques are Direct Sequence, Frequency Hopping and Time Hopping.

- CDMA allows multiple users to simultaneously use a common channel for transmission of information.
- A CDMA transmitter will code its information with a code or spreading sequence particularly allocated for the user.
- The transmitter sends the coded signal to the receiver. Using the same code sequence, the receiver decodes the received signal. The coding process is also called as spread spectrum modulation. The coded signal is called as spread spectrum signal.

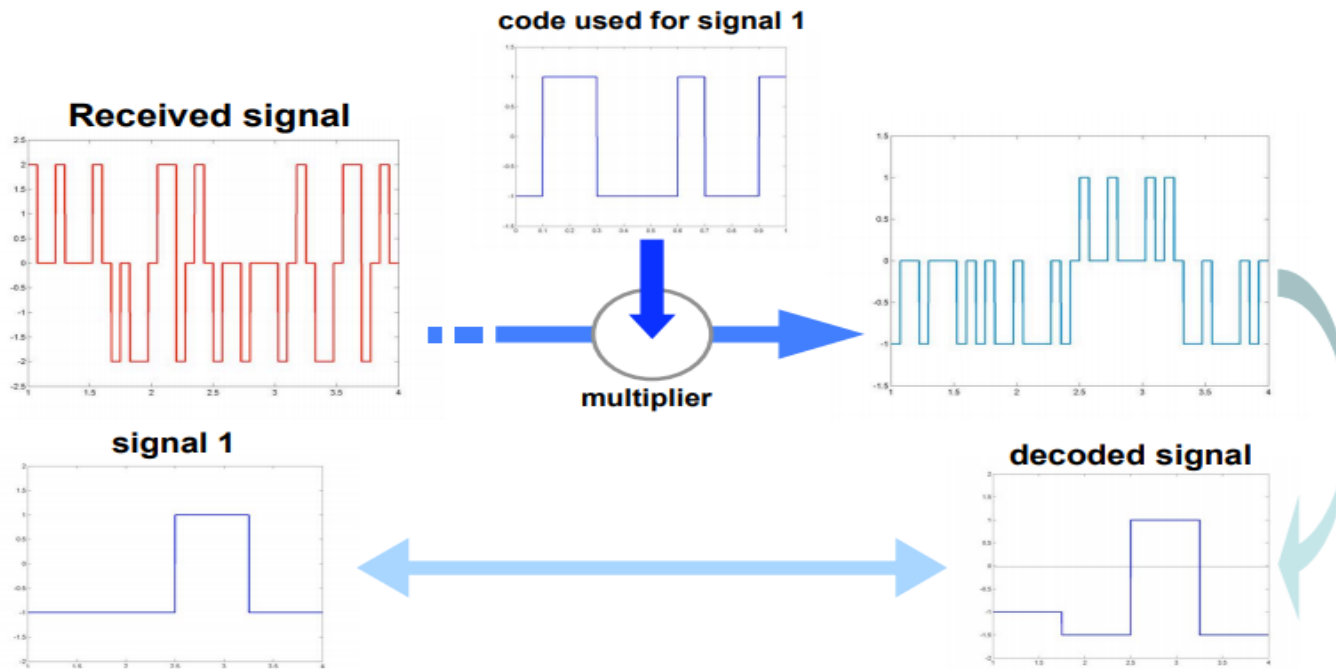
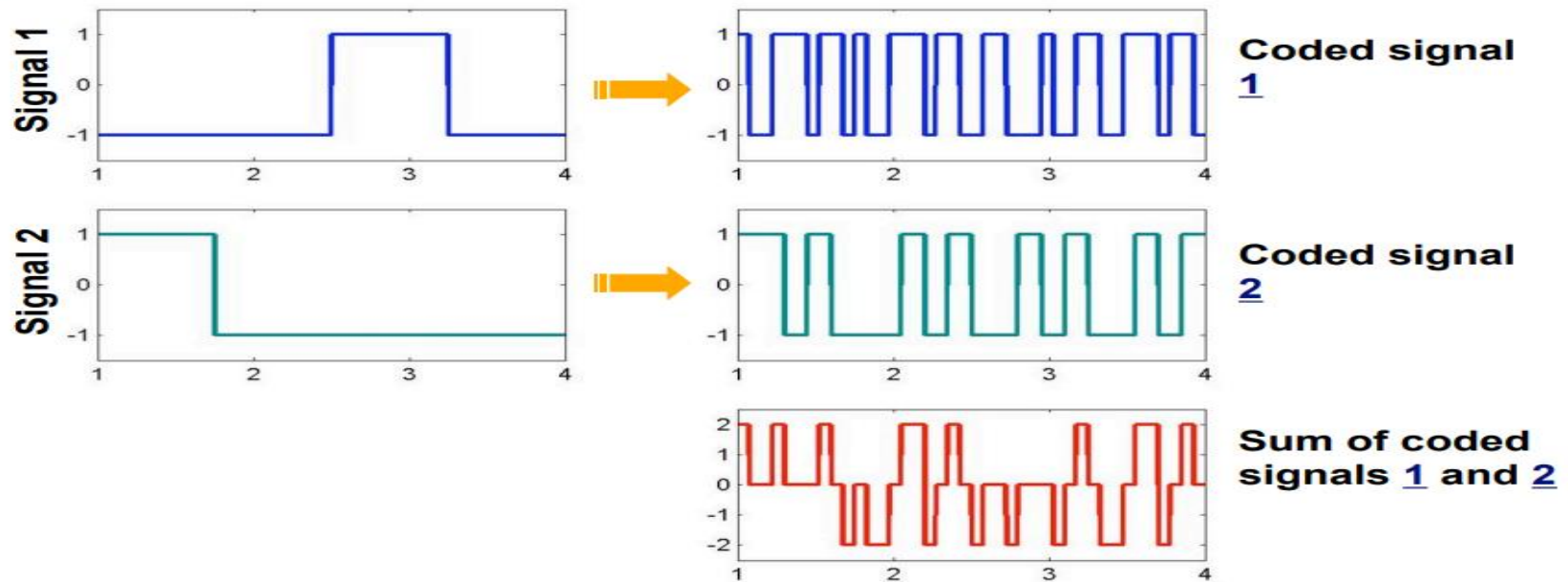


# Direct Sequence CDMA

The original data signal is multiplied by the high chip rate spreading code.

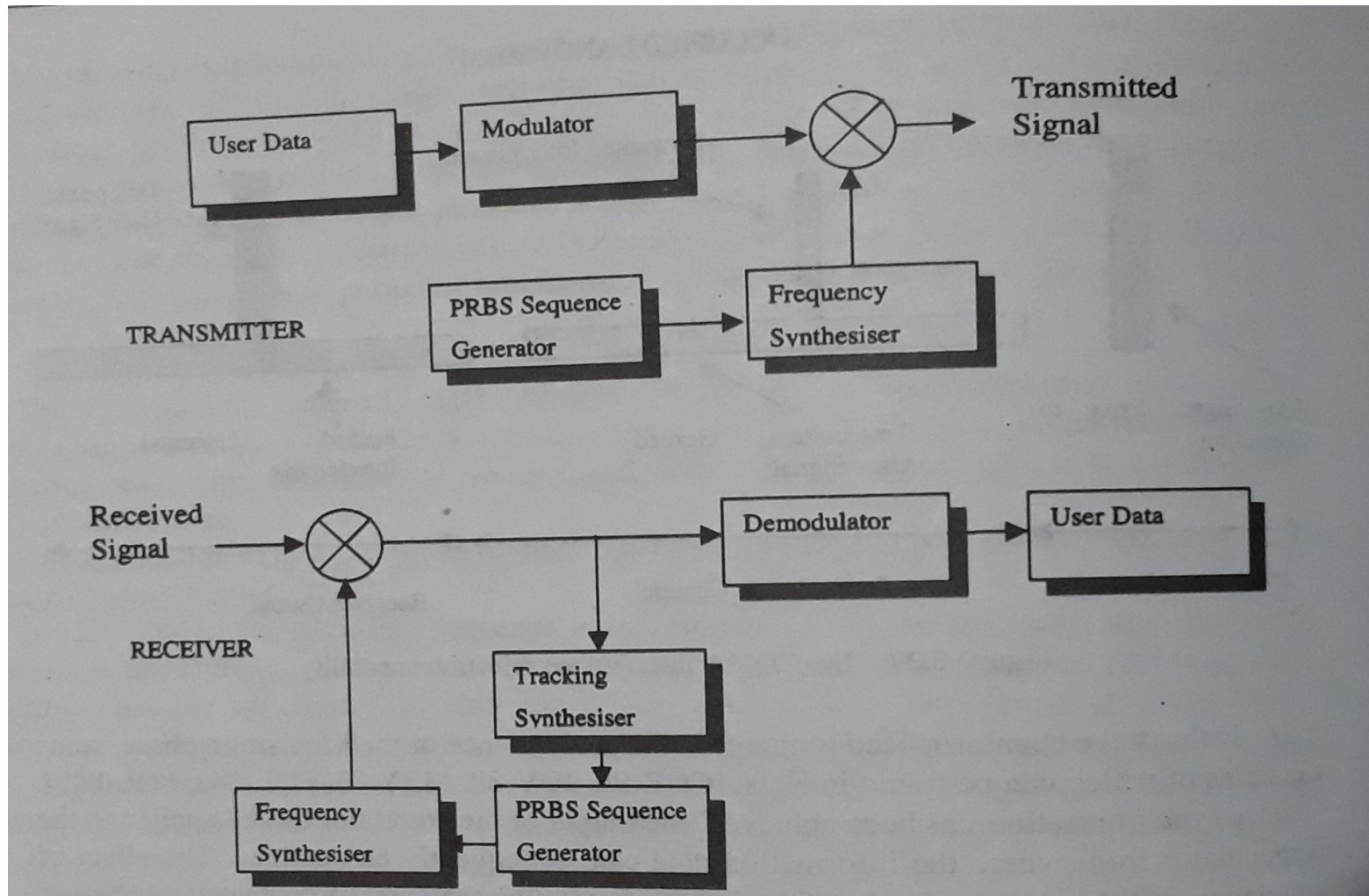


# Direct Sequence Spread Spectrum



# FH-CDMA

The carrier frequency at which the original data signal is transmitted is rapidly changed according to the spreading code.



## TH-CDMA

- The original data signal is not transmitted continuously. Instead, the signal is transmitted in short bursts where the times of the bursts are decided by the spreading code.

## DAMA

Demand Assigned Multiple Access is used when the link between the station and satellite is not a constant one.

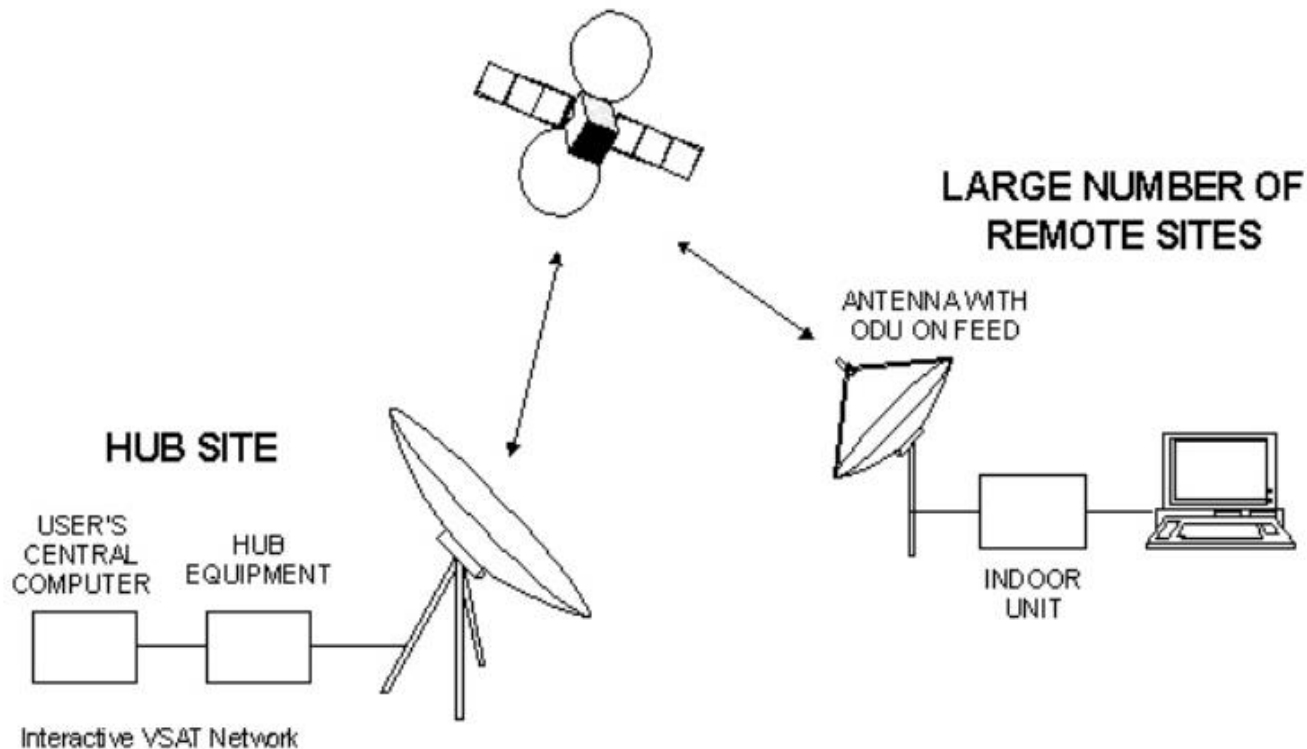
This helps assign bandwidth according to the demand.

This can be implemented on TDMA or FDMA or combination of both.

It is commonly used in VSAT (Very Small Aperture Terminal) Systems.

# DAMA

- It is often used in military environments due to the relative simplicity of implementation.
- It can operate with bent pipe transponders.



<b>Technique</b>	<b>FDMA</b>	<b>TDMA</b>	<b>CDMA</b>	<b>SDMA</b>
<b>Concept</b>	Divide the frequency band into disjoint sub-bands	Divide the time into non-overlapping time slots	Spread the signal with orthogonal codes	Divide the space in to sectors
<b>Active terminals</b>	All terminals active on their specified frequencies	Terminals are active in their specified slot on same frequency	All terminals active on same frequency	Number of terminals per beam depends on FDMA/ TDMA/ CDMA
<b>Signal separation</b>	Filtering in frequency	Synchronization in time	Code separation	Spatial separation using smart antennas
<b>Handoff</b>	Hard handoff	Hard handoff	Soft handoff	Hard and soft handoffs
<b>Advantages</b>	Simple and robust	Flexible	Flexible	Very simple, increases system capacity
<b>Disadvantages</b>	Inflexible, available frequencies are fixed, requires guard bands	Requires guard space, synchronization problem	Complex receivers, requires power control to avoid near-far problem	Inflexible, requires network monitoring to avoid intra cell handoffs
<b>Current applications</b>	Radio, TV and analog cellular	GSM and PDC	2.5G and 3G	Satellite systems, LTE

# Satellite Packet Communications

- Every communications satellite in its simplest form performs the task of transmitting information from a source earth station to the satellite (this is called the uplink). This is followed by a retransmission of the received and processed information from the satellite back to the ground (this is called the downlink).
- The downlink may either be to a select number of ground stations or it may be broadcast to all receiving terminals in the satellite's footprint. Here, we focus on specific protocols or methods guiding access to the medium used for transmission and retransmission of packets (messages) to and from the satellites.
- These protocols are referred to as Medium Access Schemes. Medium Access Control (MAC) schemes are mechanisms for sharing a single link. MAC schemes are essentially multiplexing schemes. Message access on any system can be of three types:
  - Conflict-free Scheme.
  - Contention (random access) Scheme.
  - Reservation (controlled access) Scheme



# Message Transmission by FDMA: M/G/1 Queue

## a. M/G/1 QUEUE

Consider a queuing system, in which arrivals occur according to a Poisson process with parameter  $\lambda$  and in which  $x$  is the service rendered to the customers, is distributed according to a distribution  $B(t)$ . In such a queuing system, an outside observer sees the number of customers in the system as equal to that seen by an arriving customer, which equals that seen by a departing customer. The following holds for an M/G/1 queuing system:

$$D = x + W = x + \frac{\lambda x^2}{2(1-\lambda T)}$$

Where  $D$  = Average delay time,  $p = \lambda x$  = Load factor,  $W$  = Queuing time.

Therefore, for an FDMA system, considering a typical user that generates packets according to a Poisson process with rate  $\lambda$  packets/sec and its buffering capabilities are not limited, the time required for the transmission of a packet is  $T$ . Each node can therefore be viewed as an M/G/1 queue since each packet size is not constant. Thus, using the known system delay time formula for M/G/1 queuing systems we get that the expected delay of a packet is:

$$D = T + \frac{\lambda T^2}{2(1-\lambda T)}$$

And the delay is distribution is given by,

$$D^* = X^*(s) \frac{s(1-p)}{s-\lambda+\lambda X^*(s)}$$

Where  $X^*(s)$  is the laplace transform of the transmission time.



# ALOHA (Additive Links On-line Hawaii Area)

- Message transmission by TDMA can be done using the ALOHA protocol, packet reservation and tree algorithm.
- The ALOHA scheme was invented at the University of Hawaii for the purpose of interconnecting remote stations and data terminals to a central server over a packet radio network.
- Its simplest mode of operation consists of earth stations randomly accessing a particular resource that is used to transmit packets.
- Earth stations can detect whether their transmission has been correctly received at the satellite by either monitoring the re-transmission from the satellite or by receiving an acknowledgement message from the receiving station.

# Slotted ALOHA

- The Pure Aloha implemented with a slotted channel variation is known as the slotted Aloha protocol. For the slotted Aloha variant, all packets are of equal length and time is slotted.
- Packets are only transmitted in the next subsequent slot to their arrival slot. It also assumes that there is no buffering, i.e. a station never has more than one packet to transmit in a single time slot, in which case, the station would have needed to buffer one or more packets for subsequent transmission.
- To accommodate the “no buffering” assumption, it assumes that there is an infinite number of stations, with each new arrival from a new 'source' station. Inevitable collision occurs if more than one station venture to transmit packets in one and the same time slot, and consequently the receivers cannot receive the packets correctly.
- Successful transmission happens only when there is exactly one packet transmitted in a slot. If no packet is transmitted in a slot, the slot is called idle. If there is a collision, the colliding packets are retransmitted at a later slot after a randomly chosen back-off period. Such packets are also called backlogged packets.

# Coding Schemes

- Coding techniques are used for several reasons: reduction of dc wandering, suppression of intersymbol interference, and self-clocking capability.
- The coding schemes are for error detection and correction, specifically forward error correction (FEC) techniques. FEC codes may be divided into two classes of codes, namely, linear block codes and convolutional codes. Depending on the intended use of codes, FEC enables the receiver not only to detect errors but also to facilitate their correction.

## Linear Block Codes:

In linear block codes, the encoder splits up the incoming data stream into blocks of  $k$  digits and processes each block individually by adding redundancy as a parity check according to a predefined algorithm.

The output of the encoder is a code word with  $n$  digits, where  $n > k$ . The general form of a linear block code word is  $Y = GX$ .

where  $G$  is a generator matrix that creates the check bits from the data bits, while the input message vector  $X$  and code (output) vector  $Y$  have components defined as

$$X = (x_1; x_2; x_3; \dots ; x_k) \quad Y = (y_1; y_2; y_3; \dots ; y_n)$$

## Cyclic Codes:

Cyclic codes are a subset of linear block codes. They are the most useful and popular because encoding and decoding can be implemented by using simple shift registers: error detection and correction are achieved with shift registers and some additional logic gates

## **BCH Codes:**

The BCH (Bose–Chaudhuri–Hocquenghem) codes are the most powerful and flexible group of cyclic error correction codes available. Their design is straightforward: it uses shift register and logic circuits for coding and decoding.

## **Convolutional Codes:**

A convolutional coder is a finite memory system. The name “convolutional” refers to the fact that the added redundant bits are generated by mod-2 convolutions. A generalized convolutional encoder consists of an L-stage shift register,  $n$  mod-2 adders, a commutator, and network of feedback connections between the shift register and the adders.

A very important parameter in the consideration of convolutional encoding is the constraint or memory length. The constraint length is defined as the number of shifts over which a single message bit can influence the encoder output. For example, if input message data are in groups of  $k$  bits and are fed into the L-stage shift register, then the register can hold  $(L/k)$  groups.