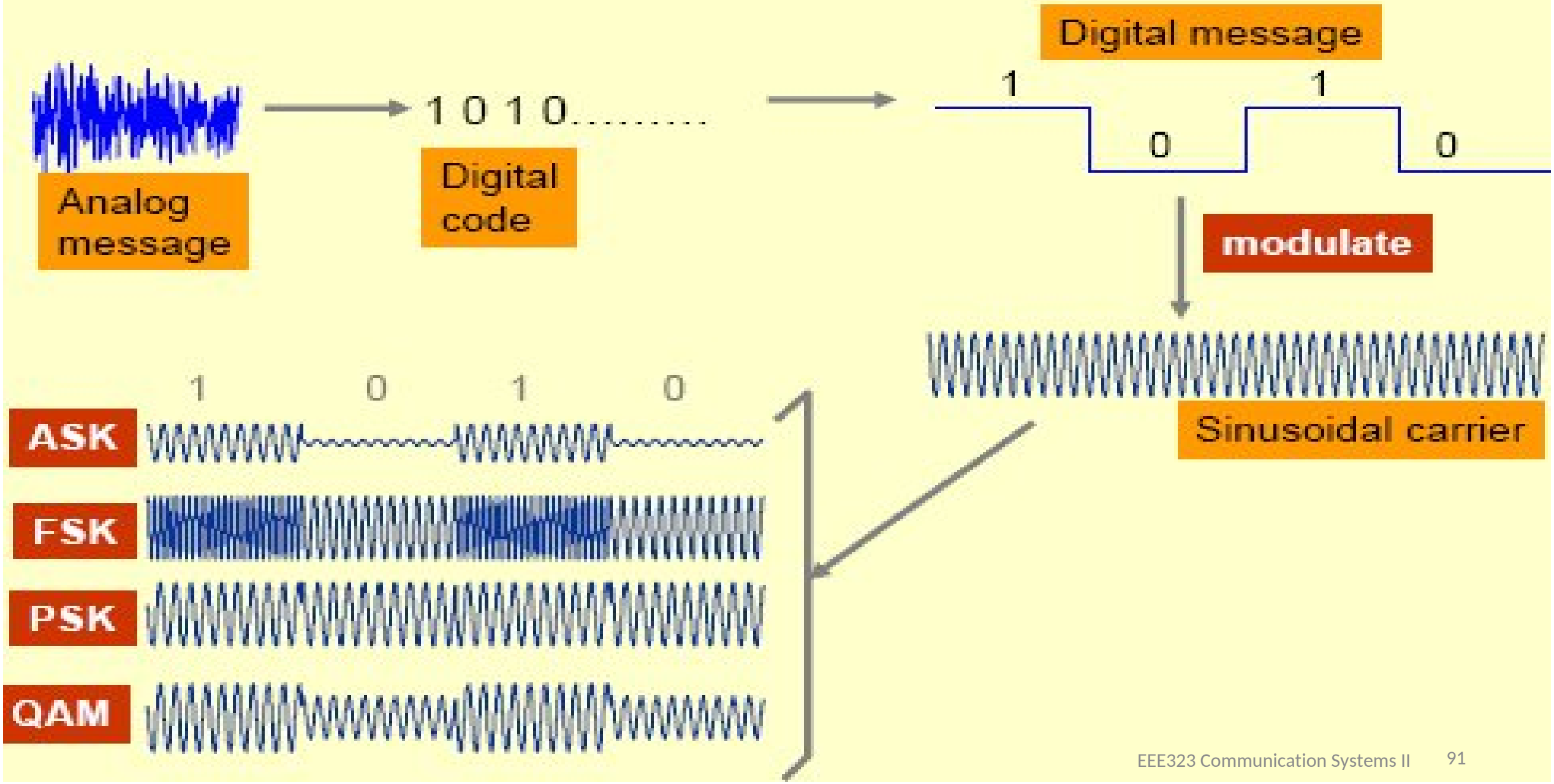
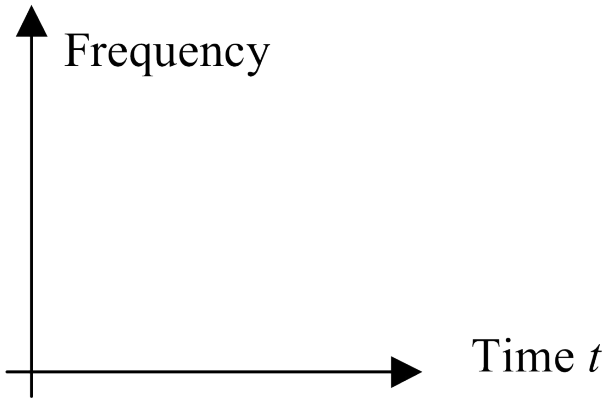
Summary of Digital Modulation Techniques

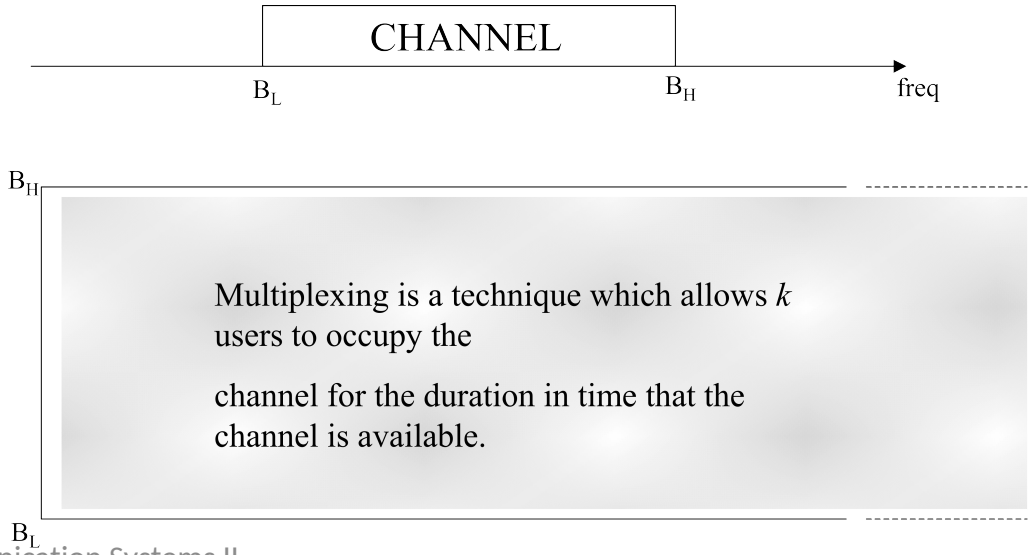


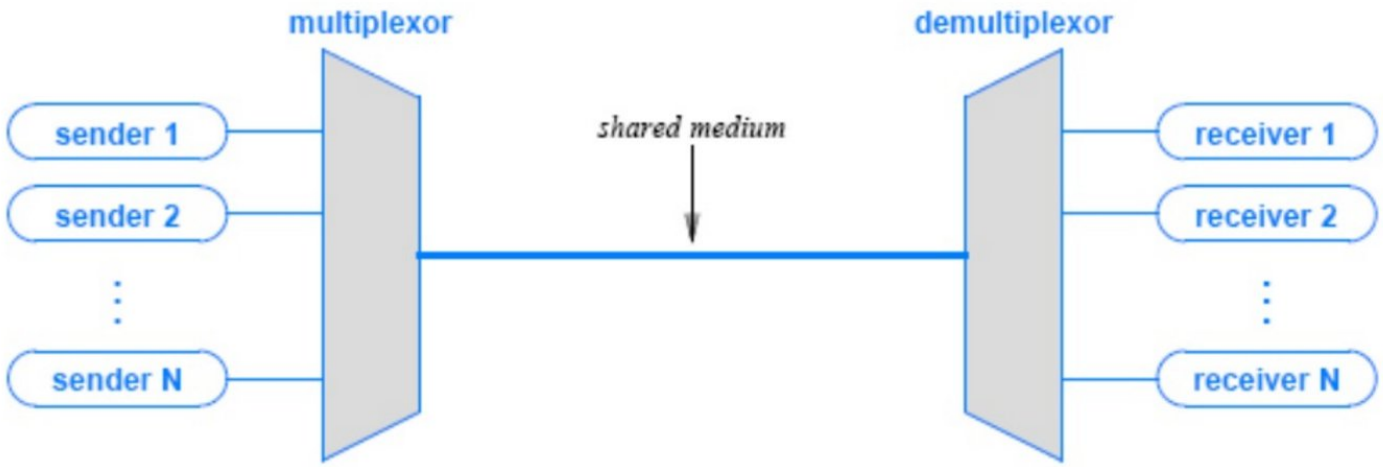
Bandwidth utilization is the wise use of available bandwidth to achieve specific goals.
Efficiency can be achieved by multiplexing; i.e., sharing of the bandwidth between multiple users. Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. Multiplexing is the set of techniques that allows the (simultaneous) transmission of multiple signals across a single data link.

- **Multiplexing** is the name given to techniques, which allow more than one message to be transferred via the same communication channel. The channel in this context could be a transmission line, *e.g.* a twisted pair or co-axial cable, a radio system or a fibre optic etc.

- A channel will offer a specified bandwidth, which is available for a time *t*, where *t* may [illegible]. Thus, with reference to the channel there are 2 'degrees of freedom', *i.e.* bandwidth or frequency and time.







There are four basic approaches to multiplexing that each have a set of variations and implementations –

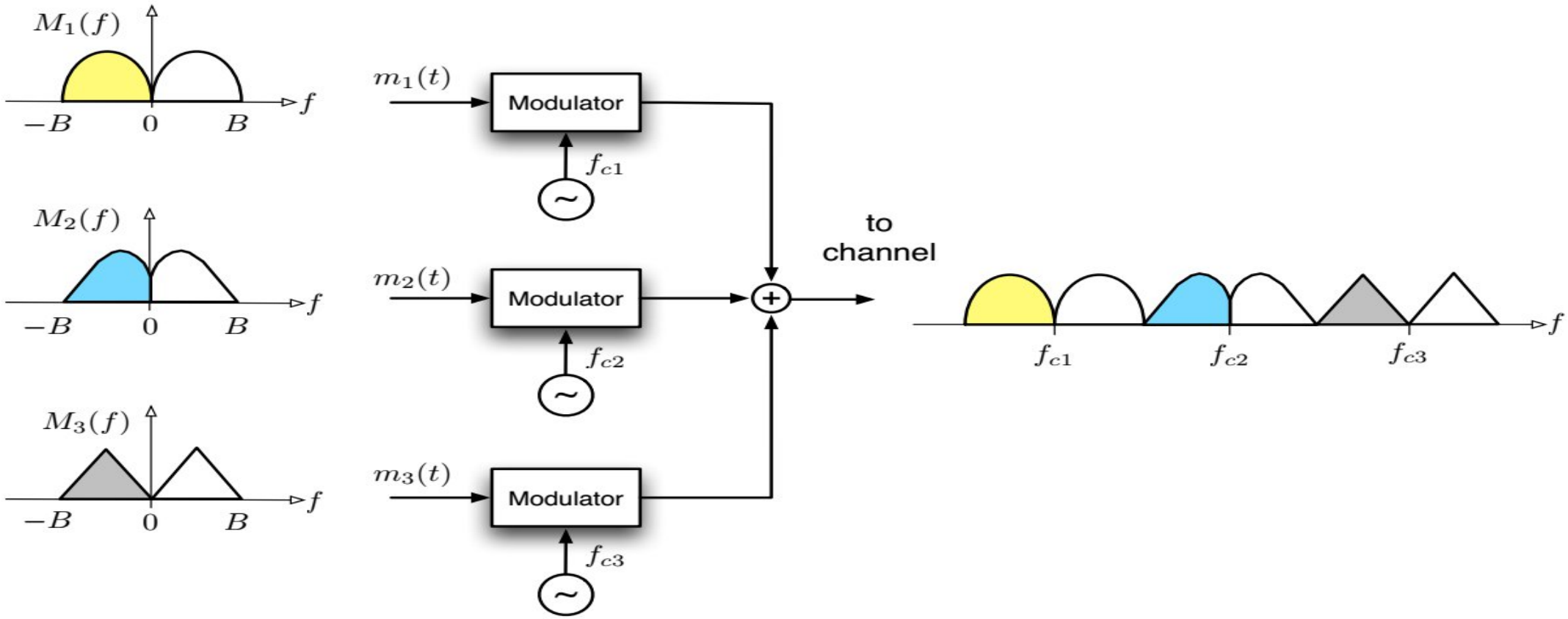
1. Frequency Division Multiplexing (FDM).
2. Time Division Multiplexing (TDM) .
3. Wavelength Division Multiplexing (WDM).
4. Code Division Multiplexing (CDM).

TDM and FDM are widely used while WDM is a form of FDM used for optical fiber. CDM is a mathematical approach used in cell phone mechanisms.

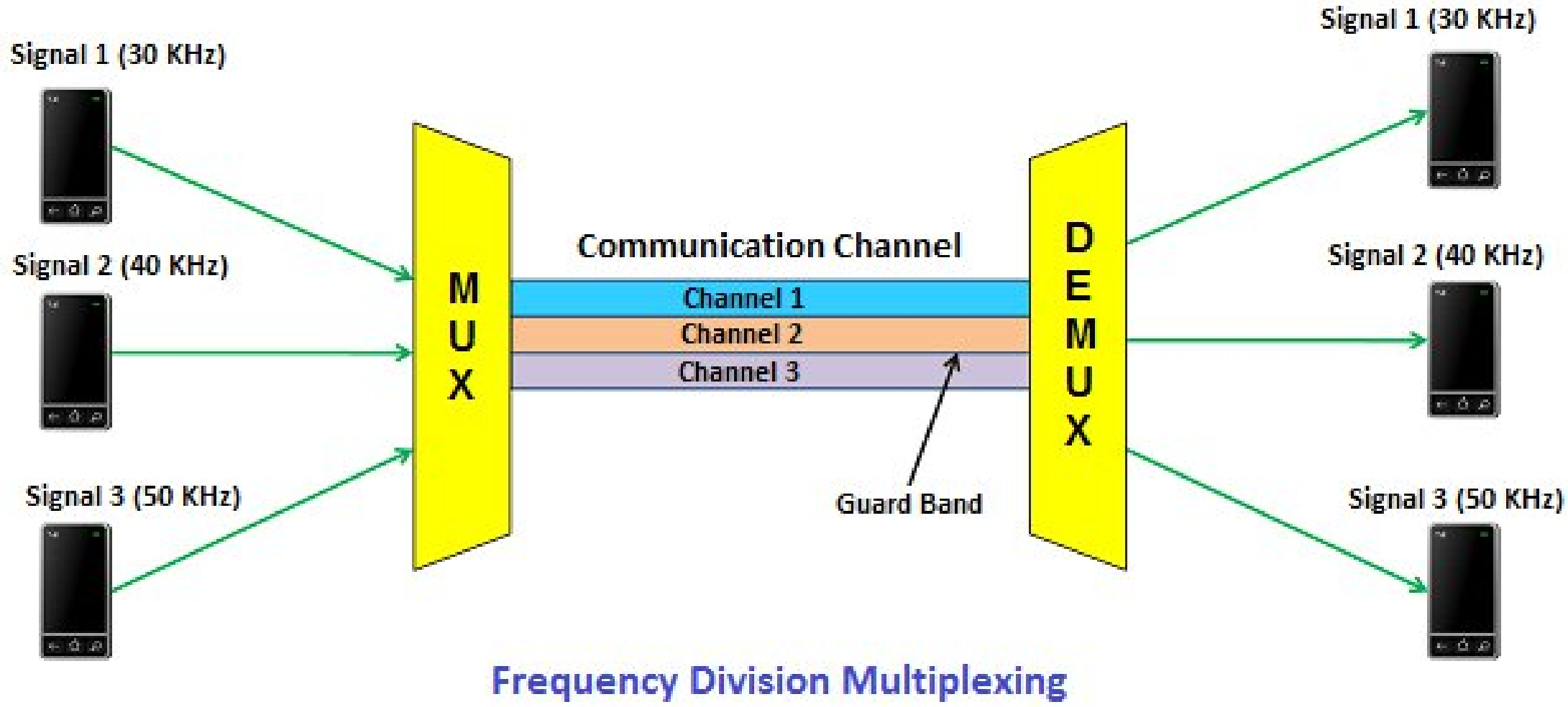
Only FDM and TDM will be discussed in this course.

FDM – multiple sources that originally occupied the same frequency spectrum are each converted to different frequency band and transmitted simultaneously.

- FDM is an **analog technique** – the information entering an FDM system must be analog. If the source is digital, it must be converted to analog before being frequency-division multiplexed.
- Split the total channel bandwidth into several smaller channels of different frequencies.
- Different signals travel over the medium concurrently.
- **Guard bands** keep the modulated signals from overlapping and interfering with one another.
- In FDM, the medium must be capable of carrying a range of frequencies that **can support the sum of all the individual frequency ranges.**
- **Modulation** is used to shift the centre frequency of the baseband signal up into a preassigned frequency slot.

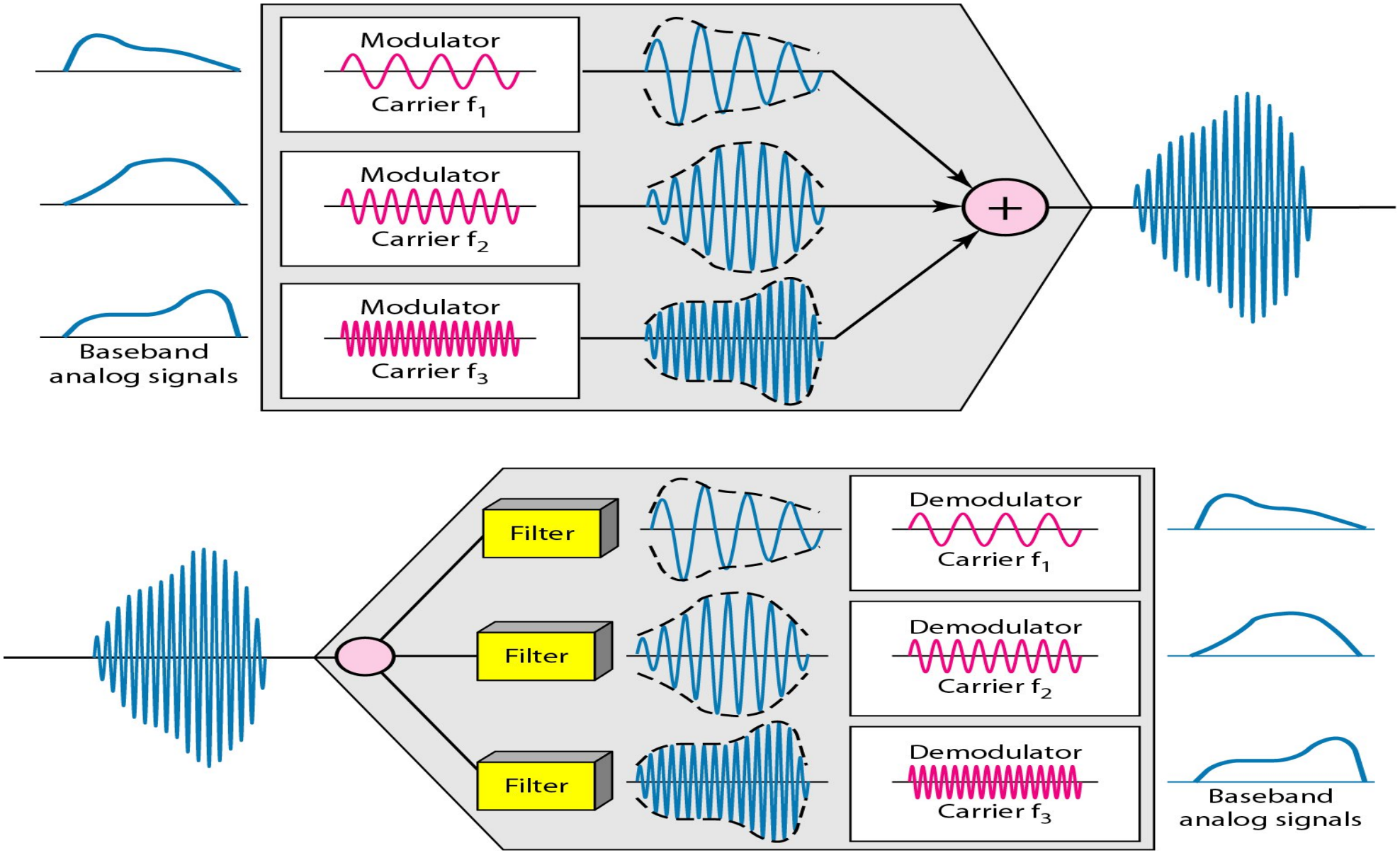


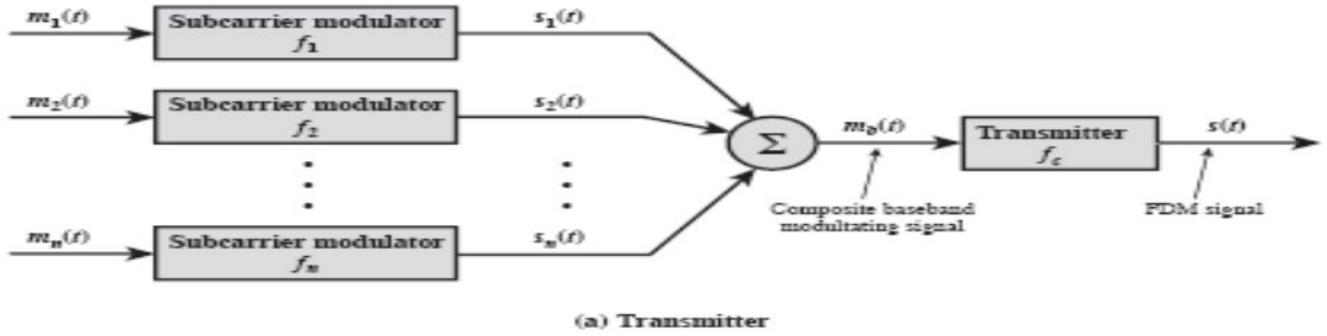
- Using FDM we can transmit multiple signals over the same channel.
- Each signal has its own frequency band.
- Carrier frequencies are selected so that the spectra of modulated signals do not interfere with adjacent frequency bands.



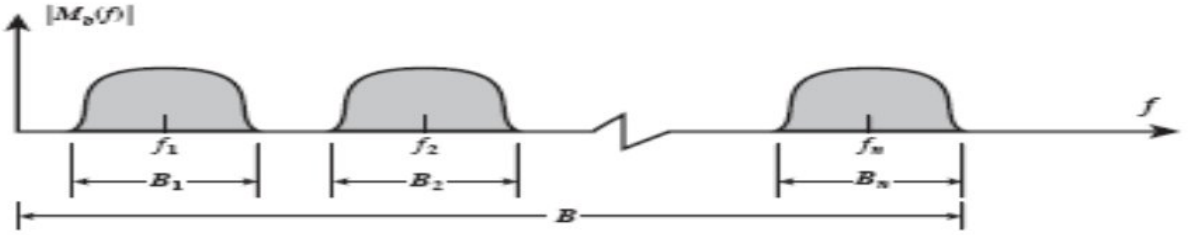
Frequency Division Multiplexing

FDM multiplexing and de-multiplexing example





(a) Transmitter



(b) Spectrum of composite baseband modulating signal

(c) Receiver

A number of signal, $m_i(t)$, i=1..,n are to be multiplexed onto the same Tx medium.

Each signal $m_i(t)$, is modulate onto a carrier f_i, refers as **subcarrier.** Modulated signals are then summed to produce a composite signal $m_b(t)$.

Figure (b) shows the result – signal $m_i(t)$ is shifted to be centered of f_i.

f_i must be chosen so that the BW of the various signals do not overlap i.e channel must be separated by unused BW (guard band).

At the Rx end, the FDM signal is demodulated to retrieved $m_b(t)$, which is then passed through n BPF.a

With FDM, each narrowband channels are stacked on top of one another in the frequency domain.

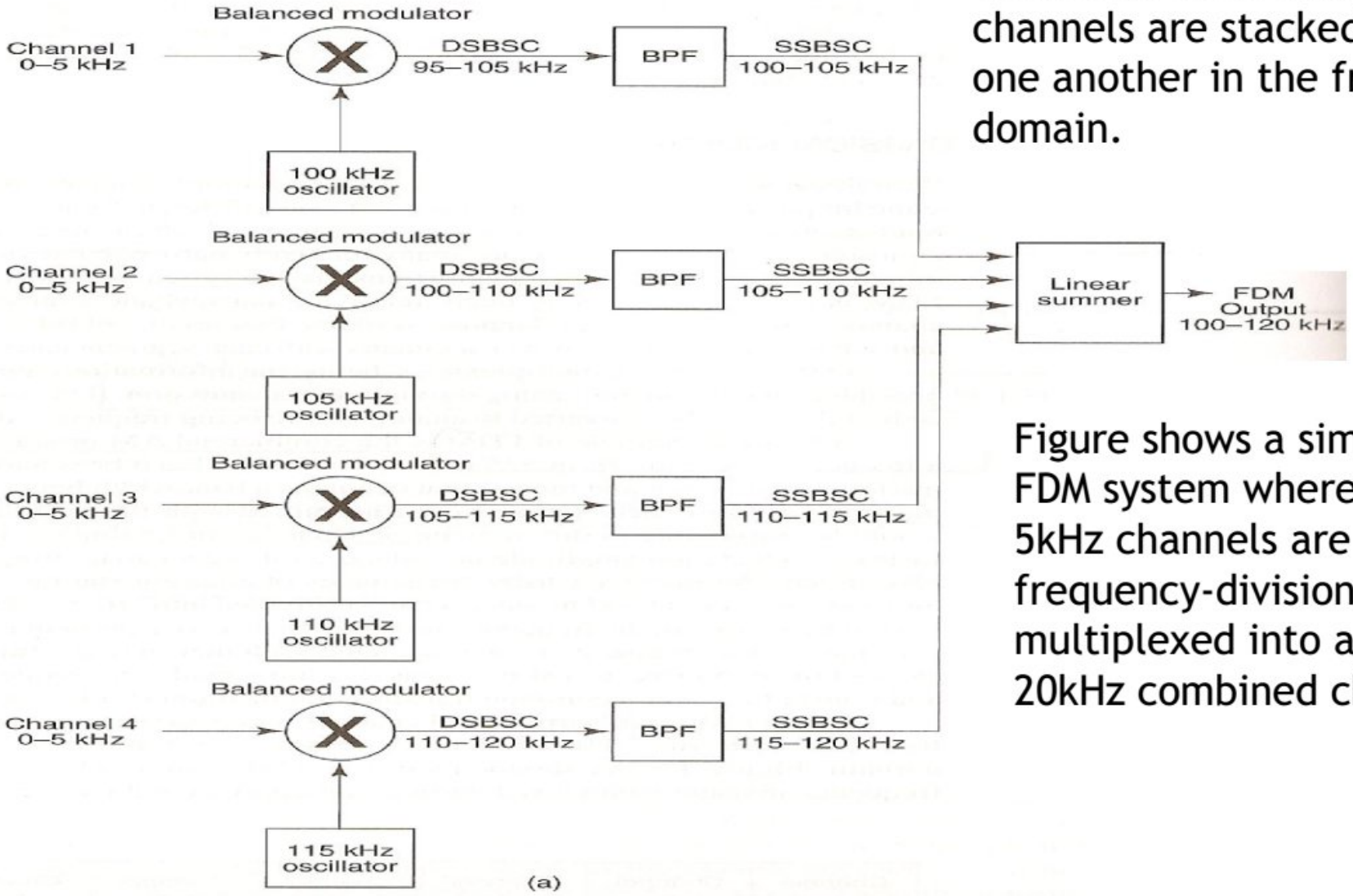
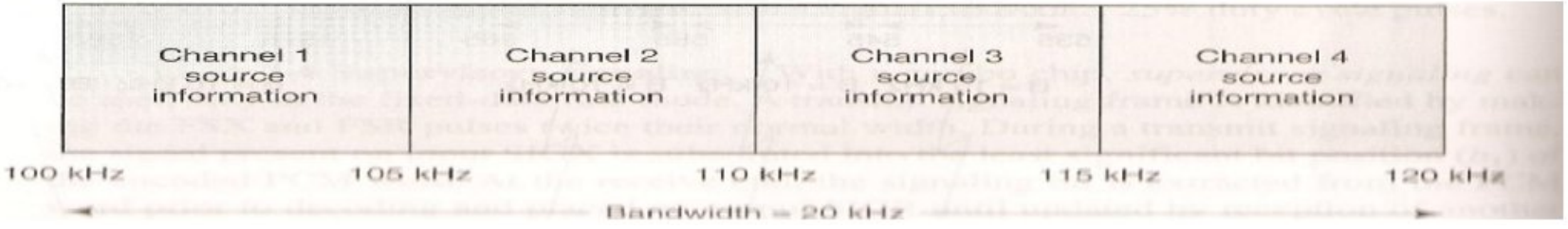


Figure shows a simple FDM system where four 5kHz channels are frequency-division multiplexed into a single 20kHz combined channel.

(a)



Example: A cable TV service uses a single coaxial cable with a bandwidth of 860 MHz to transmit multiple TV signals to subscribers. Each TV signal is 6 MHz wide. How many channels can be carried?

Solution: Total channels = 860/6 = 143.33 or 143

Example : Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with bandwidth of 44.5 kHz using FDM. Calculate the number of guard bands and the bandwidth for each guard band.

Solution

To multiplex **10** voice channels, we need **9** guard bands. The available bandwidth is

then BT_{guard} = 44.5 KHz - (4 KHz) × 10 = 4.5 kHz =4500 Hz… Thus the guard band bandwidth is 4500/ 9 = 500 Hz

Example : Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Solution

For five channels, we need at least four guard bands. This means that the required bandwidth is at least $5 \times 100 + 4 \times 10 = 540$ kHz.