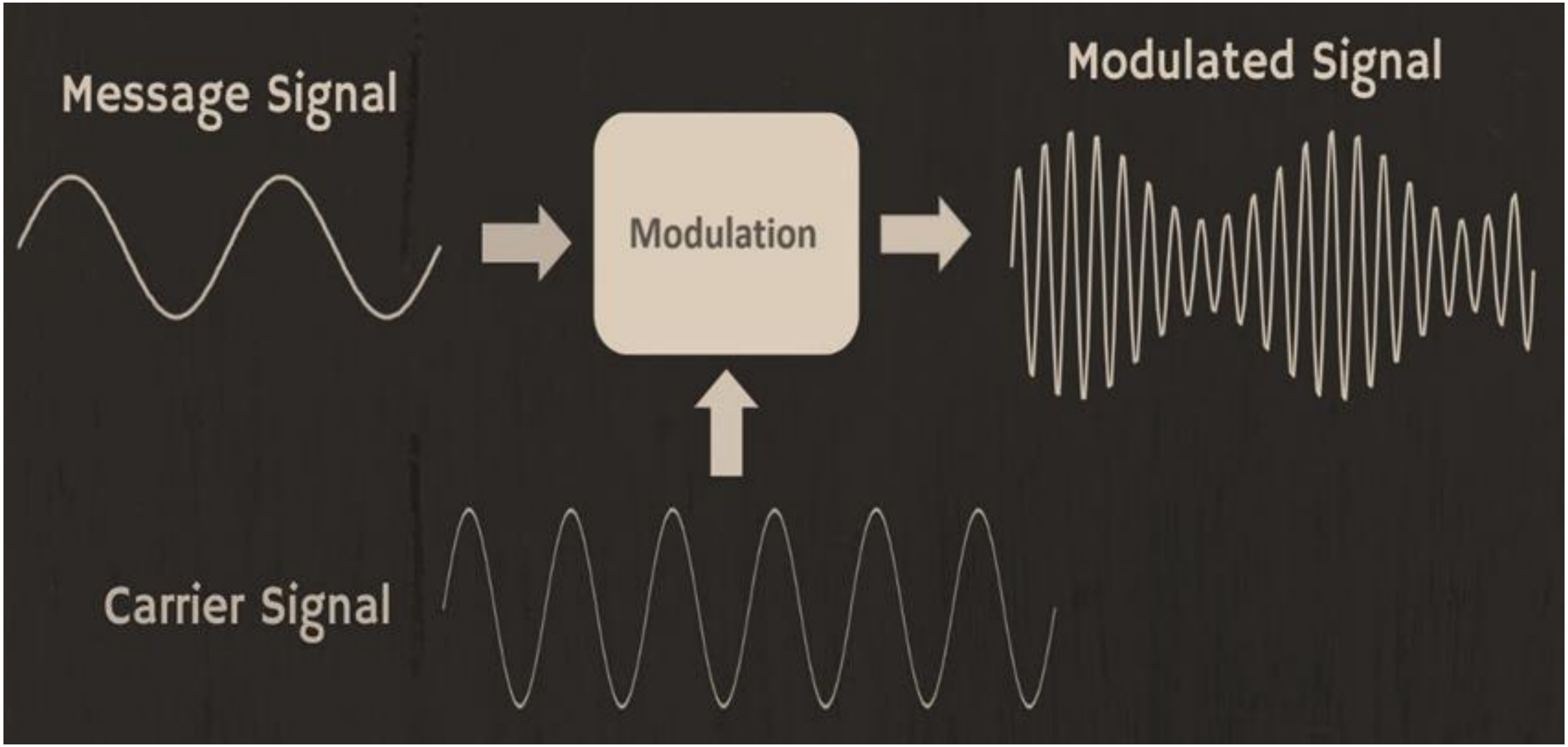
Communications Technology

Dr./ Ahmed Mohamed Rabie

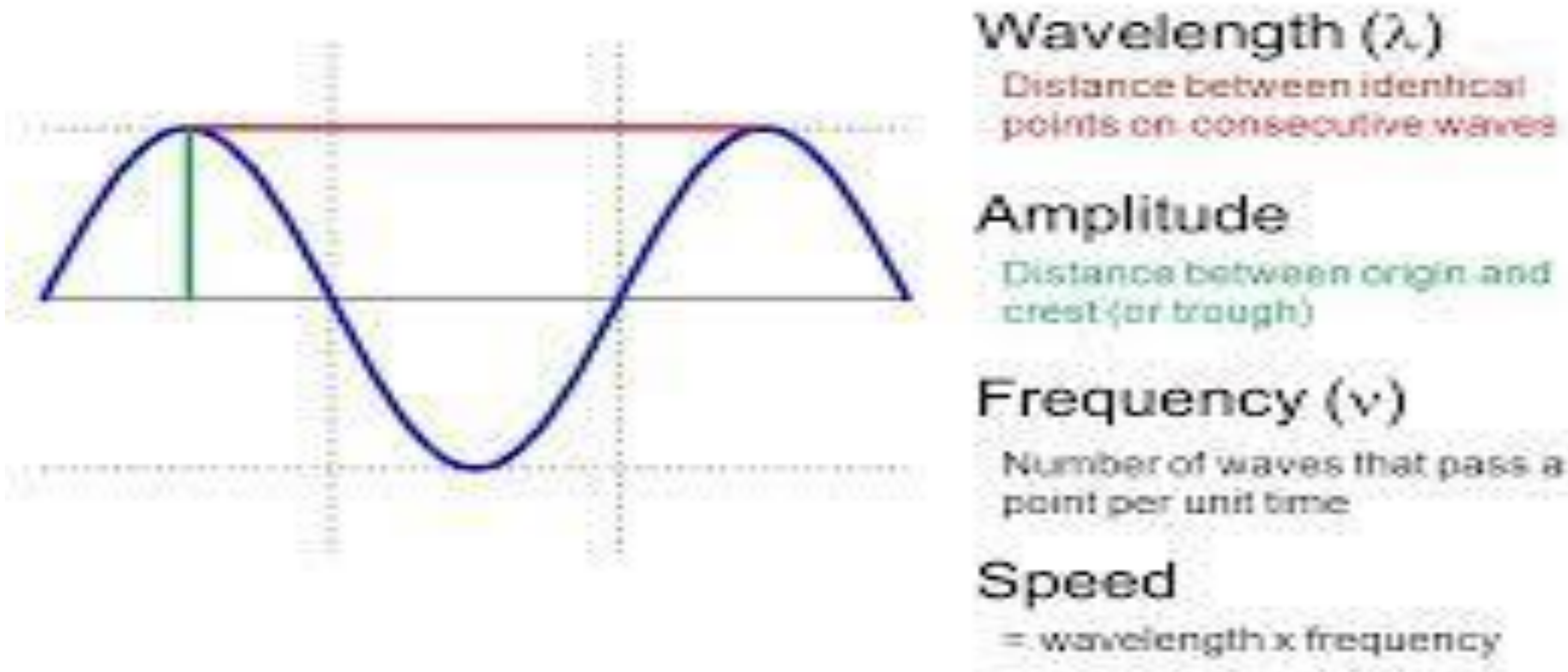
Chapter 1

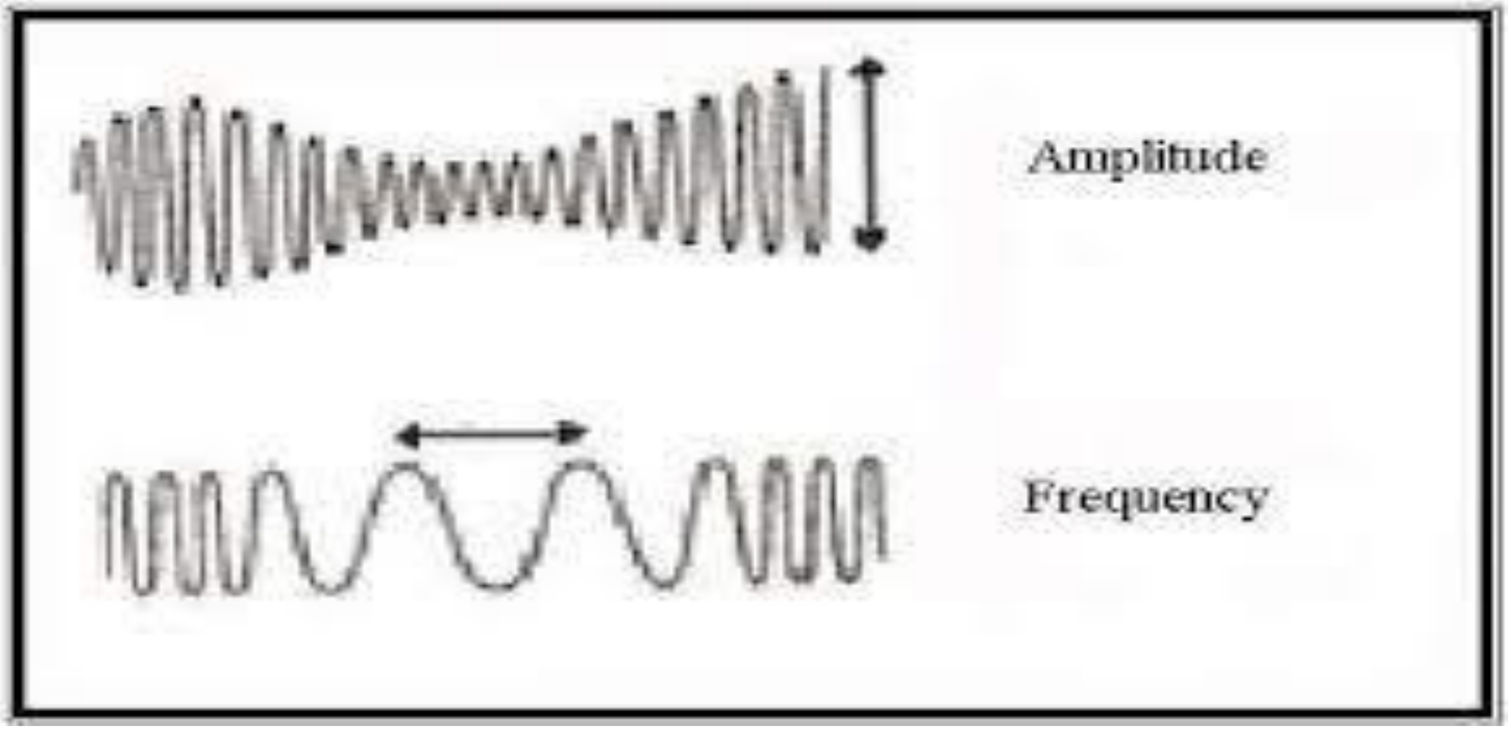
Introduction

Modulation is the process of converting data into radio waves by adding information to an electronic or optical carrier signal. A carrier signal is one with a steady waveform, constant height, or amplitude, and frequency. The carrier wave used by radio frequency (RF) transmissions doesn't carry much information itself.


Message Signal
Modulation
Modulated Signal
Carrier Signal

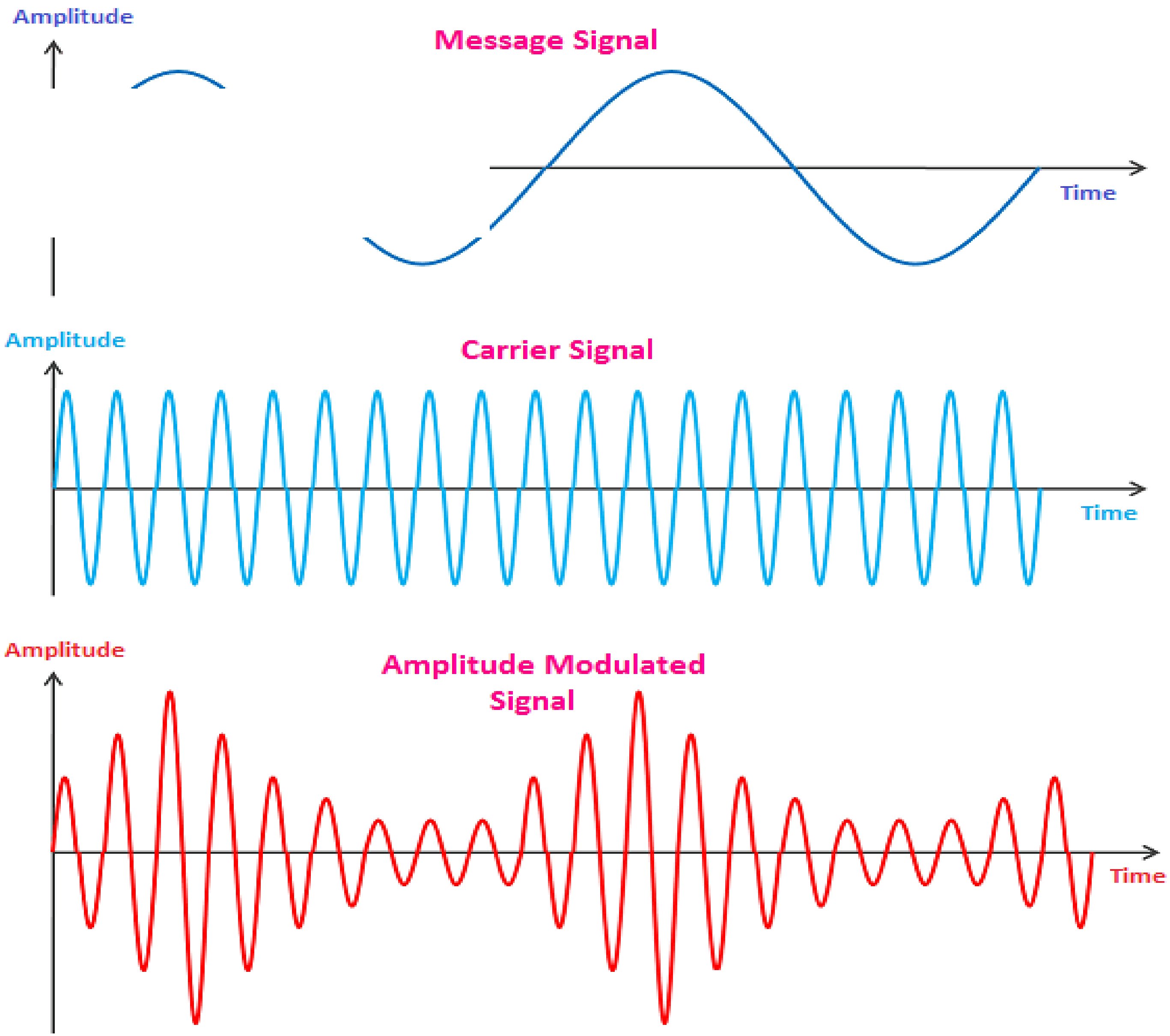
To include speech or data, another wave has to be superimposed on the carrier wave, thus changing the shape of the carrier wave. The process of doing so is called modulation. To transmit sound, the audio signal must first be converted into an electric signal, using a transducer. After conversion, it is used to modulate a carrier signal.


Wavelength (λ)
Distance between identical points on consecutive waves
Amplitude
Distance between origin and crest (or trough)
Frequency (ν)
Number of waves that pass a point per unit time
Speed
= wavelength x frequency

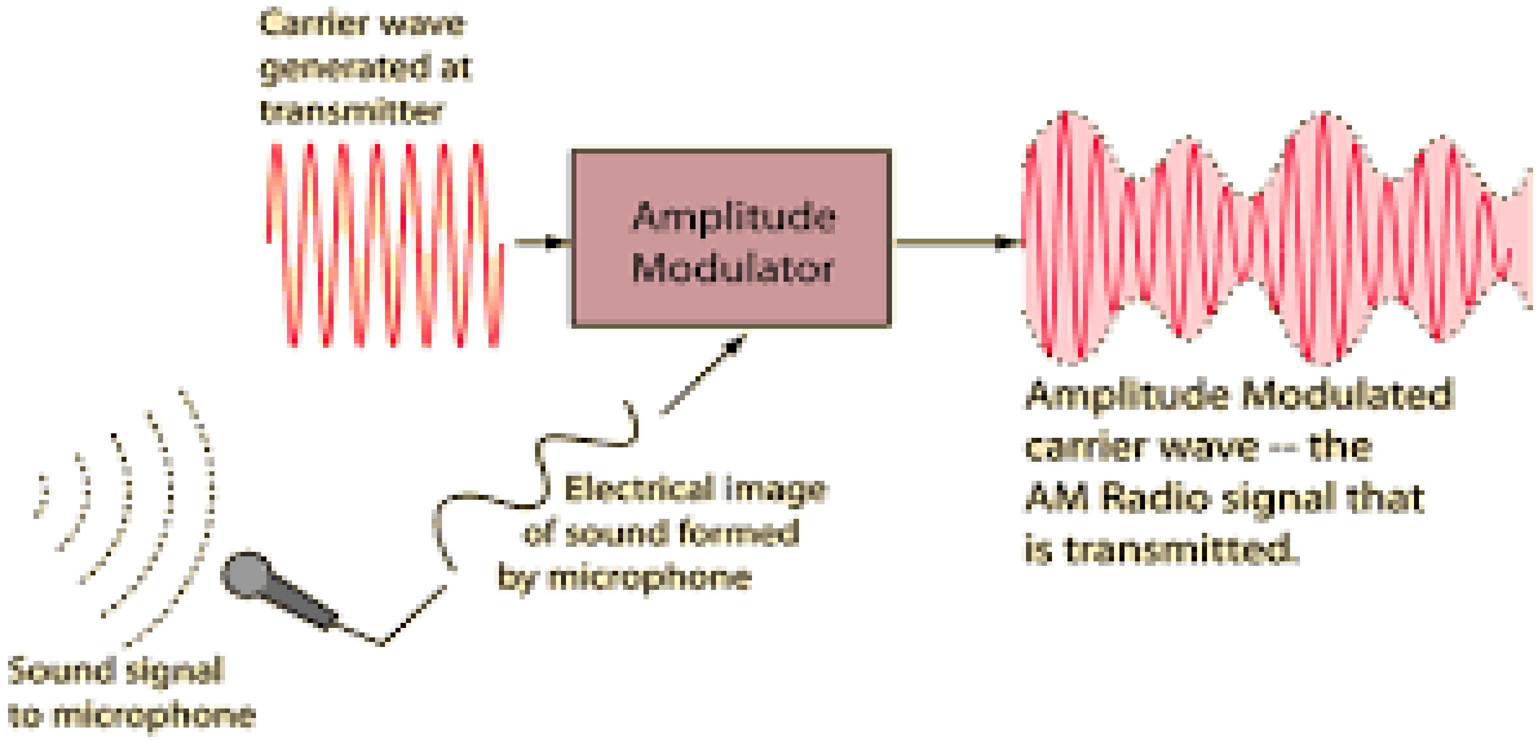

Amplitude
Frequency

A very **common application of FDM** is AM and FM radio broadcasting. Radio uses the air as the transmission medium. A special band from 530 to 1700 kHz is assigned to AM radio. All radio stations need to share this band. Each AM station needs 10kHz of bandwidth. Each station uses a different carrier frequency, which means it is shifting its signal and multiplexing.

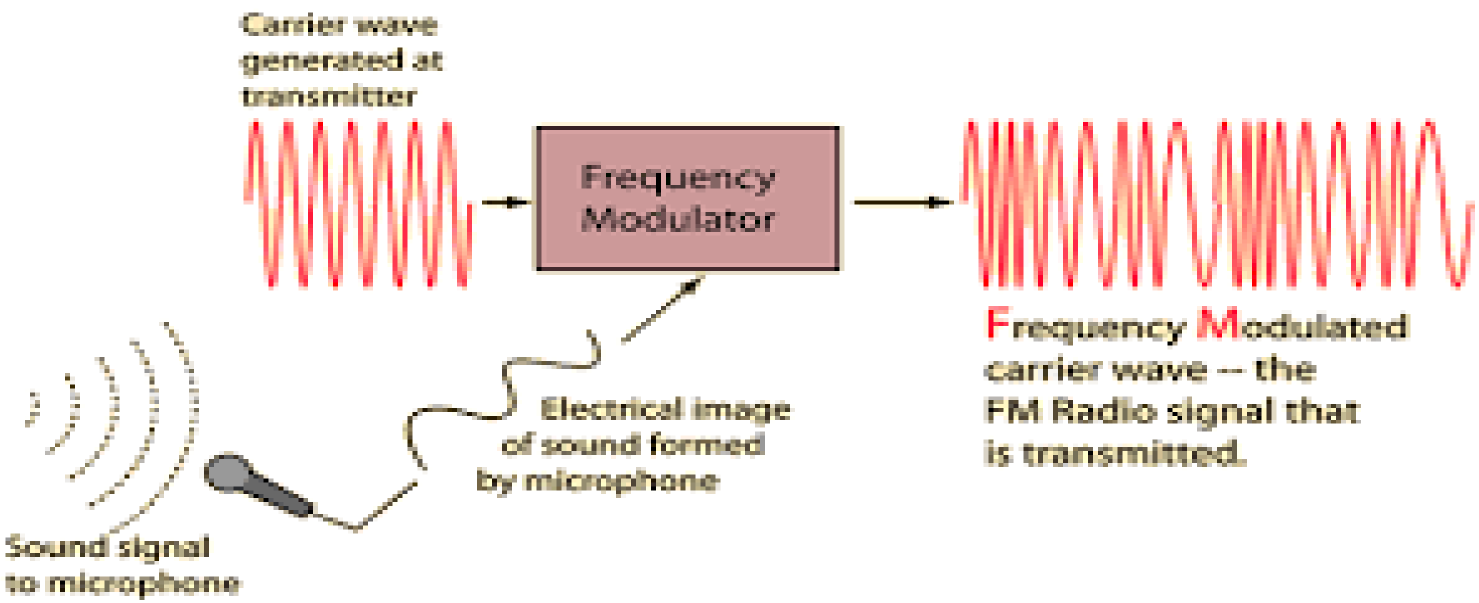
Amplitude Modulation

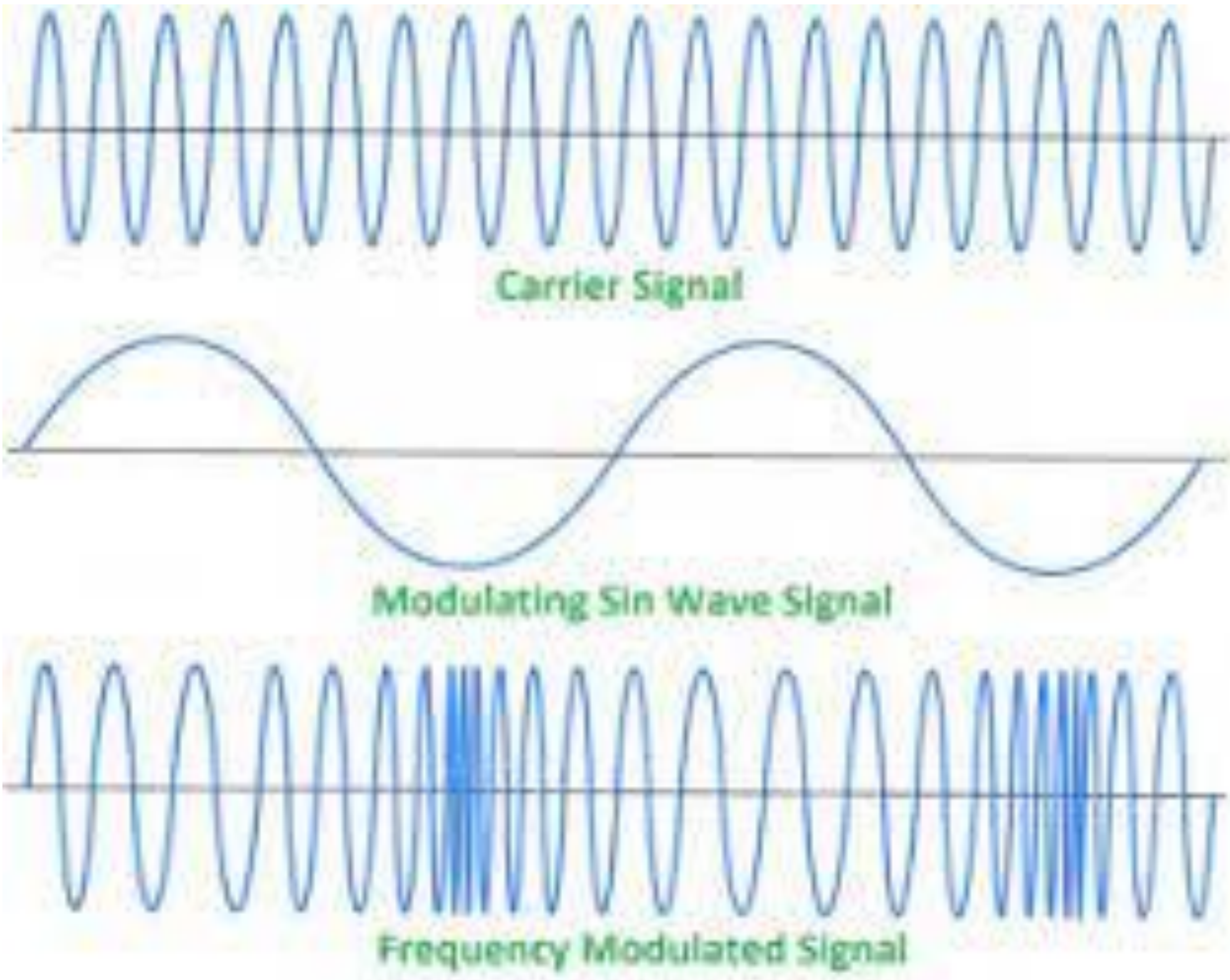


The signal that goes to the air is a combination of signals. A receiver receives all these signals, but filters (by tuning) only the one which is desired. Without multiplexing, only one AM station could broadcast to the common link, the air. However, we need to know that there is physical multiplexer or demultiplexer here.

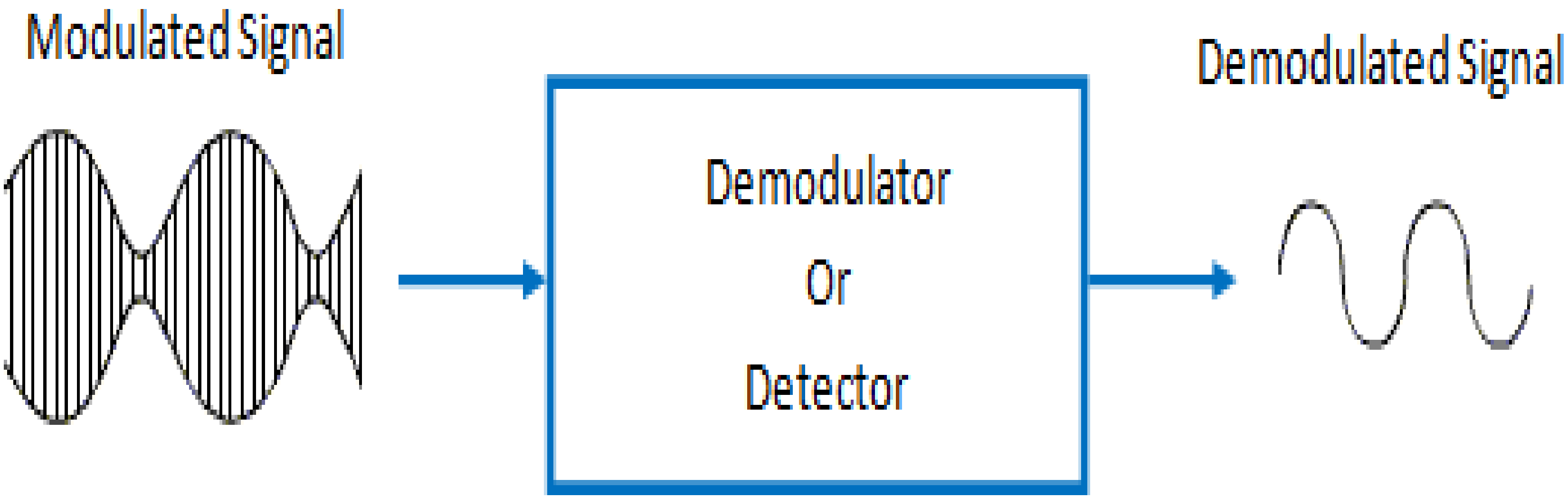

Carrier wave generated at transmitter
Amplitude Modulator
Amplitude Modulated carrier wave -- the AM Radio signal that is transmitted.
Electrical image of sound formed by microphone
Sound signal to microphone

FM broadcasting. However, FM has a wider band of 88 to 108 MHz because each station needs a bandwidth of 200 kHz.




Carrier Signal
Modulating Sin Wave Signal
Frequency Modulated Signal

Demodulation is defined as extracting the original information-carrying signal from a modulated carrier wave. A demodulator is an electronic circuit that is mainly used to recover the information content from the modulated carrier wave. There are different types of modulation and so are demodulators. The output signal via a demodulator may describe the sound, images, or binary data.


Modulated Signal
Demodulator
Or
Detector
Demodulated Signal

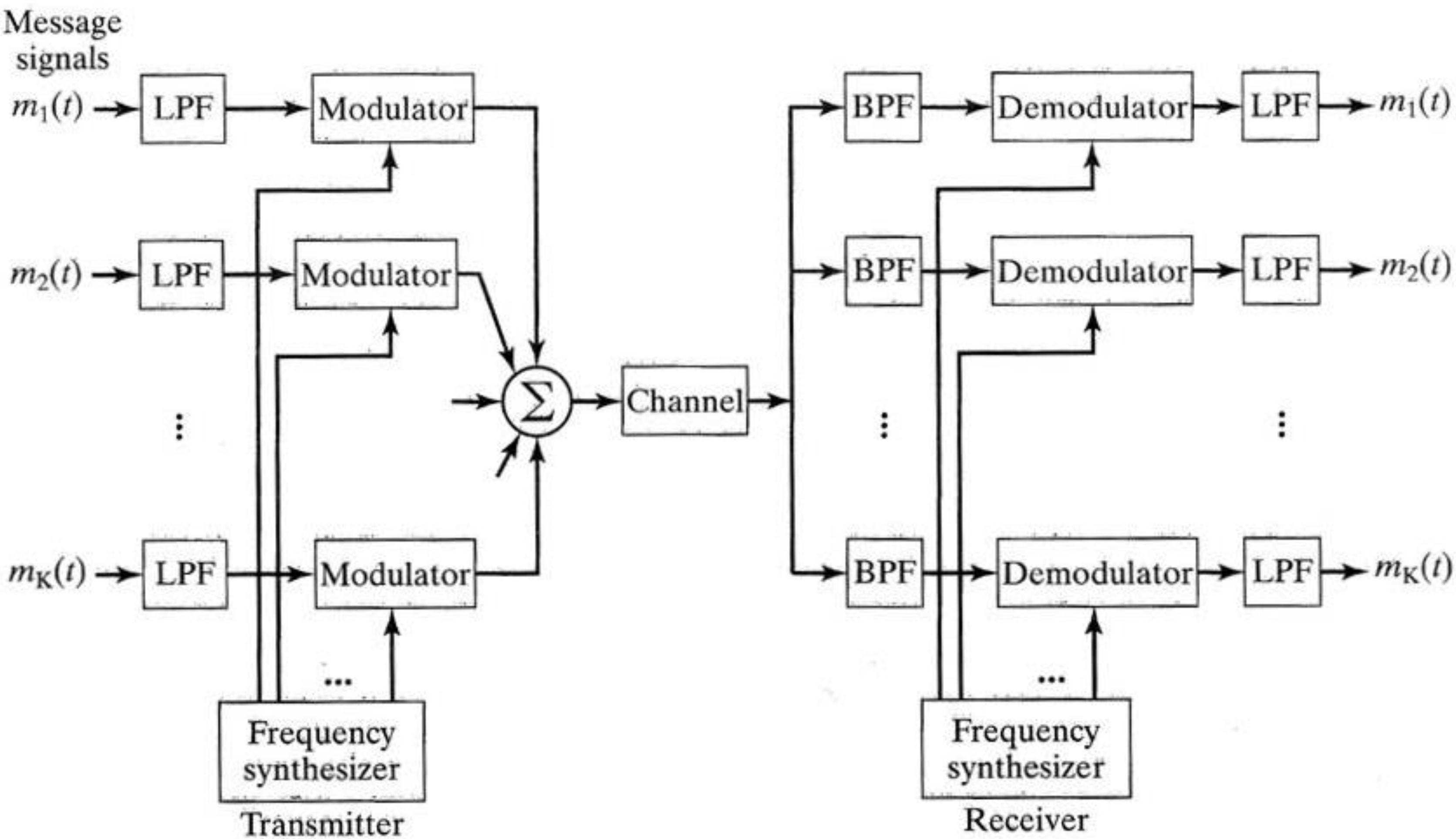
Example 4

The Advanced Mobile Phone System (AMPS) uses two bands. The first band of 824 to 849 MHz is used for sending, and 869 to 894 MHz is used for receiving. Each user has a bandwidth of 30 kHz in each direction. The 3-kHz voice is modulated using FM, creating 30 kHz of modulated signal. How many people can use their cellular phones simultaneously?

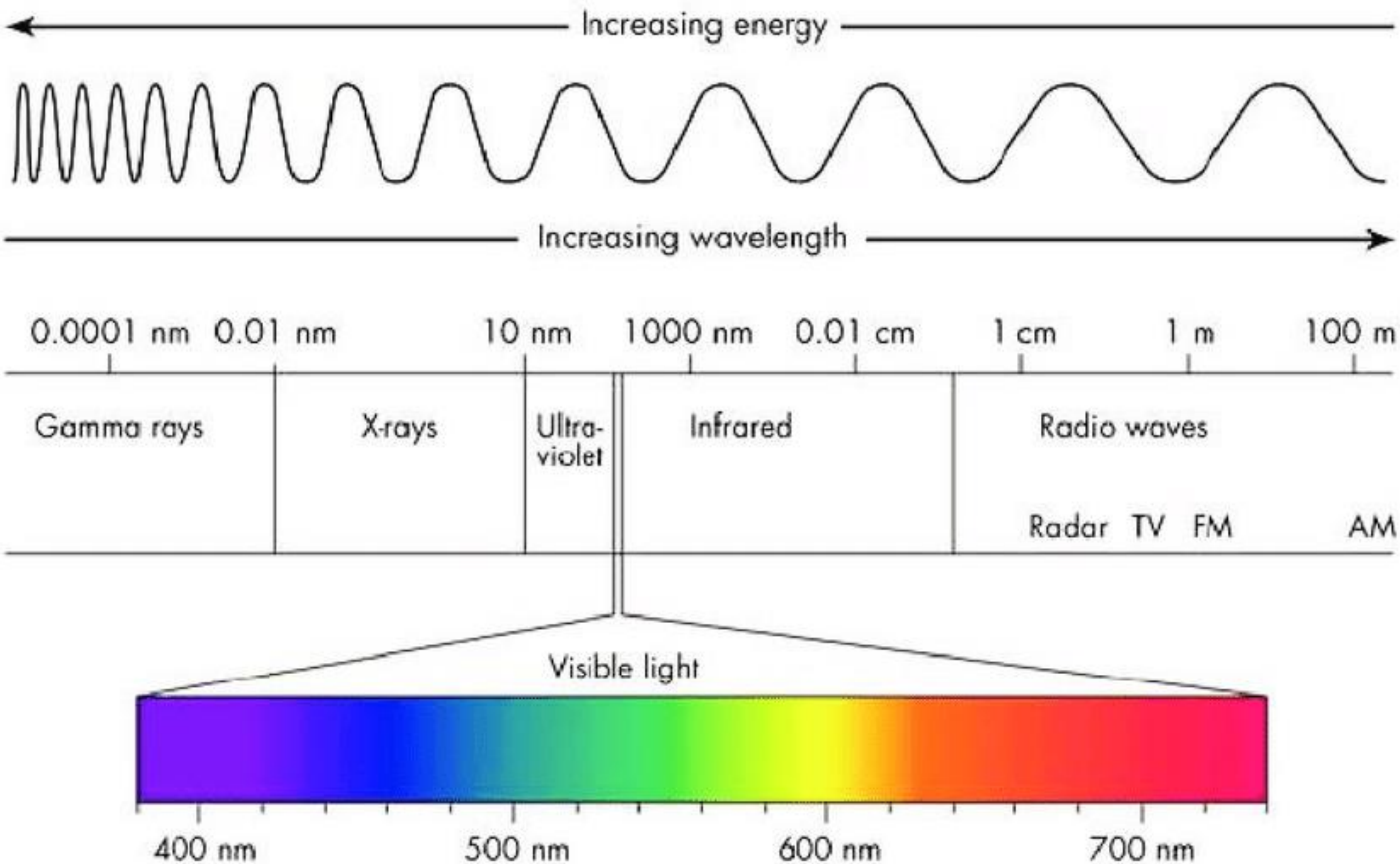
Each band is 25 MHz. If we divide 25 MHz by 30 kHz, we get 833.33.

FDM can be implemented very easily. In many cases, such as radio and television broadcasting, there is no need for a physical multiplexer or demultiplexer. As long as the stations agree to send their broadcasts to the air using different carrier frequencies, multiplexing is achieved.

In other cases, such as the cellular telephone system, a base station needs to assign a carrier frequency to the telephone user. There is not enough bandwidth in a cell to permanently assign a bandwidth range to every telephone user. When a user hangs up, her or his bandwidth is assigned to another caller.

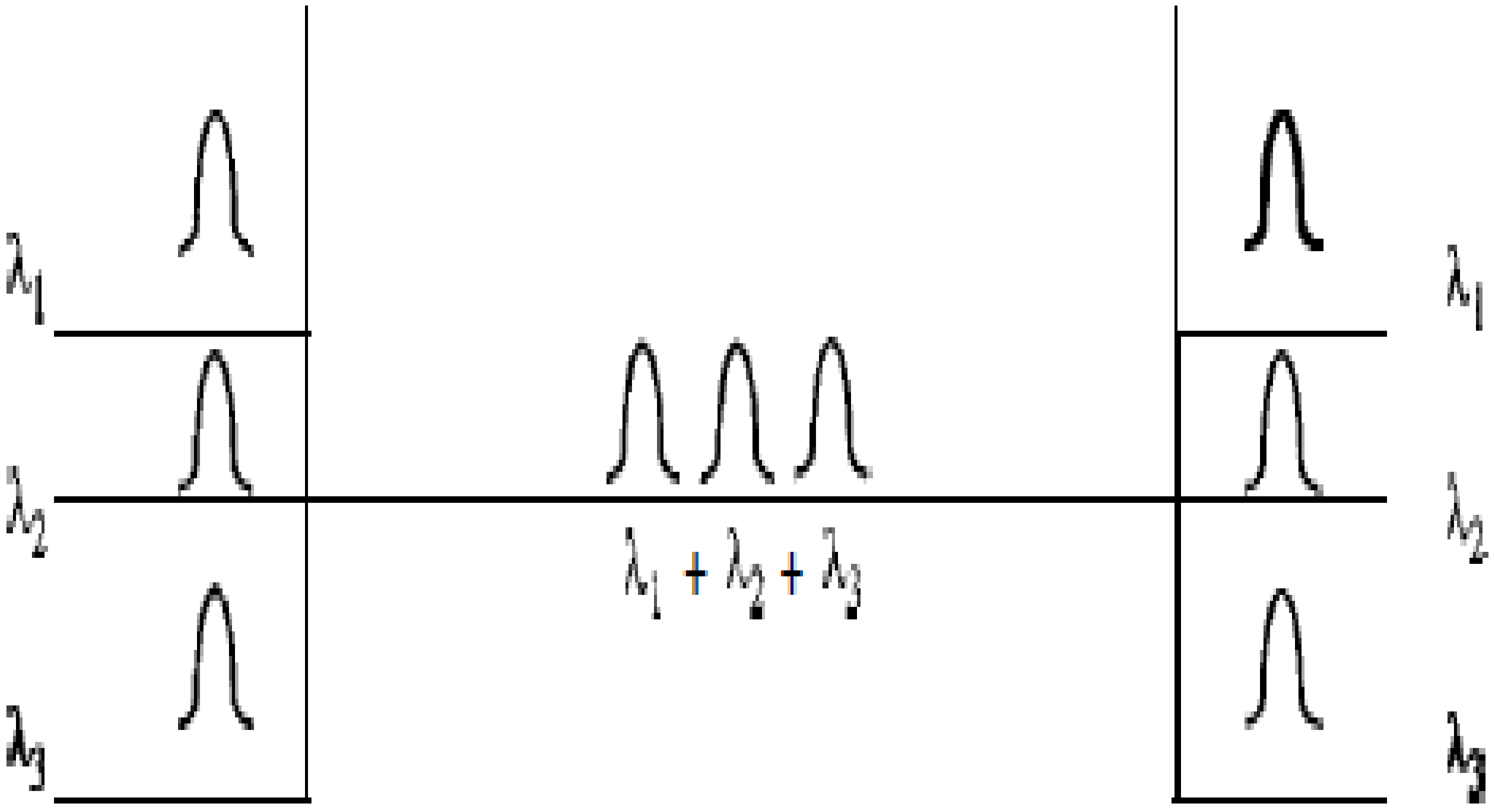

Message signals
$m_1(t)$
$m_2(t)$
$m_K(t)$
LPF
Modulator
Σ
Channel
BPF
Demodulator
LPF
$m_1(t)$
$m_2(t)$
$m_K(t)$
Frequency synthesizer
Transmitter
Frequency synthesizer
Receiver

2- Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable. The optical fiber data rate is higher than the data rate of metallic transmission cable. Using a fiber-optic cable for one single line wastes the available bandwidth. Multiplexing allows us to combine several lines into one.


Increasing energy
Increasing wavelength
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma rays
X-rays
Ultra-
violet
Infrared
Radio waves
Radar
TV
FM
AM
Visible light
400 nm
500 nm
600 nm
700 nm

WDM is conceptually the same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fiber-optic channels. The idea is the same: We are combining different signals of different frequencies. The difference is that the frequencies are very high. Very narrow bands of light from different sources are combined to make a wider band of light. At the receiver, the signals are separated by the demultiplexer.

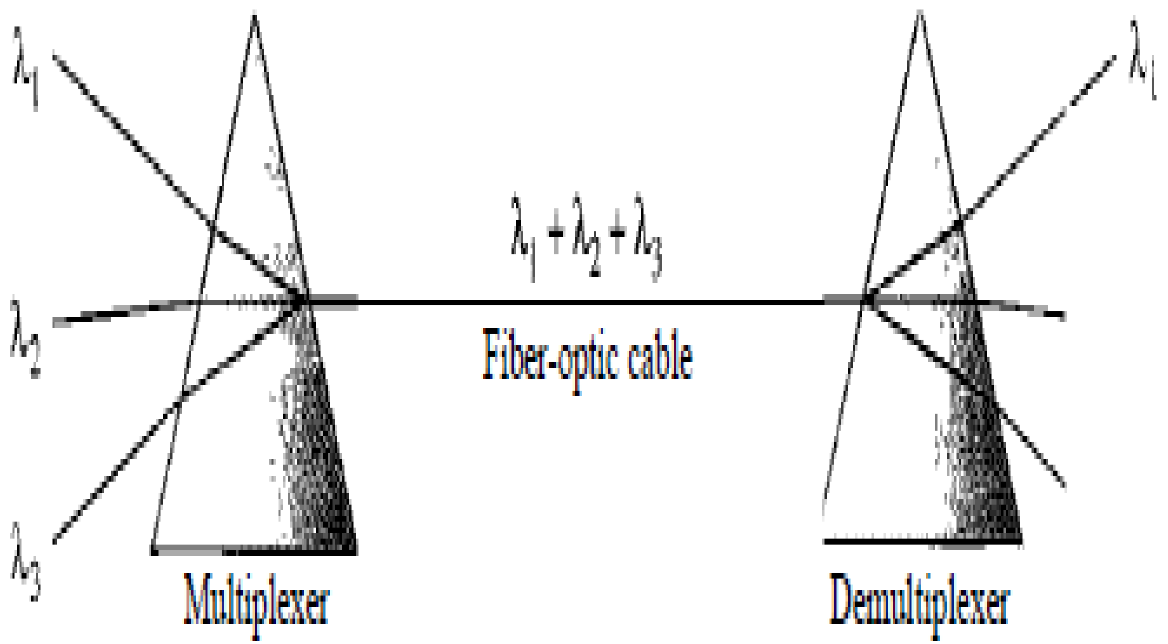
Wavelength-division multiplexing



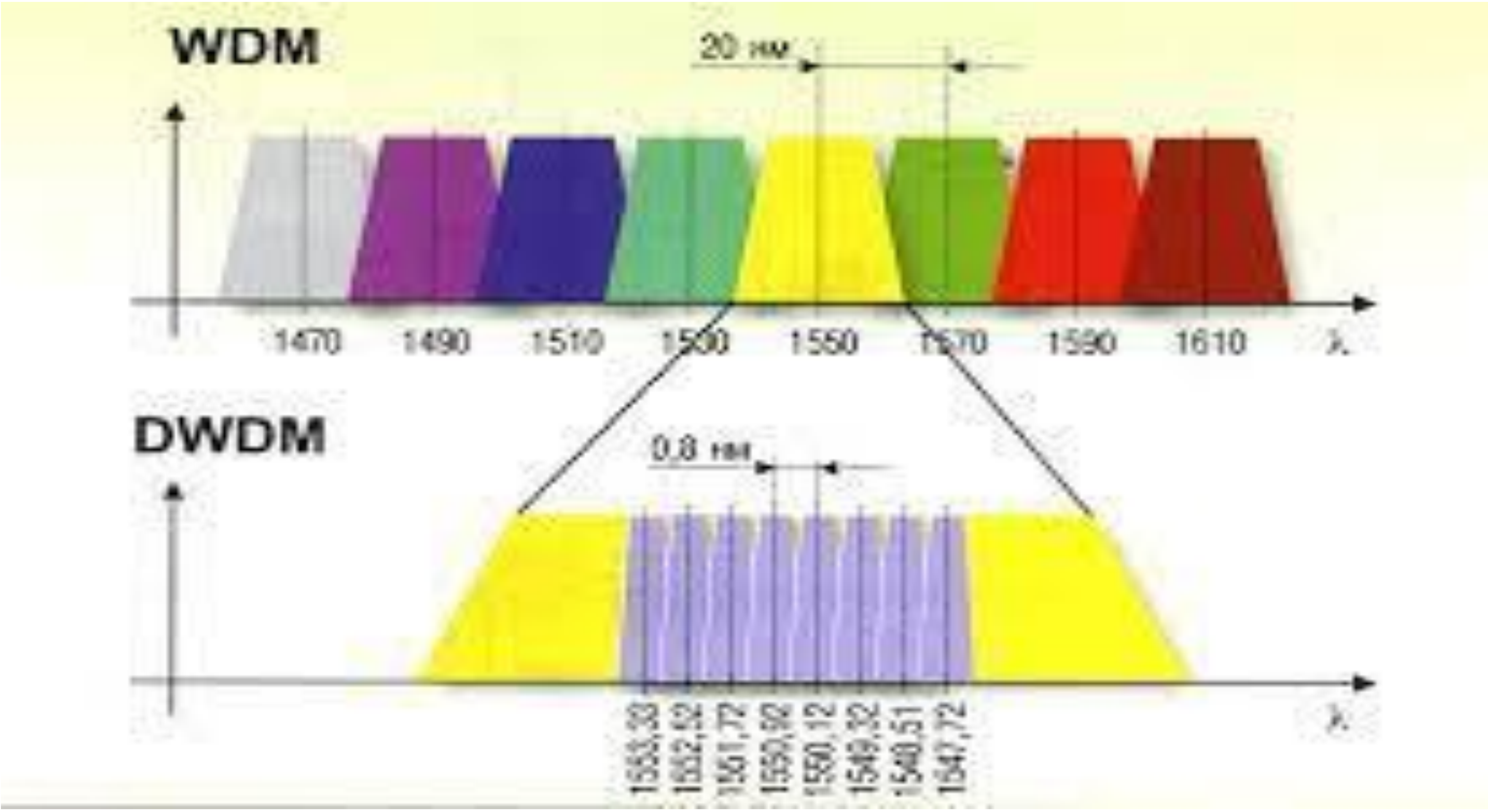
WDM is an analog multiplexing technique to combine optical signals. Although WDM technology is very complex, the basic idea is very simple. We want to combine multiple light sources into one single light at the multiplexer and do the reverse at the demultiplexer. The combining and splitting of light sources are easily handled by a **prism**.

Recall from basic physics that a prism bends a beam of light based on the angle of incidence and the frequency. Using this technique, a multiplexer can be made to combine several input beams of light, each containing a narrow band of frequencies, into one output beam of a wider band of frequencies. A demultiplexer can also be made to reverse the process.

Prisms in wavelength-division multiplexing and demultiplexing



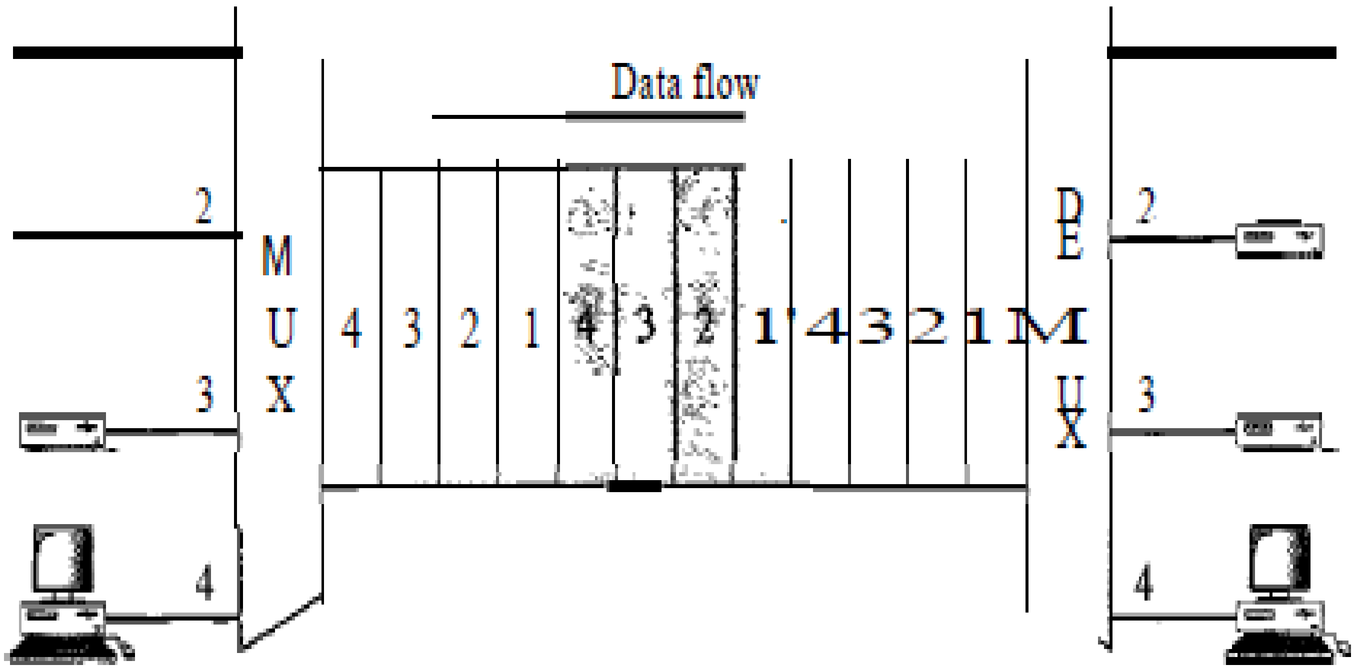
A new method, called dense WDM **(DWDM)**, can multiplex a very large number of channels by spacing channels very close to one another. It achieves even greater efficiency.


WDM
20 нм
1470
1490
1510
1530
1550
1570
1590
1610
λ
DWDM
0,8 нм
1553,33
1552,52
1551,72
1550,92
1550,12
1549,32
1548,51
1547,72
λ

	WDM	DWDM
Channel width	13nm	1nm
Channel spacing	20nm	0.8nm
Number of channels	4 to 18	Up to 160
Optical amplifiers	Not used	Used
Range	Up to 120km	Up to 500 km
Power /wave length	1.6w	5w

3- Synchronous Time-Division Multiplexing: Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a line Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link. Note that the same link is used as in FDM; here, however, the link is shown sectioned by time rather than by frequency. In the figure, portions of signals 1,2,3, and 4 occupy the link sequentially.

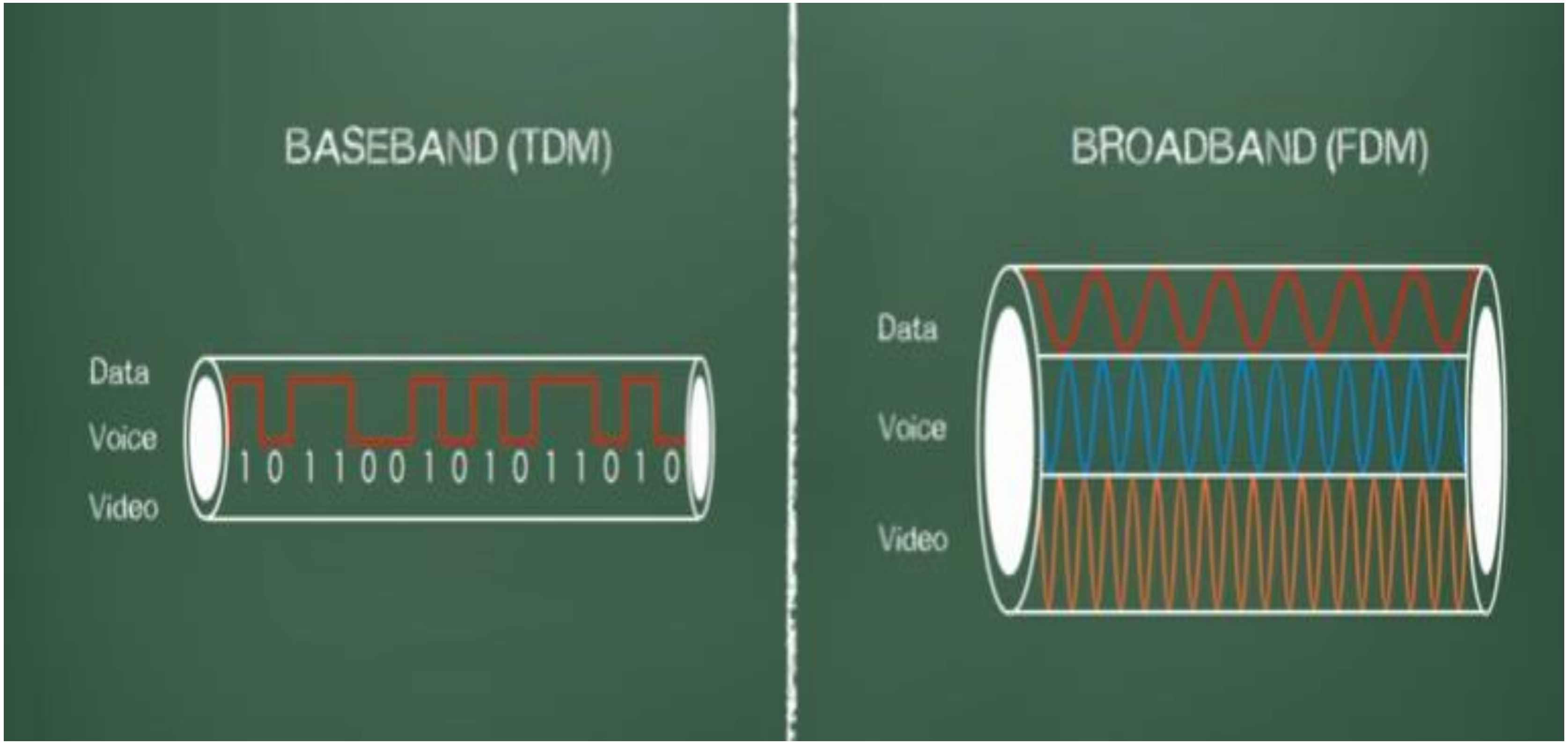
TDM



All the data in a message from source 1 always go to one specific destination, be it 1, 2, 3, or 4. The delivery is fixed and unvarying, unlike switching. We also need to remember that **TDM** is, in principle, a digital multiplexing technique. Digital data from different sources are combined into one timeshared link. However, this does not mean that the sources cannot produce analog data; analog data can be sampled, changed to digital data, and then multiplexed by using TDM.

Sr no.	FDM	TDM
1.	The signals which are to be multiplexed are added in the time domain . But they occupy different slots in the frequency domain .	The signals which are to be multiplexed can occupy the entire bandwidth in the time domain .
2.	FDM is usually preferred for the analog signals .	TDM is preferred for the digital signals .
3.	Synchronization is not required .	Synchronization is required .
4.	The FDM requires a complex circuitry at Tx and Rx .	TDM circuitry is not very complex .
5.	FDM suffers from the problem of crosstalk due to imperfect BPF .	In TDM the problem of crosstalk is not severe .
6.	Due to bandwidth fading in the Tx medium , all the FDM channels are affected .	Due to fading only a few TDM channels will be affected .
7.	Due to slow narrowband fading taking place in the transmission channel may be affected in FDM .	Due to slow narrowband fading all the TDM channels may get wiped out .

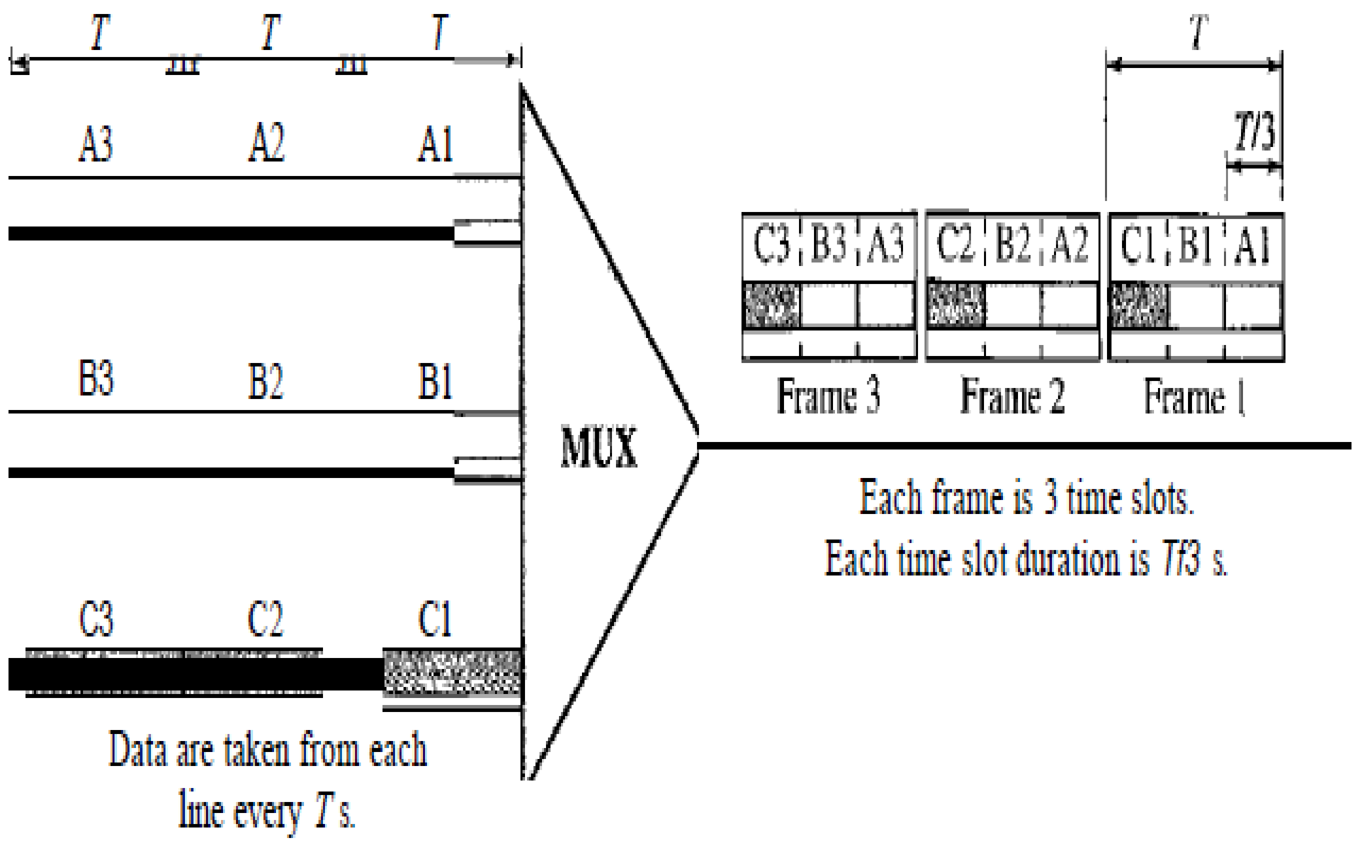
TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one. We can divide TDM into two different schemes: synchronous and statistical. In **synchronous** TDM, each input connection has an allotment in the output even if it is not sending data.


BASEBAND (TDM)
Data
Voice
Video
1 0 1 1 0 0 1 0 1 0 1 1 0 1 0
BROADBAND (FDM)
Data
Voice
Video

Baseband refers to a single-channel digital system and that single channel is used to communicate with devices on a network. **Broadband**, on the other hand, is wide bandwidth data transmission which generates an analog carrier frequency, which carries multiple digital signals or multiple channels.

In **synchronous TDM**, the data flow of each input connection is divided into units, where each input occupies one input time slot. A unit can be 1 bit, one character, or one block of data. Each input unit becomes one output unit and occupies one output time slot. However, the duration of an output time slot is n times shorter than the duration of an input time slot. If an input time slot is T s, the output time slot is Tin s, where n is the number of connections. In other words, a unit in the output connection has a shorter duration; it travels faster.

Synchronous time-division multiplexing



In synchronous TDM, a round of data units from each input connection is collected into a frame If we have n connections, a frame is divided into n time slots and one slot is allocated for each unit, one for each input line. If the duration of the input unit is T, the duration of each slot is T/n and the duration of each frame is T (unless a frame carries some other information.

The data rate of the output link must be n times the data rate of a connection to guarantee the flow of data. The data rate of the link is 3 times the data rate of a connection; likewise, the duration of a unit on a connection is 3 times that of the time slot (duration of a unit on the link). In the figure we represent the data prior to multiplexing as 3 times the size of the data after multiplexing. This is just to convey the idea that each unit is 3 times longer in duration before multiplexing than after.

In synchronous TDM, the data rate of the link is n times faster, and the unit duration is n times shorter. Time slots are grouped into frames. A frame consists of one complete cycle of time slots, with one slot dedicated to each sending device. In a system with n input lines, each frame has n slots, with each slot allocated to carrying data from a specific input line.