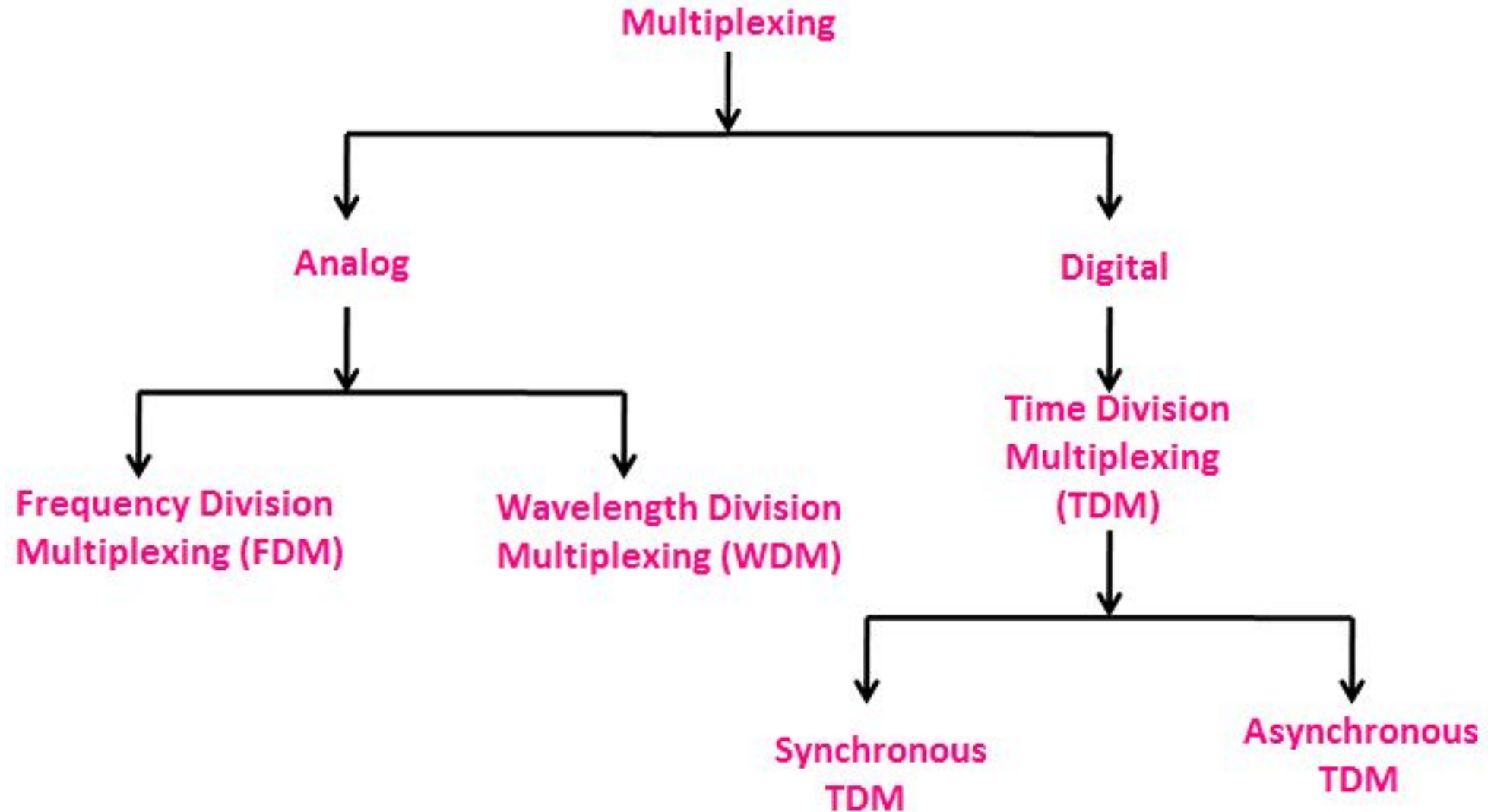


Chapter 7

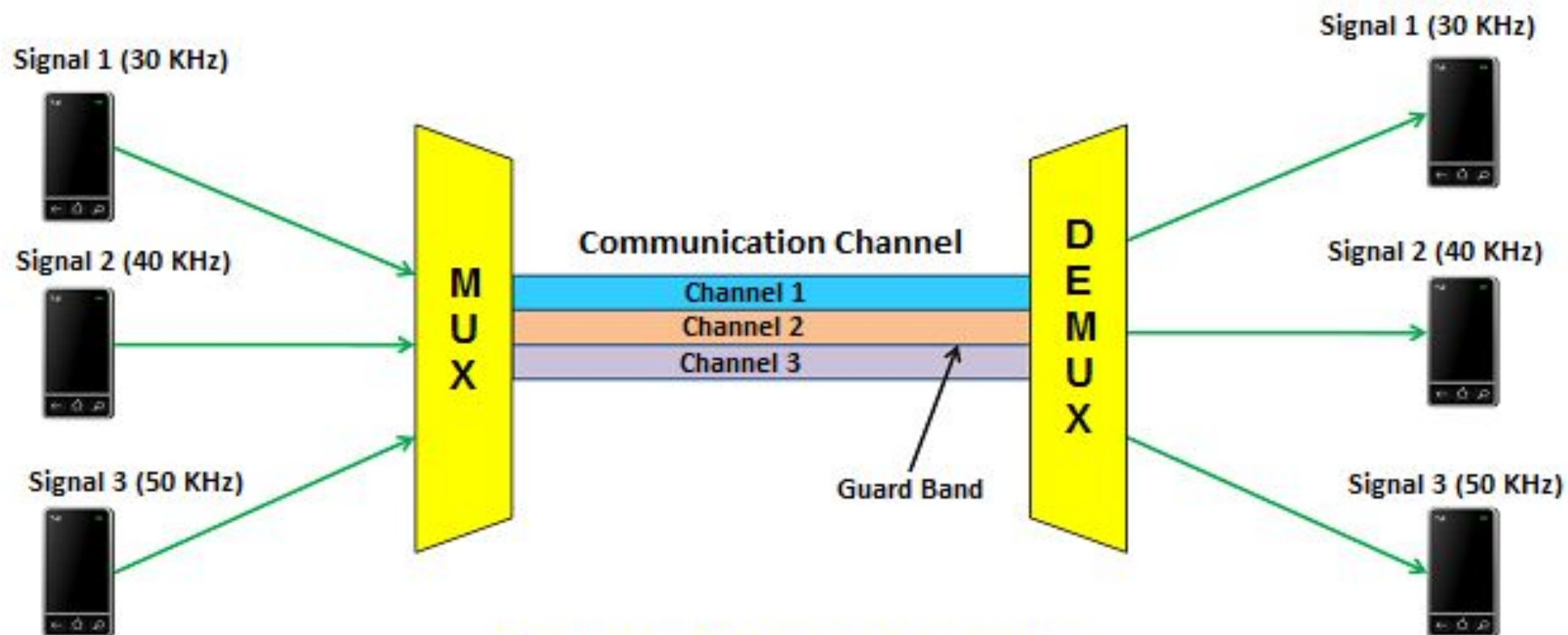
Frequency Division Multiplexing

Multiplexing is a technique which combines multiple signals into one signal, suitable for transmission over a communication channel such as coaxial cable or optical fiber.



Frequency division multiplexing (FDM) systems:

- It is system of multiplexing number of individual message signal over the common channel.
- In FDM available channel bandwidth is divided into number of non overlapping frequency slots and each message signal is assigned a slot of frequency within the pass band of the channel.



Frequency Division Multiplexing

- The three band limited signals 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. (To avoid cross talk and intermodulation).
- The modulation is SSB-USB.
- The output of each modulator is then added to produce the composite signal having three multiplexed signals.

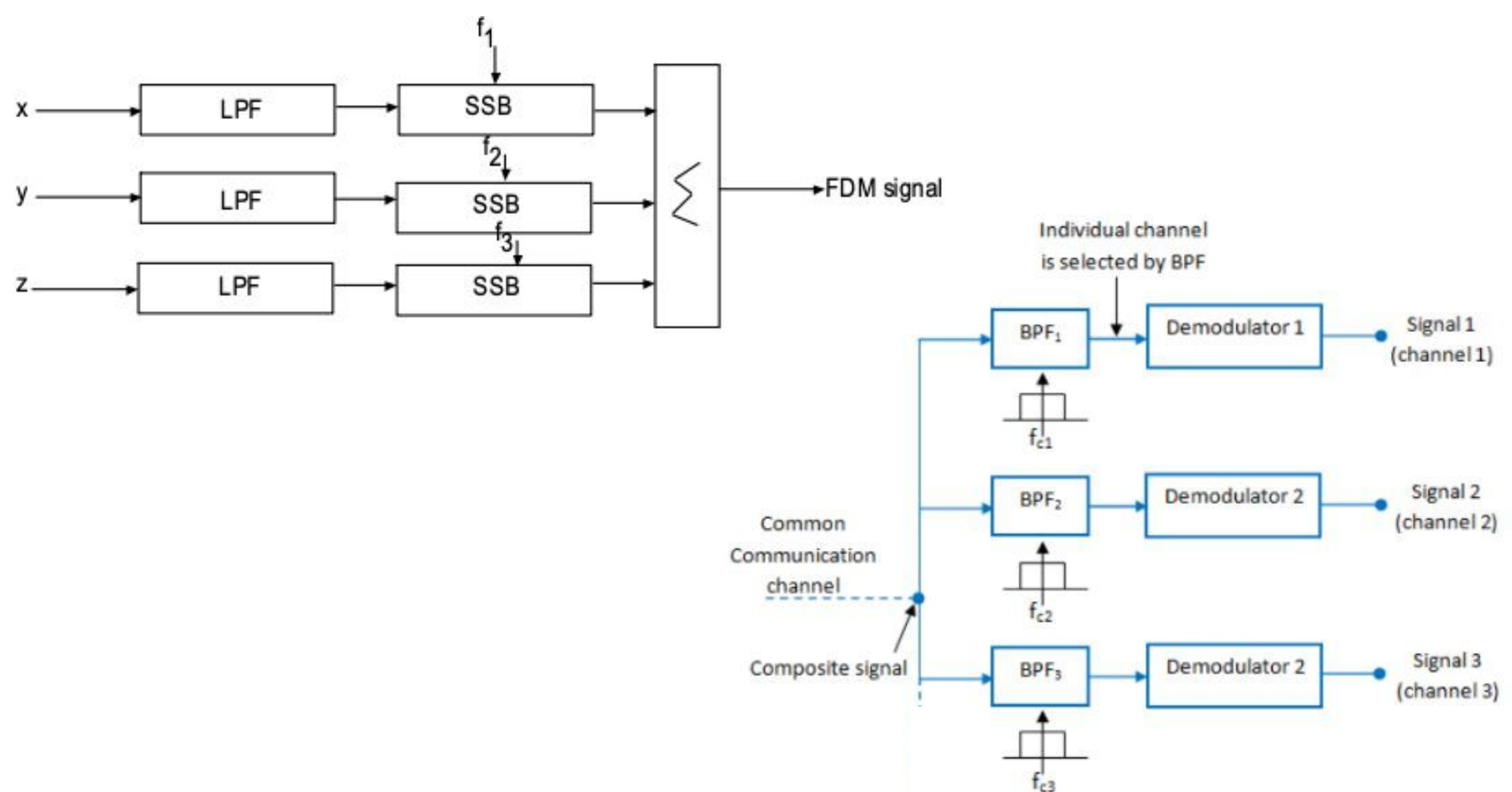


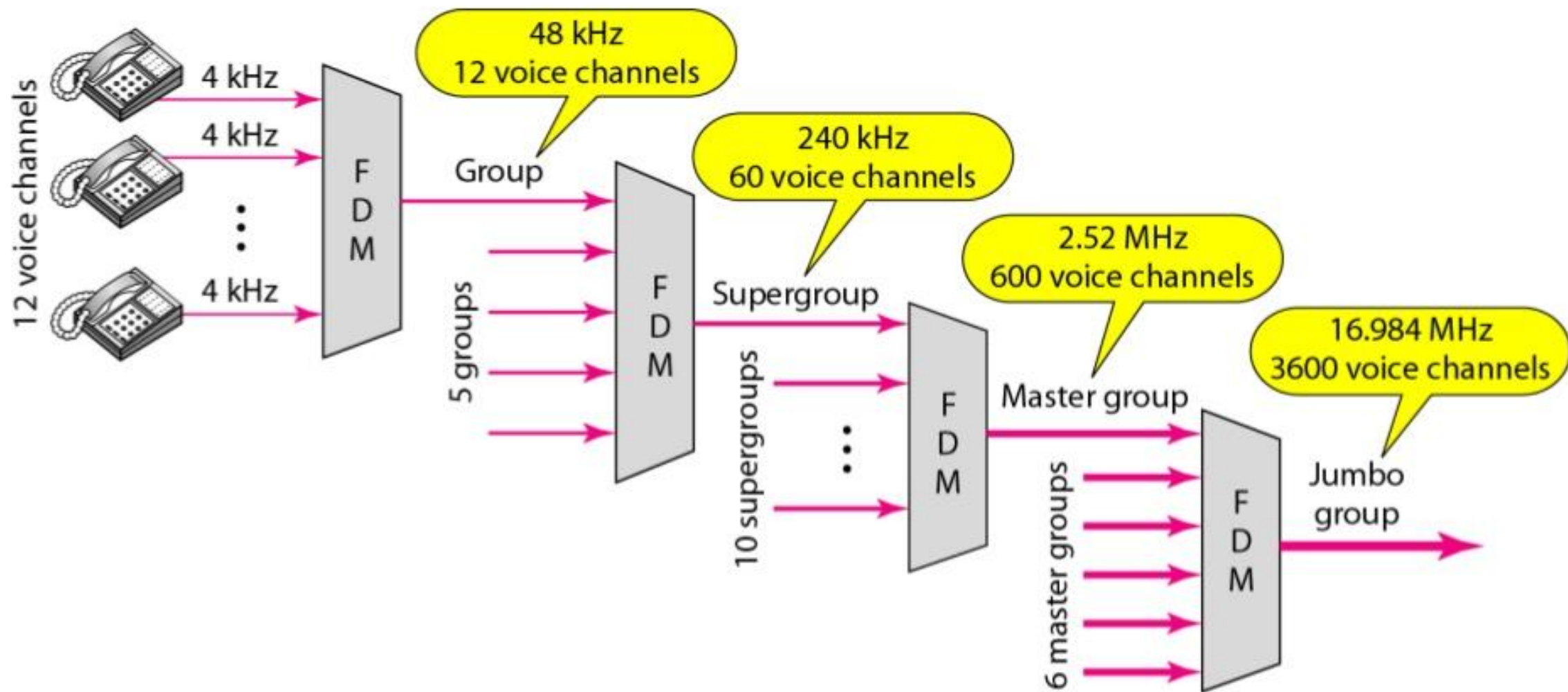
Figure: FDM Tx and Rx

- 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.

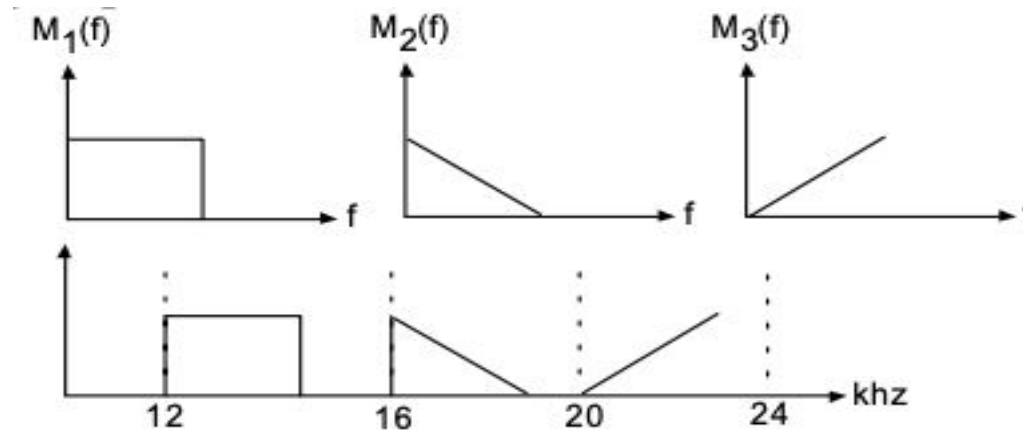
FDM in Telephony hierarchy

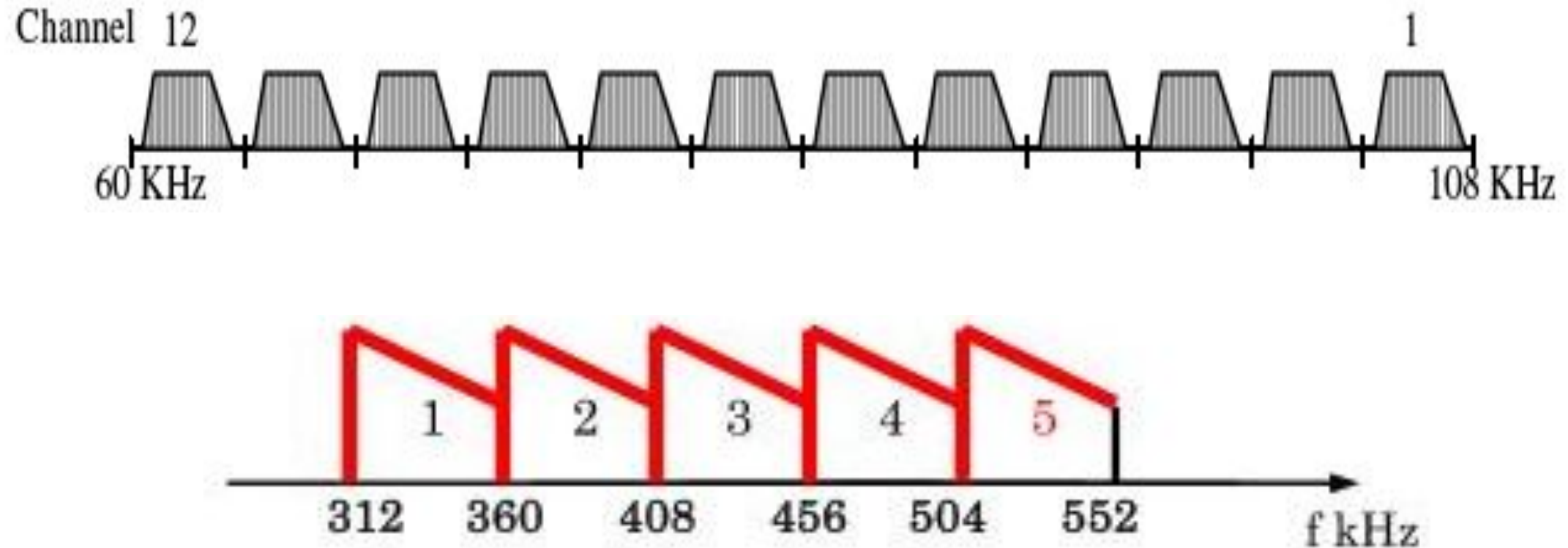
- FDM is extensively used in telephony to transmit number of telephone channel simultaneously over a channel of cable or microwave link.
- Basic telephone channel is band limited to 300 to 3400 Hz. (bandwidth 3100 Hz).
- A frequency slot of 4kHz is assigned to each telephone channel so that there is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

No. of Voice Channel	Bandwidth	Spectrum	Terminology
Voice channel (1)	4 KHz	12,16,20KHz	
3	12 KHz	12KHz-24KHz	Pre Group
12	48 KHz	(60-108)KHz	Group
60	240 KHz	(312-512)KHz	Super Group
600	2.520 MHz	(564-3084)KHz	Master Group
3600	16.984 MHz	(0.564-17.548) MHz	Super master group



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





- Ten sets of super group produce master group of 600 voice channel with bandwidth of 2520 KHz.
- Six sets of master group produce super master group with bandwidth of near about 17 MHz.

Filter and oscillator requirements in FDM:

- FDM system imposes very conditional requirements on SSB filters (band pass filters) and frequency stability of oscillator.
- As in FDM, the guard band between two adjacent frequency slots is not very large, the frequency stability of the oscillators should be very high in order to avoid overlapping.
- Similarly the requirements on SSB filters are also very conditional due to the same reason.
- Moreover each filter has to be tuned to its own frequency depending upon the frequency slots. Instability of the tuning and drift in centered frequency due to environmental conditions would result in overlapping and cross talk.

Introduction to satellite communication system:



- Artificial satellite of the Earth is an object orbiting around Earth containing radio equipment such as receiver, amplifier, signal processor, transmitter etc. and powered by solar photo voltaic module.
- Since August, 1965 numerous satellites have been launched for communication, navigation, defense broadcasting and other purposes.
- Satellite system may be domestic (used by a single country like Canadian Tele-sat System (CTS) or Indian Satellite system (INSAT)), regional system used by two or more countries (French-German Symphonic system) and global system of inter continental satellite like (NTELSAT, INMARSAT, ASIASESAT etc.).
- The uses of satellite systems, space segments allocation and frequency allocation are coordinated by international telecommunication union (ITU) based in Geneva.

- 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 and the gravitation force of the earth.
- For this to happen, the height of the satellite has to be greater than 600km from the earth surface.

Name	Band	Main Service
VHF	30 - 300 MHz	messaging
UHF	300 - 1000 MHz	military, navigation, mobile
L	1 - 2 GHz	mobile, audio broadcasting, radio localization
S	2 - 4 GHz	mobile, navigation
C	4 - 8 GHz	fixed
X	8 - 12 GHz	military
Ku	12 - 18 GHz	fixed, video broadcasting.
K	18 - 27 GHz	fixed
Ka	27 - 40 GHz	fixed, video broadcasting. Inter satellite
Millimetric waves	> 40 GHz	Inter satellite

Specific frequency bands allocated for use in satellite system

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 or geostationary orbit.
- 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 04 Second).
- In this case the satellite is seen stationary with respect to the Earth station. Therefore in practice geostationary orbit satellites are extensively used.
- Weather forecasting satellite are usually located at lower orbits (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.
- The area in the Earth surface where the level of signal from 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.
- 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, **PCM** multiple Access **D**emand Assignment **E**quipment). In this a common pool of about 800 channels(carriers) are available to all ground station having 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 .

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.

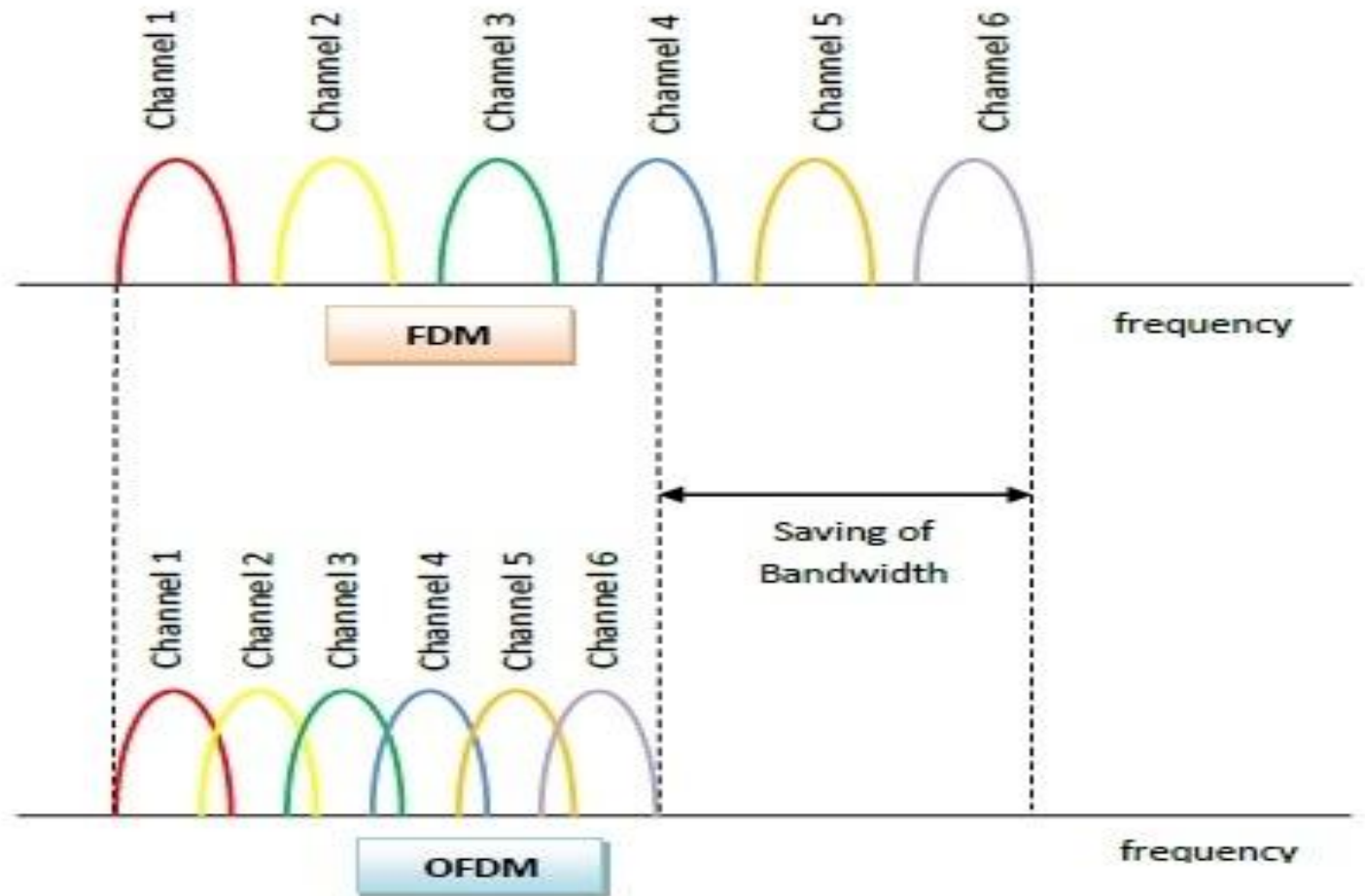
Orthogonal Frequency Division Multiplexing

- 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.
- Consequently, they do not need any guard bands and thus have better utilization of available bandwidth.
- In data communications and networking, 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.
- 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.

Working Principle of OFDM

- OFDM is a specialized FDM having the constraint that the sub-streams in which the main signal is divided, are orthogonal to each other.
- Orthogonal signals are signals that are perpendicular to each other. A main property of orthogonal signals is that they do not interfere with each other.
- When any signal is modulated by the sender, its sidebands spread out either side.
- A receiver can successfully demodulate the data only if it receives the whole signal.
- In case of FDM, guard bands are inserted so that interference between the signals, resulting in cross-talks, does not occur.
- However, since orthogonal signals are used in OFDM, no interference occurs between the signals even if their sidebands overlap.
- So, guard bands can be removed, thus saving bandwidth.
- The criteria that needs to be maintained is that the carrier spacing should be equal to the reciprocal of the symbol period.

- 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 of OFDM:

- Wi-Fi
- DSL internet access
- 4G wireless communications
- Digital television
- Radio broadcast services

Thank You