Chapter 07:
Frequency Division Multiplexing

Department of Electronics and Computer Engineering
Pashchimanchal campus, IOE, TU

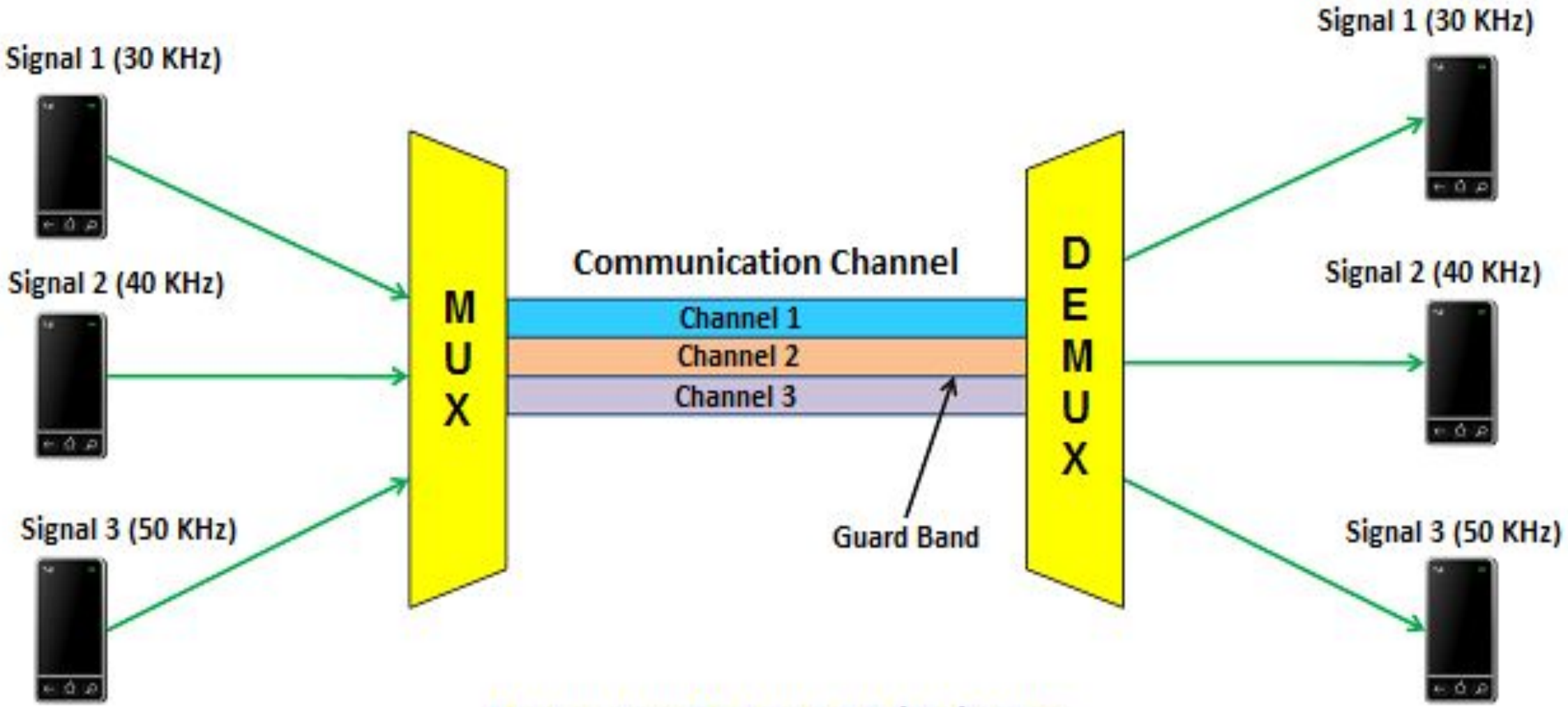
Frequency division multiplexing (FDM) systems:

- It is system of combining number of individual message signal over the common channel.

- In FDM available channel bandwidth is divided into number of non overlapping frequency slots separated with guard band and each message signal is assigned a slot of frequency within the pass band of the channel.

- An example of FDM signal with three message signal is discussed below:

Frequency division multiplexing (FDM) systems:



Frequency division multiplexing (FDM) systems:

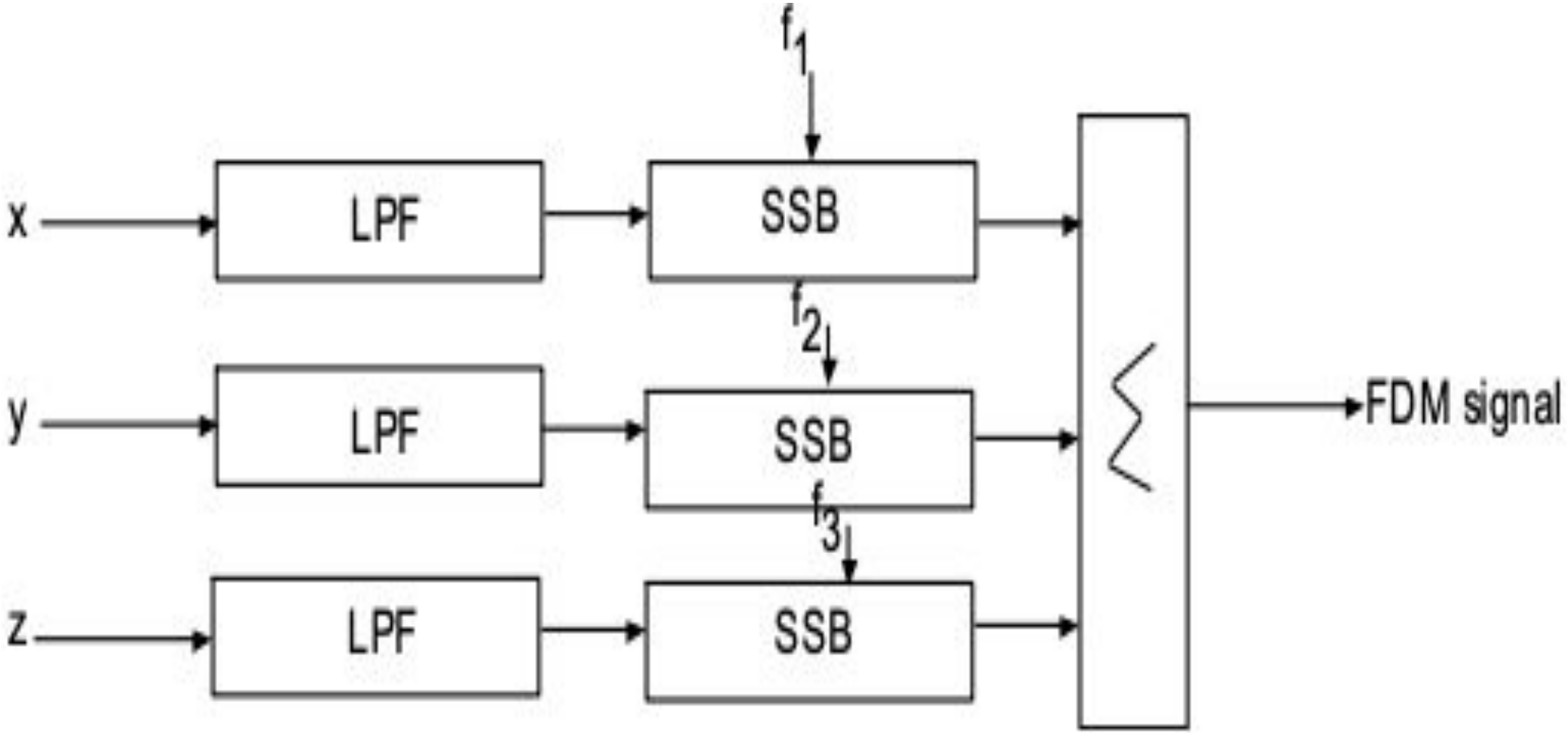
- The three band limited signal x, y, z modulate the three separate sub carrier signals with frequencies f_1, f_2, f_3

  expressed in frequency domain with reasonable margin to avoid overlapping.

- The modulation is SSB-USB.

- The output of the each modulator then added to produce the composite signal having three multiplexed signals.

Frequency division multiplexing (FDM) systems:



Frequency division multiplexing (FDM) systems:

- The multiplexed signal is finally may be transmitted as it is or used to modulate another high frequency carrier signal before transmission.
- At the receiving end the multiplexed signal is passed through band pass filters tuned at the subcarrier frequencies.
- Therefore separate the multiplexed signal into separate channels.
- Each of the signals is then passed to the SSB demodulator to recover original message signal.

FDM in Telephony hierarchy

- FDM is extensively used in telephony to transmit number of telephone channel simultaneously over a channel of cable or microwave link.
- Basic telephone channel is band limited to 300 to 3400 Hz.
- Band width 3100 Hz.
- A frequency slot of 4 KHz is assigned to each telephone channel so that there is guard band of 900 hz for each channel.

FDM in Telephony hierarchy

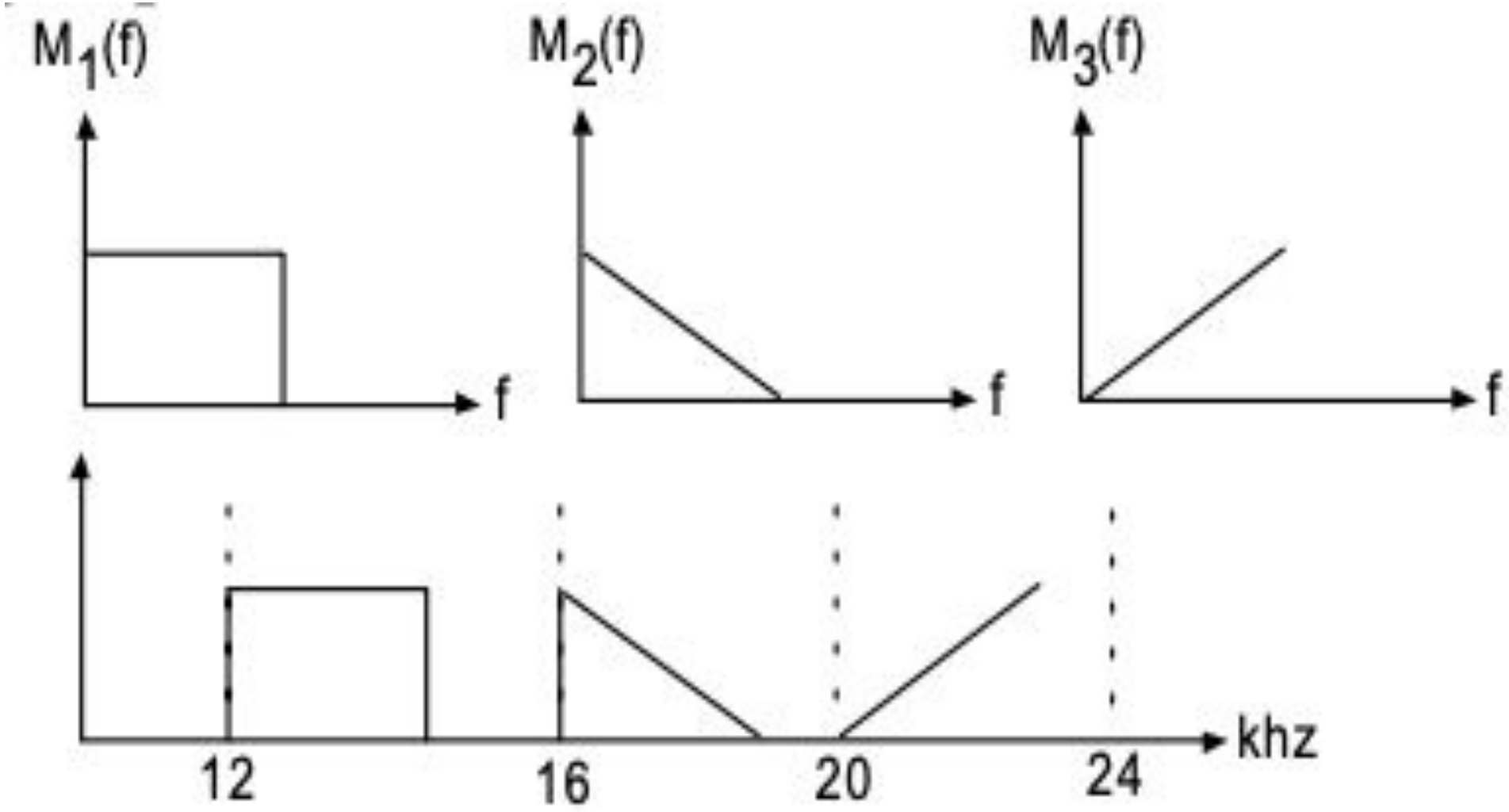
- The first 3 telephone channels are multiplexed at 12, 16 and 20 khz to form a **pre group** a three telephone channels.

- The multiplexing (frequency shifting in SSB-USB).

- The example of spectrum of individual telephone channels and multiplexed pre- group is shown below.

- The total bandwidth of the pre-group consisting of three telephone channel is 12 khz.

FDM in Telephony hierarchy



FDM in Telephony hierarchy

No of Voice channel	Bandwidth	Spectrum	AT&T	ITU-T
12	48 KHz	60-108 KHz	Group	Group
60	240 KHz	312-552 KHz	Super Group	Super Group
300	1.232 MHz	812-2044 KHz	—	Master Group
600	2.52 MHz	564-3084 KHz	Master Group	—
900	3.872 MHz	8.516-12.388 MHz	—	Super Master Group
N X 600	Master Group Multiplier			
3600	16.984 MHz	0.564-17.548 MHz	Jumbo Group	
10800	57.442	3.124-60.516 MHz	Jumbo Group Multiplier	

FDM in Telephony hierarchy

Four sets of pre-groups produce 12 channel group carrier frequencies 60, 72 , 84 and 96 khz is assigned to each pre-group.

The bandwidth of the 12 group channel is 48khz.

Five sets of 12 channel group produce 60 channel group. The frequency assigned are 312,360,408,456,504 and 552. The bandwidth of super group is 240khz.

Ten sets of super group produce master group of 600 voice channel with the bandwidth of 2520khz.

Finally six set of master group produce super master group with a bandwidth of 17 Mhz.

TV signal can also be transmitted over the voice channel. As the composite video signal (video+FM audio) bandwidth of about 6 Mhz, a super master 17 Mhz can be used for simultaneous transmission of two TV channels and about 1200 voice channels.

Filter and Oscillator requirements in FDM

- To track the frequency and phase of the carrier component of and incoming signal.

- Oscillator are used to tune the frequency.

- In FDM, the guard band between two adjustment frequency slots is not very large, the frequency stability of the oscillators should be very high in order to avoid overlapping.

- Each filter has to be tuned to its own frequency depending upon the frequency slots.
- In stability of the tuning and drift in centered frequency due to environmental conditions would result in overlapping and cross talk.

Introduction to satellite communication system

- Satellite communication system has a transponder placed in earths orbit which is connected to the earth station or Ground station. The communication between them is called Satellite Communication.

- Involves the transmission of a signal from an Earth station to a satellite(transponder) in space (Uplink).

- The satellite (transponder) then receives and amplifies the signal and retransmits it back to Earth station (Downlink).

Introduction to satellite communication system

- Transponders are placed in orbit so called Geo stationary orbit.
- Signal received are re-amplified by Earth stations and terminals.
- Most common uplink frequency is 8 GHz and downlink of 4 GHz (C-band)
- From August,1965 numerous satellite have been launched for communication navigation , defense broadcasting and other purposes.

Introduction to satellite communication system

- Artificial satellite orbiting around the earth has Tx, Rx, signal processor , amplifier powered by solar voltaic module .

- Satellite system may be domestic use by a single country like Canadian Telesat System (CTS), Indian Satellite system (INSAT)), regional system used by two or more countries, French-German Symphonic system), Global system of inter continental satellite like (NTELSAT,INMARSAT,ASIASAT etc).

- The uses of satellite systems, space segments allocation and frequency allocation are coordinated by international telecommunication union (ITU) based in Jeneva.

Introduction to satellite communication system

- Specific frequency bands allocated for use in satellite system are:
  - C-band (4–8 GHz) ...
  - X-band (8–12 GHz) ...
  - Ku-band (12–18 GHz) ...
  - Ka-band (26–40 GHz)

- In general uplink and downlink frequencies are different to avoid interference.

- Satellite stage in the orbit in its position because of balance of centripetal forces on the satellite an the gravitation force of the earth.

- For this to happen, the height of the satellite has to be greater then 36000km from the earth surface.

Orbit of Satellite

- Orbit is a imaginary path in the space along which the satellite rotates the earth.
- The basic orbit are elliptical inclined, circular polar and circular equatorial.
- Circular equatorial orbit situated at the height of about 36000km is called geostationary orbit(or synchronous orbit).
- Any satellite located at this height will rotate around the earth at the same time as taken by earth to rotate about its axis (23 hrs. 56 minutes).

Orbit of Satellite

- In this case the satellite is seen stationary with respect to the earth station.
- Geostationary orbit satellites are extensively used.
- Weather forecasting satellite are usually located at lower orbits (Low earth orbit (LEO)).

Elements of satellite communication:

- Satellite contains active elements like receiver, amplifier , transmitter, antenna etc.
- Each set of these equipment (transmitter and receiver) is called transponder.
- The antenna is device shared by both receiver and transmitter.

Elements of satellite communication:

- The area in the earth surface where the level of signal form the satellite is greater or equal to satisfactory level is called “Foot print”.

- As the signal level transmitted by the satellite is very low, the level of the received signal is also extremely low .

- Therefore a special front end amplifier called low noise amplifiers (LNA) is used in the satellite receivers.

Frequency division multiple Access (FDMA) system in satellite communication:

- To increase the satellite utilization factor, most of the satellite system used Demand Assigned Multiple Access (DAMA) system.

- In this system the earth station ‘A’ desire to establish communication with another earth station ‘B’, send request signal to satellite.

- The satellite assigns the station ‘A’ any of the free channel presently unoccupied, to established link between A and B.

Frequency division multiple Access (FDMA) system in satellite communication:

- The assignment could be in frequency slot (FDM) or in time slot (TDM).

- If the assignment is in frequency slot, the system is called frequency division multiple access(FDMA).

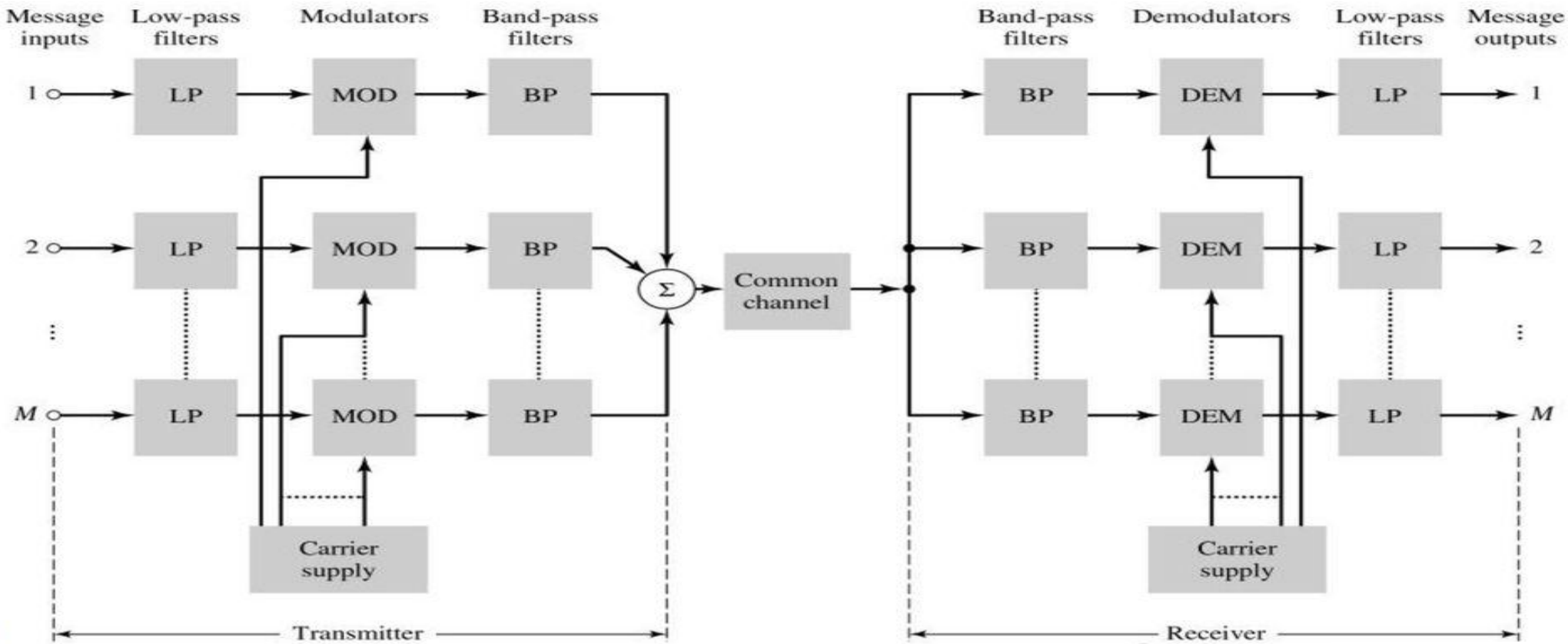
- A good example of FDMA is SPADE system (**S**ingle channel per carrier, **Pulse code** Modulated Multiple Access **D**emand Assignment **E**quipment). It consist of 800 channels(carriers) to all ground station for common signaling channel.

- If station ‘A’ wishes to establish link with station ‘B’, the station ‘A’ selects a free channel randomly and through the signaling link, send the information on the selected channel.

- When the station ‘B’ conforms it, the link is established. Because of various constraints in using FDMA, presents satellite system used only TDMA .

Frequency Division Multiplexing (FDM)

➢ Block diagram of FDM system, showing the important constituents of the transmitter and receiver.



Uses and Applications

- It allows sharing of a single transmission medium like a copper cable or a fiber optic cable, among multiple independent signals generated by multiple users.

- FDM has been popularly used to multiplex calls in telephone networks.

- It can also be used in cellular networks, wireless networks and for satellite communications.

Orthogonal Frequency Division Multiplexing

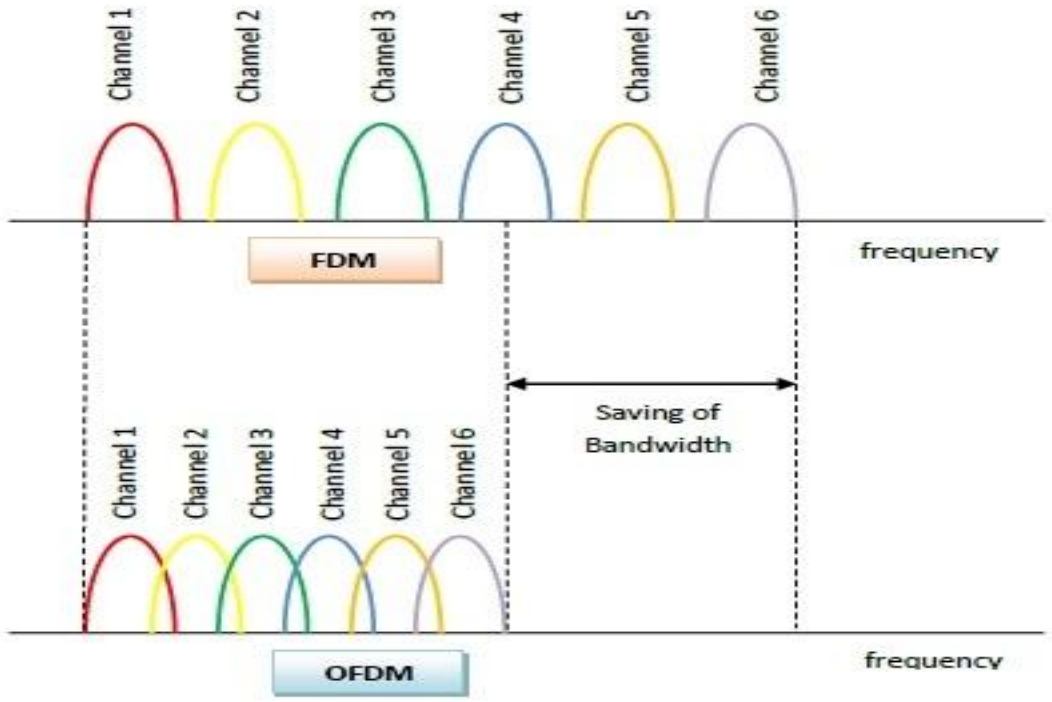
- OFDM is a technique where the channel bandwidth is split into many closely packed sub-carriers or narrowband channels each of which transmits signals independently using techniques like QAM (Quadrature Amplitude Modulation).
- OFDM has no guard bands and thus have better utilization of available bandwidth.
- In data communications and networking, orthogonal frequency-division multiplexing (OFDM) is a method of digital data modulation, whereby a single stream of data is divided into several separate sub-streams for transmission via multiple channels.

Orthogonal Frequency Division Multiplexing

- OFDM uses the principle of frequency division multiplexing (FDM), where the available bandwidth is divided into a set of sub-streams having separate frequency bands.

- OFDM was introduced in 1966 by Chang at Bell Labs and was improved by Weinstein and Ebert in 1971.

- In order that OFDM works, there should be very accurate synchronization between the communicating nodes.
- If frequency deviation occurs in the sub-streams, they will not be orthogonal any more, due to which interference between the signals will occur.



Usages

OFDM is used in the following area −

- Wi-Fi
- DSL internet access
- 4G wireless communications
- digital television
- radio broadcast services

End of Unit – 8

Thank you !!!