Multiplexing "التجميع" التعدد

Frequency-Division Multiplexing (FDM)

التعدد بتقسيم التردد

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.

MULTIPLEXING

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single physical medium.

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. As data and telecommunications use increases, so does traffic.

The Concept of Multiplexing

- Multiplexing to refer to the combination of information streams from multiple sources for transmission over a shared medium
  - Multiplexor is a mechanism that implements the concept
- Demultiplexing to refer to the separation of a combination back into separate information streams
  - Demultiplexor to refer to a mechanism that implements the concept
- Figure illustrates the concept
  - each sender communicates with a single receiver
  - all pairs share a single transmission medium
  - multiplexor combines information from the senders for transmission in such a way that the demultiplexor can separate the information for receivers

11.2 The Concept of Multiplexing

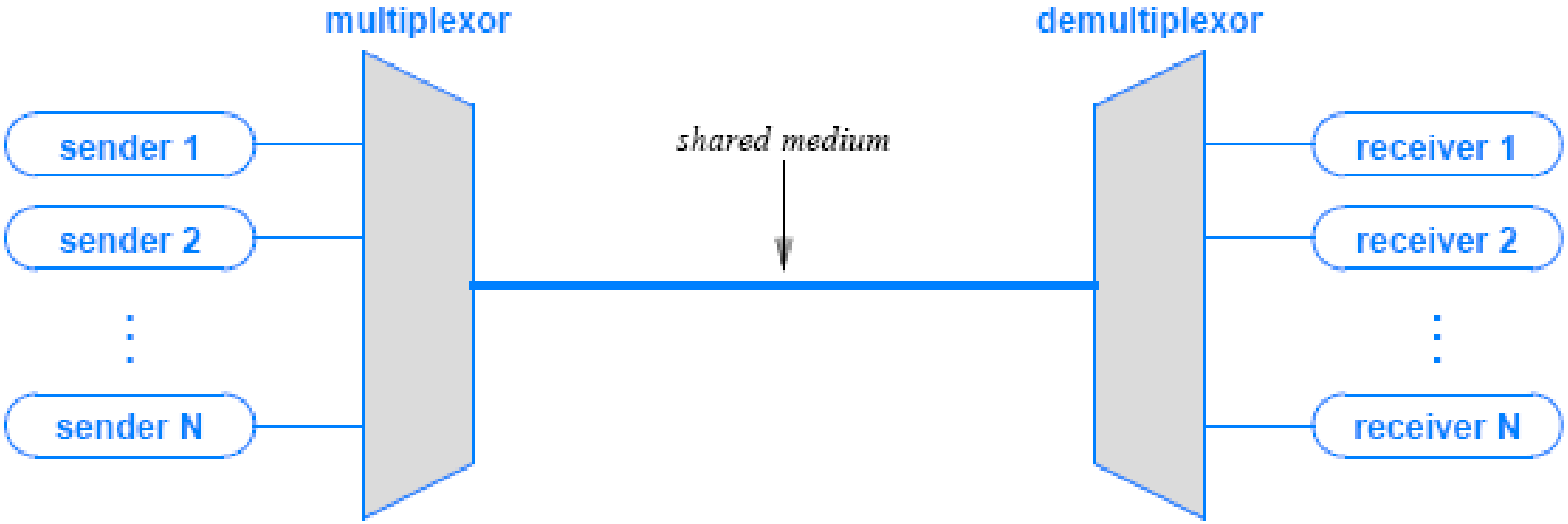
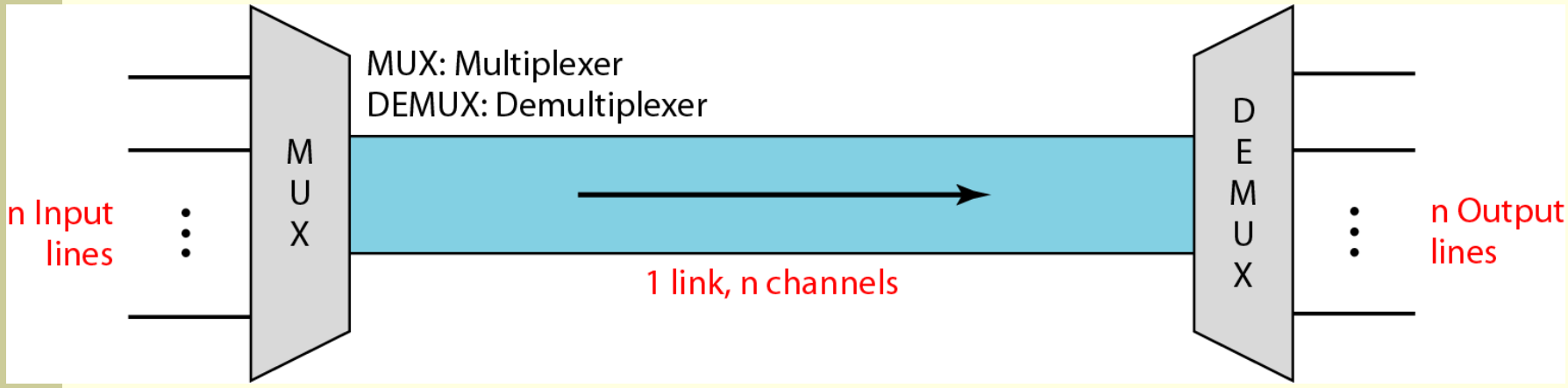


Figure 11.1 The concept of multiplexing in which independent pairs of senders and receivers share a transmission medium.

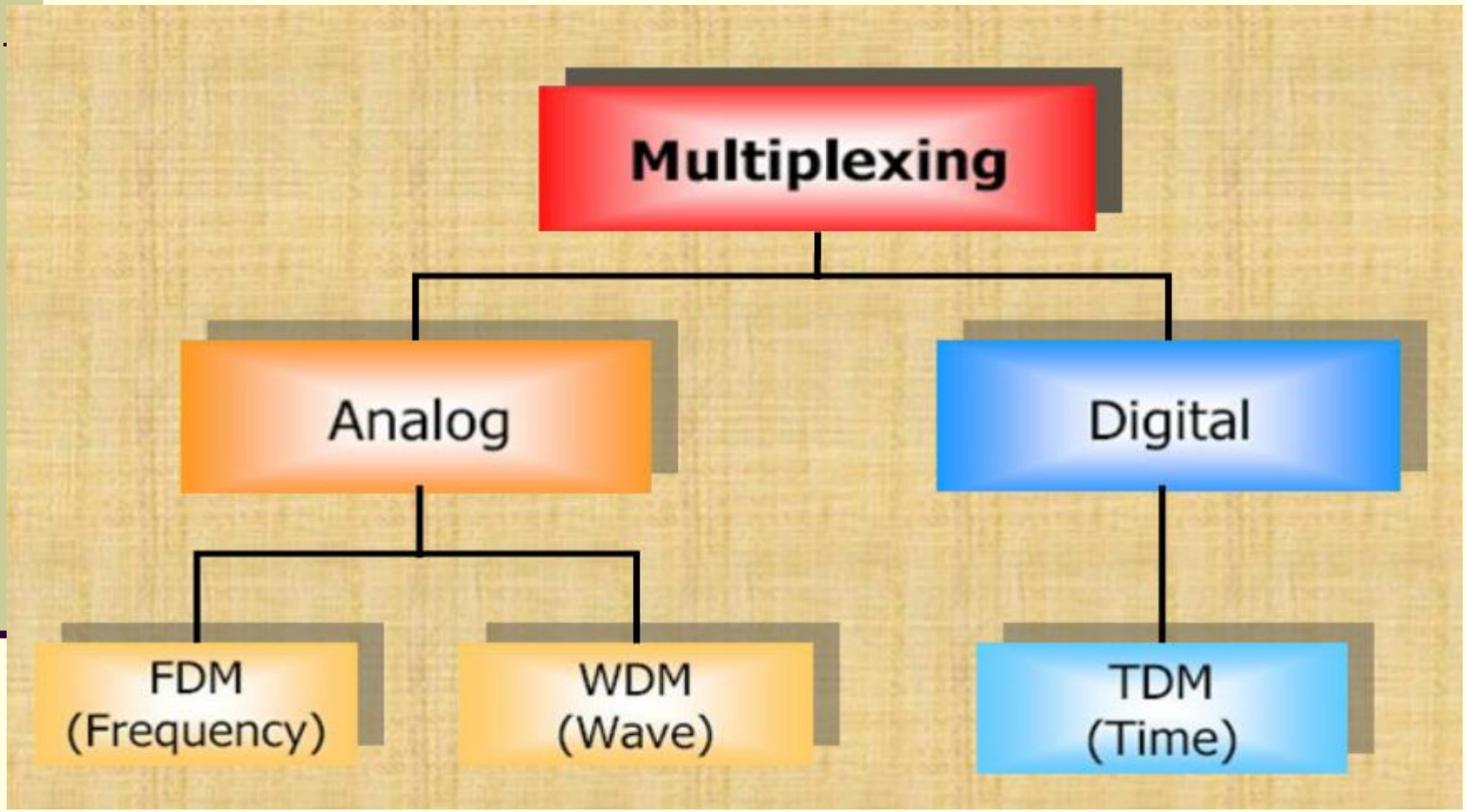
The Basic Types of Multiplexing

- There are four basic approaches to multiplexing that each have a set of variations and implementations
  - Frequency Division Multiplexing (FDM)
  - Wavelength Division Multiplexing (WDM)
  - Time Division Multiplexing (TDM)
  - Code Division Multiplexing (CDM)
- TDM and FDM are widely used
- WDM is a form of FDM used for optical fiber
- CDM is a mathematical approach used in cell phone mechanisms

Dividing a link into channels



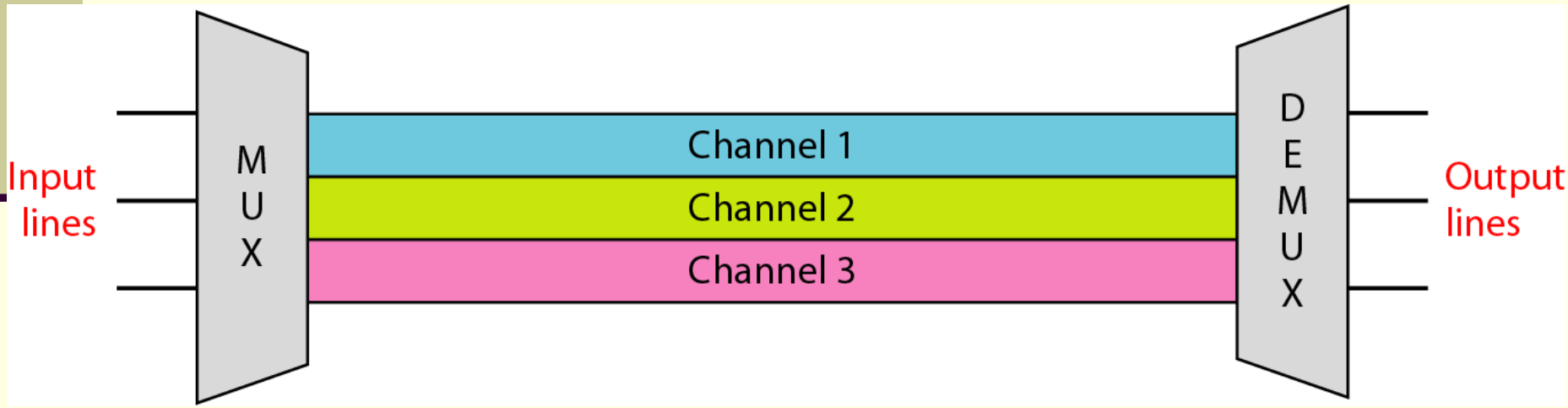
Categories of multiplexing



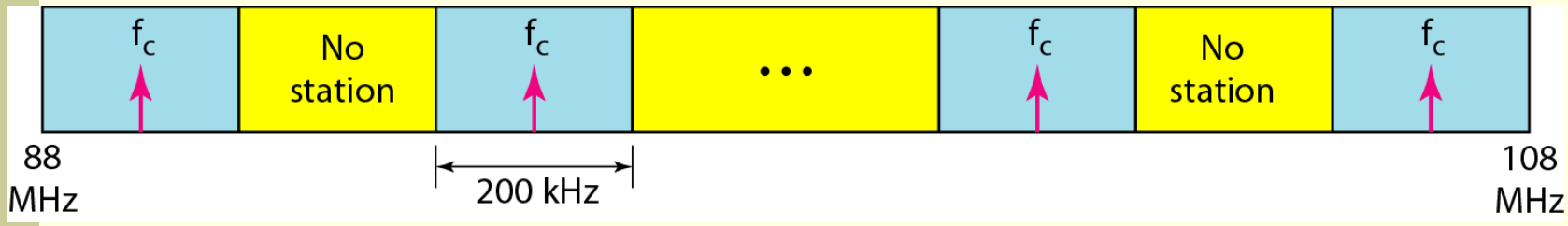
Frequency division multiplexing Wave division multiplexing Time division multiplexing

Frequency-division multiplexing (FDM)

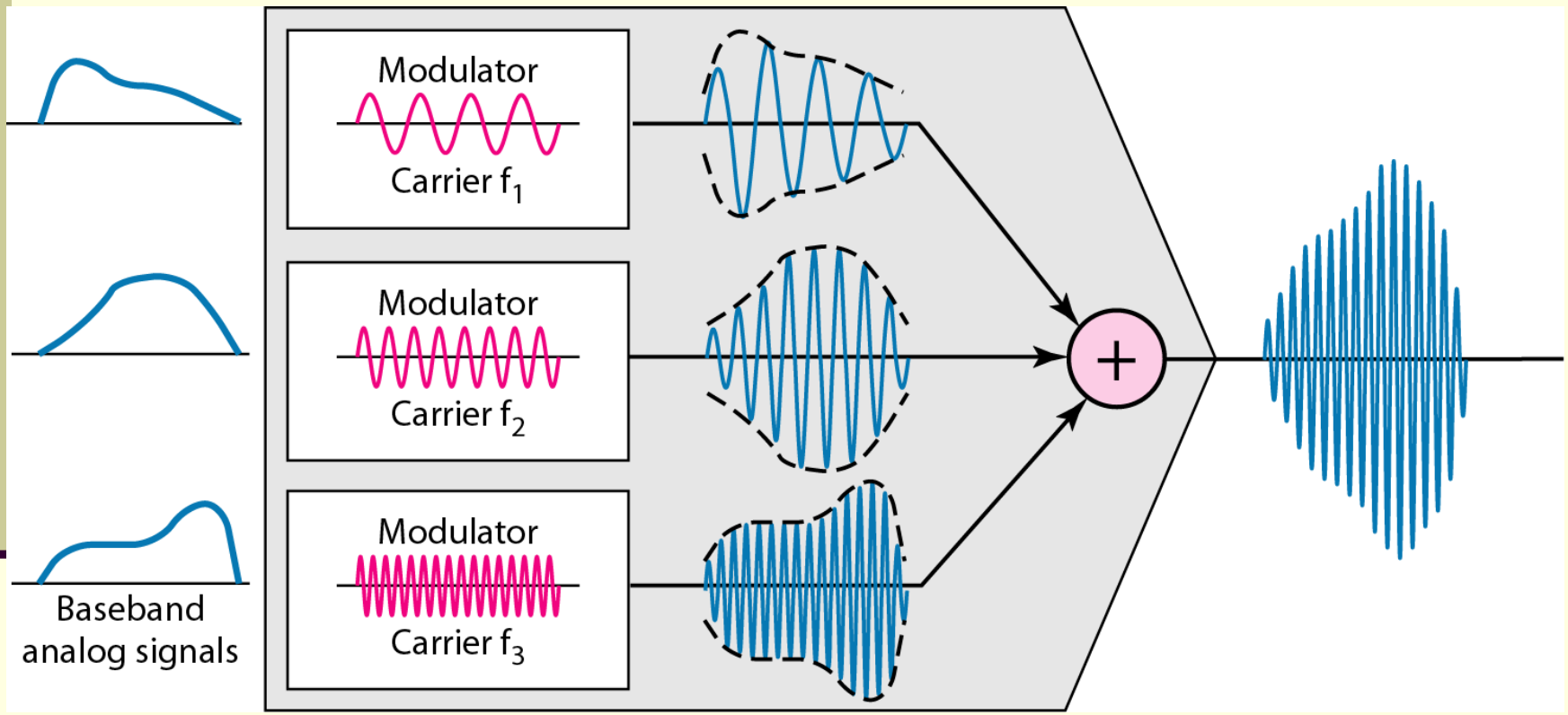
FDM is an analog multiplexing technique that combines analog signals. It uses the concept of modulation.



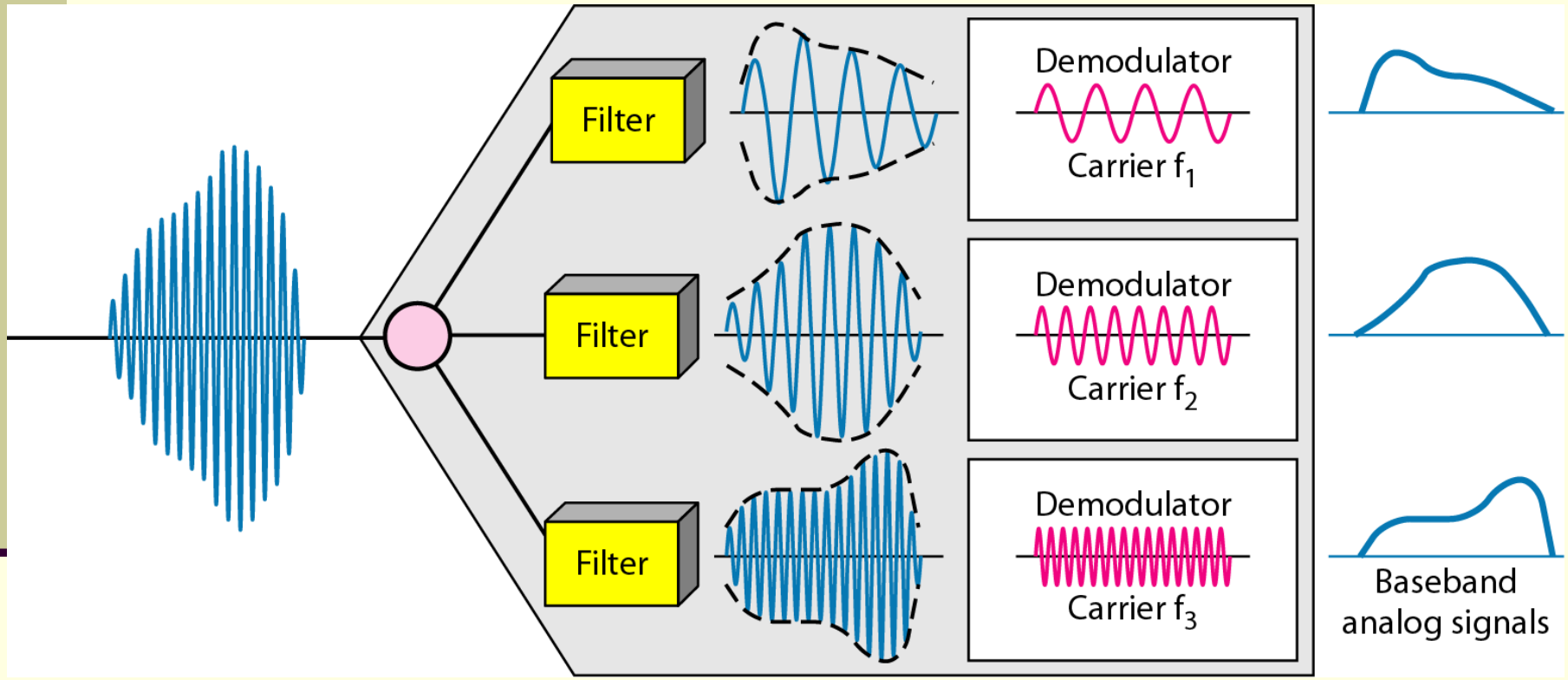
FM



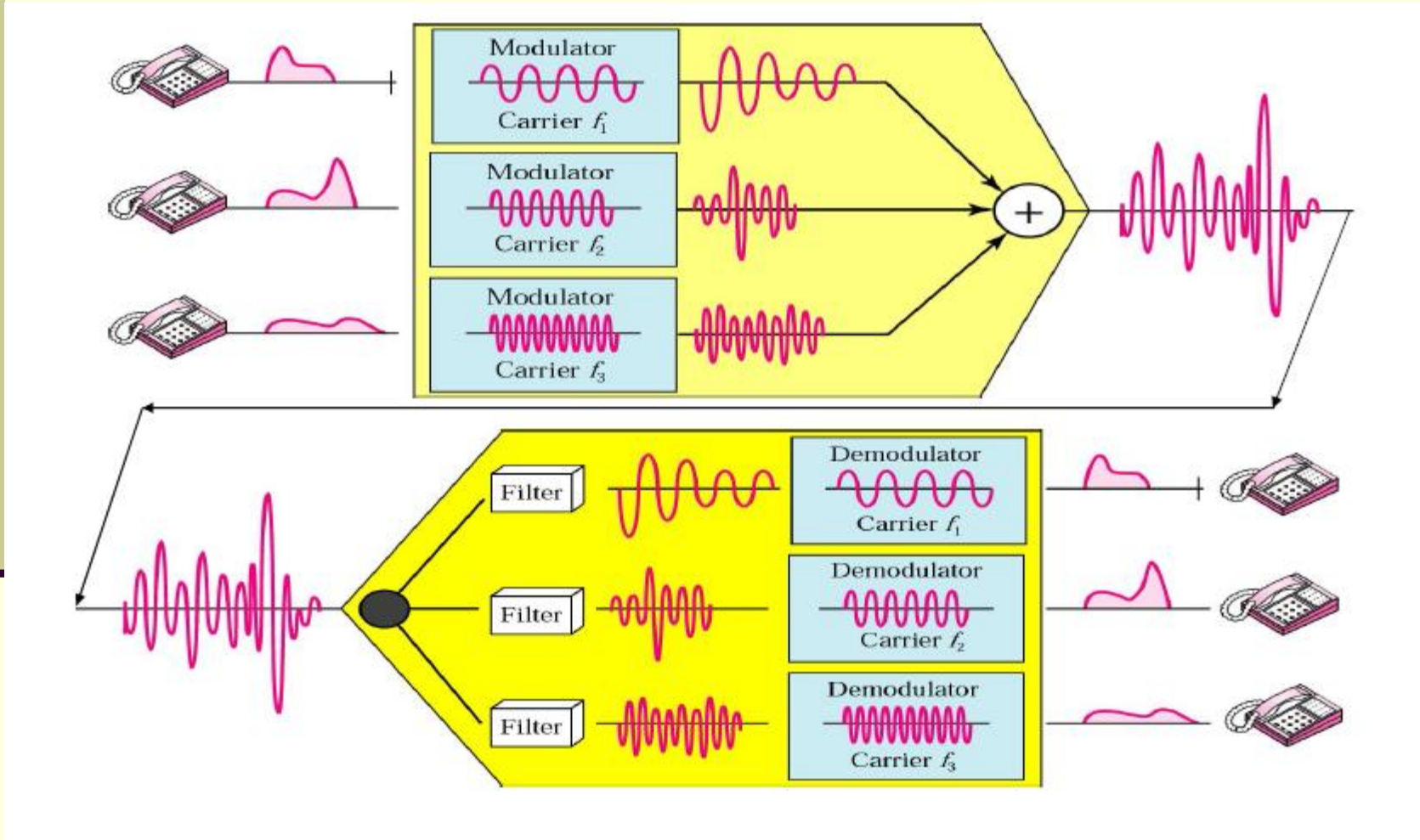
FDM multiplexing process



FDM demultiplexing example



FDM (Frequency division multiplexing) process



Frequency Division Multiplexing

- A set of radio stations can transmit electromagnetic signals simultaneously
  - without interference provided, they each use a separate channel (i.e., carrier frequency)
- It is possible to send simultaneously multiple carrier waves over a single copper wire
- A demultiplexor applies a set of filters that each extract a small range of frequencies near one of the carrier frequencies
- Figure illustrates the organization
  - A key idea is that the filters used in FDM only examine frequencies
  - If a sender/receiver pair is assigned a particular carrier frequency
- FDM mechanism will separate the frequency from others without otherwise modifying the signal

11.4 Frequency Division Multiplexing

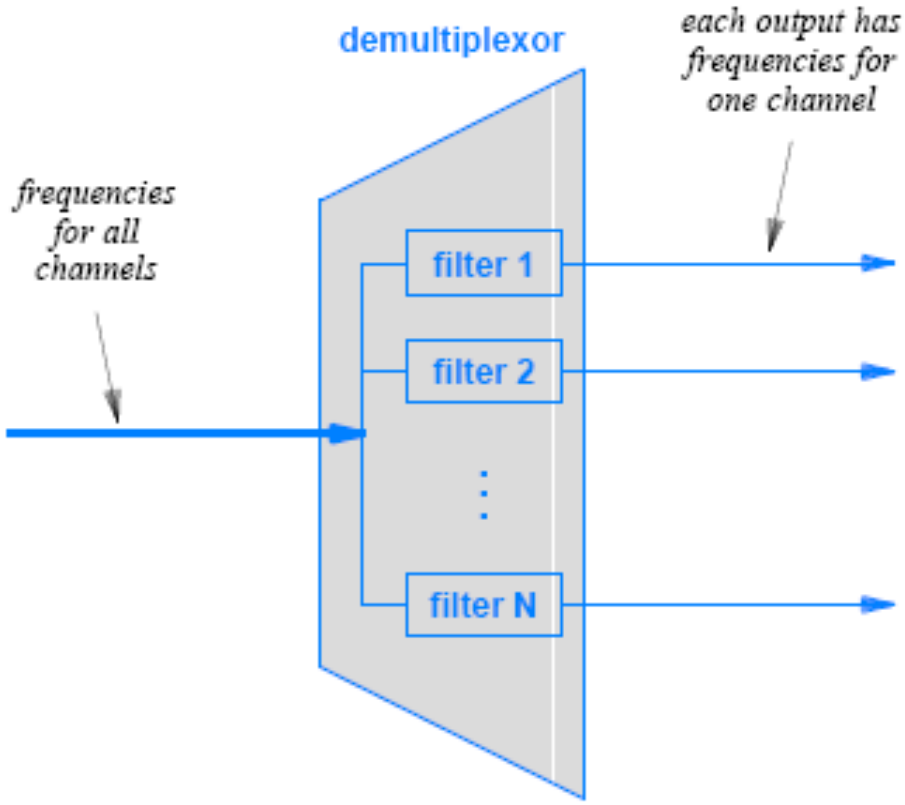


Figure 11.2 Illustration of the basic FDM demultiplexing where a set of filters each selects the frequencies for one channel and suppresses other frequencies.

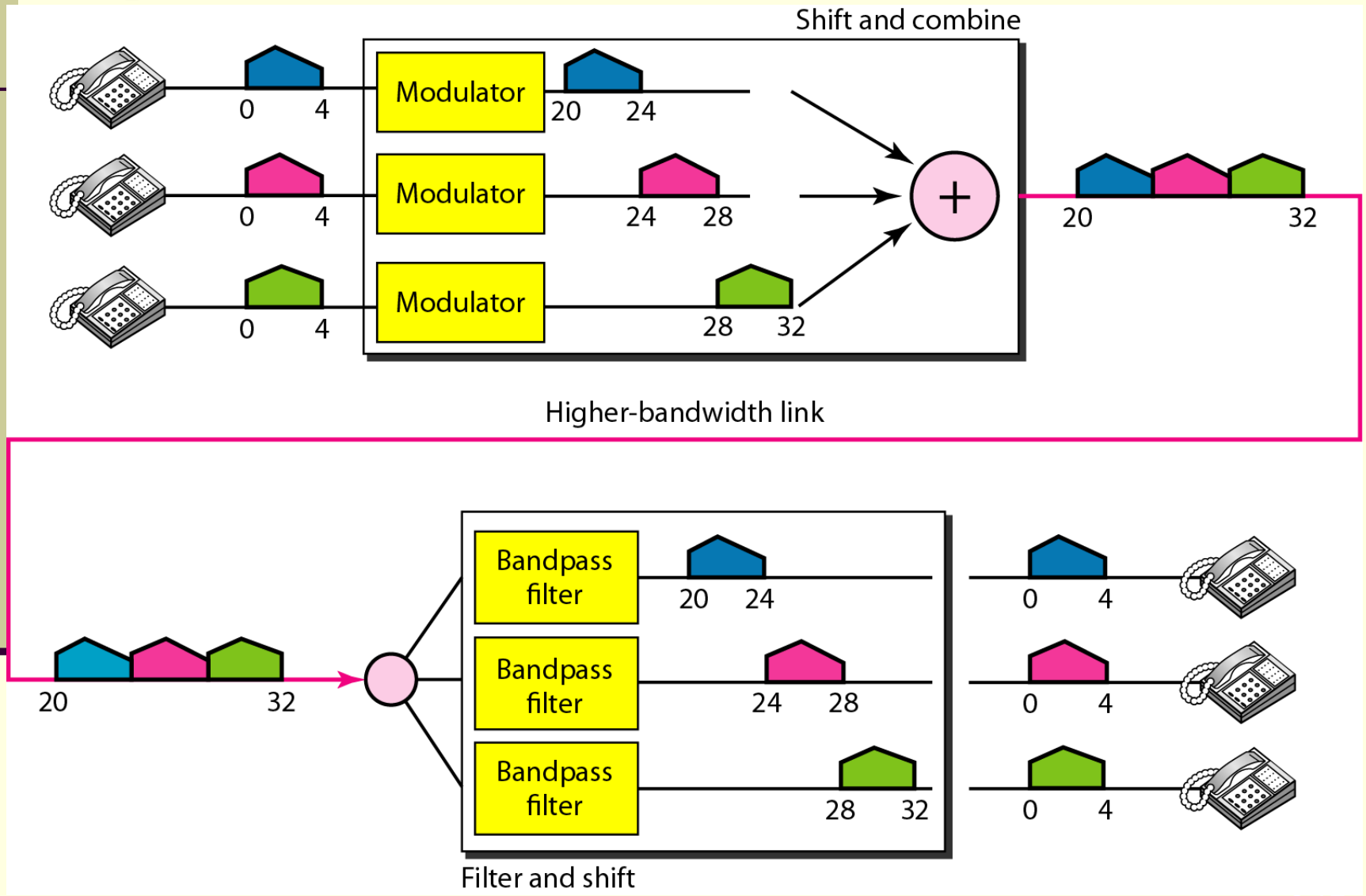
Example 1

Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

Solution

We shift (modulate) each of the three voice channels to a different bandwidth, as shown in Figure 6.6. We use the 20- to 24-kHz bandwidth for the first channel, the 24- to 28-kHz bandwidth for the second channel, and the 28- to 32-kHz bandwidth for the third one. Then we combine them as shown in Figure next slide.

Example 1


Shift and combine
Modulator
Modulator
Modulator
0
4
20
24
24
28
28
32
20
32
Higher-bandwidth link
Bandpass filter
Bandpass filter
Bandpass filter
Filter and shift

Frequency Division Multiplexing

- Advantage of FDM arises from the simultaneous use of a transmission medium by multiple pairs of entities
- We imagine FDM as providing each pair with a private transmission path
  - as if the pair had a separate physical transmission medium
  - Figure 11.3 illustrates the concept
- Practical FDM systems - there are some limitations
  - If the frequencies of two channels are too close, interference can occur
  - Furthermore, demultiplexing hardware that receives a combined signal must be able to divide the signal into separate carriers
  - FCC in USA regulates stations to insure adequate spacing occurs between the carriers
  - Designers choosing a set of carrier frequencies with a gap between them known as a guard band
- Figures and show an example
  - that alloates 200 KHz to each of 6 channels with a guard band of 20 KHz between each

11.4 Frequency Division Multiplexing

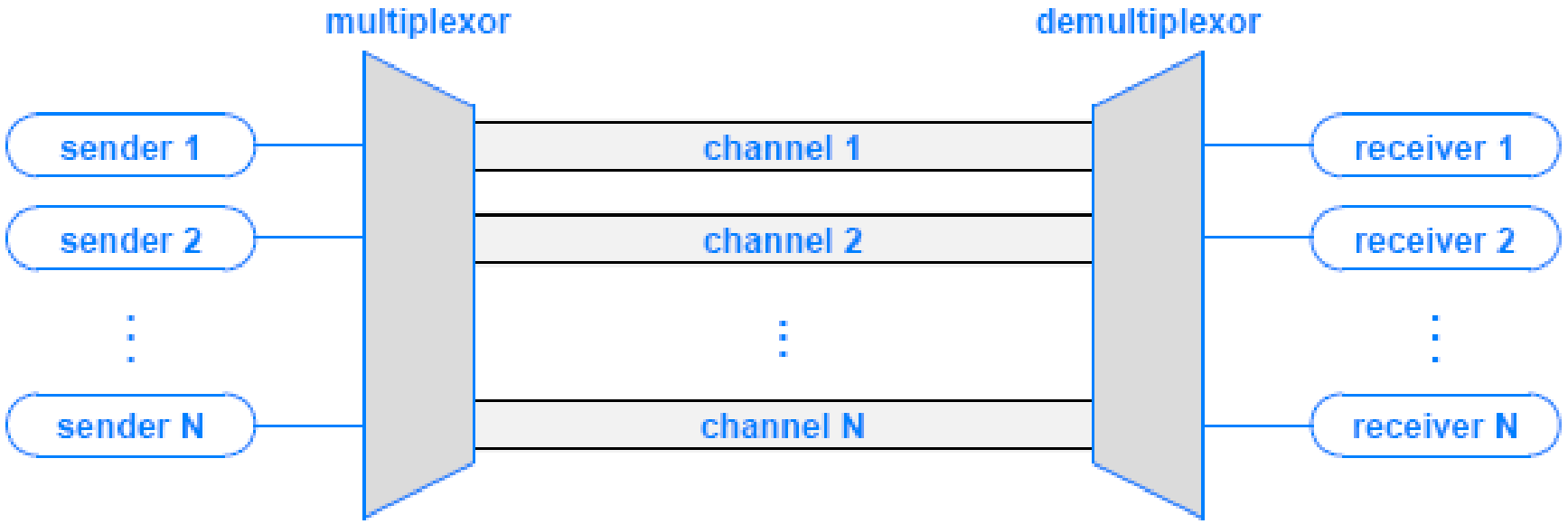


Figure 11.3 The conceptual view of Frequency Division Multiplexing (FDM) as providing a set of independent channels.

11.4 Frequency Division Multiplexing

Channel	Frequencies Used
1	100 KHz - 300 KHz
2	320 KHz - 520 KHz
3	540 KHz - 740 KHz
4	760 KHz - 960 KHz
5	980 KHz - 1180 KHz
6	1200 KHz - 1400 KHz

Figure 11.4 An example assignment of frequencies to channels with a guard band between adjacent channels.

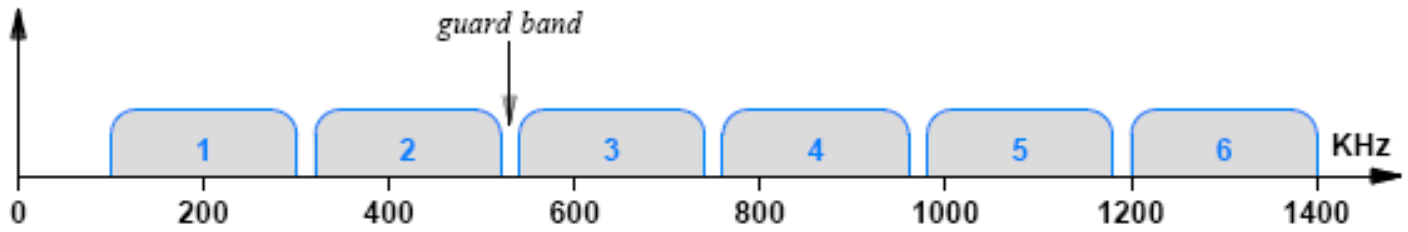
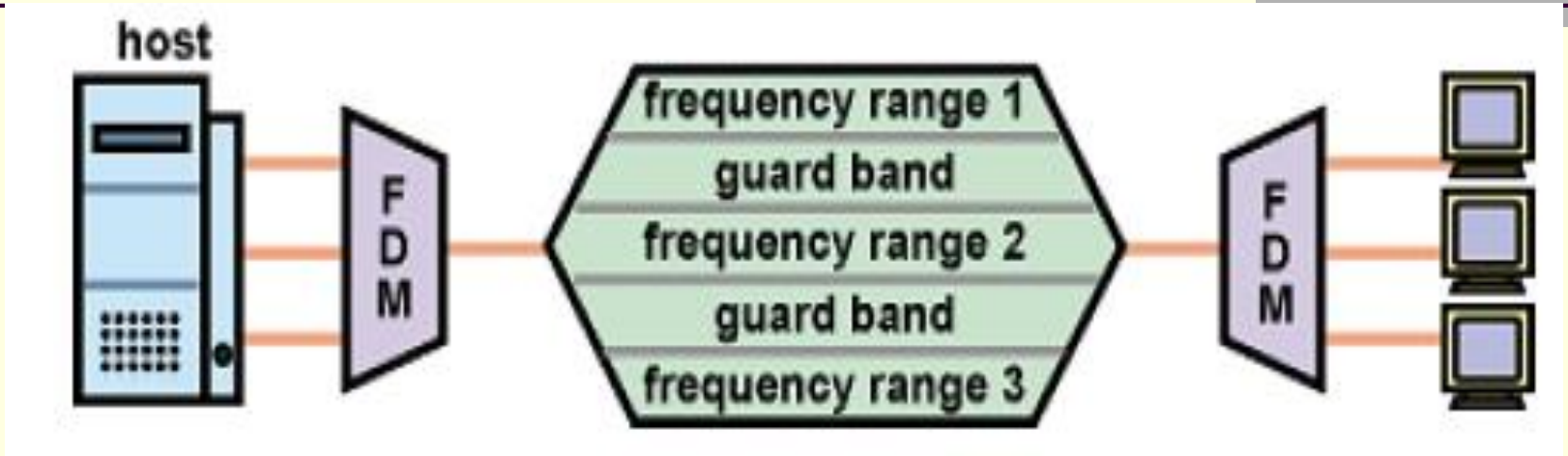


Figure 11.5 A frequency domain plot of the channel allocation from Figure 11.4 with a guard band visible between channels.

FDM Guard Band



We want to find the minimum bandwidth for a circuit with FDM multiplexing, where:

- there are four sources, each requiring 2,000 Hz
- the guard bands are 200 Hz
- To satisfy the requirement, we calculate as follows:
- 4 X 2,000 Hz for the data
- 3 X 200 Hz for the guard bands
- to get a total of 8.6 KHz

Example 2

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?

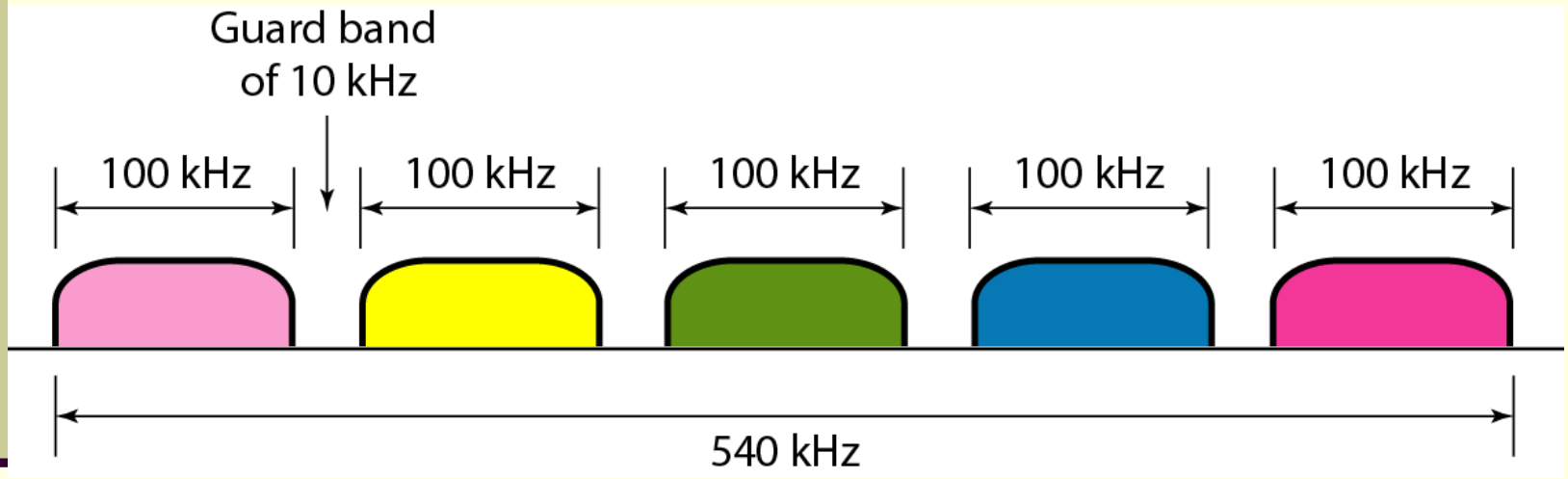
Solution

For five channels, we need at least four guard bands. This means that the required bandwidth is at least

$$5 \times 100 + 4 \times 10 = 540 \text{ kHz},$$

as shown in next slide

Example 2


Guard band
of 10 kHz
100 kHz
100 kHz
100 kHz
100 kHz
100 kHz
540 kHz

Using a Range of Frequencies Per Channel

- Consider the following characteristics of FDM:
  - Long-lived: FDM, the idea of dividing the electromagnetic spectrum into channels, arose in early experiments in radio
  - Widely used: FDM is used in broadcast radio and television, cable television, and the AMPS cellular telephone
  - Analog: FDM multiplexing and demultiplexing hardware accepts and delivers analog signals
    - Even if a carrier has been modulated to contain digital information, FDM hardware treats the carrier as an analog wave

Advantages of FDM

1. Here user can be added to the system by simply adding another pair of transmitter modulator and receiver demodulators.

1. FDM system support full duplex information flow which is required by most of application.

Disadvantages of FDM

1. In FDM system, the initial cost is high. This may include the cable between the two ends and the associated connectors for the cable.

2. In FDM system, a problem for one user can sometimes affect others.

3. In FDM system, each user requires a precise carrier frequency.