CHAPTER 4

Signal Transmission

(Part 1 of 2)

Introduction

The characteristics and performance of a communication system depend on many aspects of signal transmission:

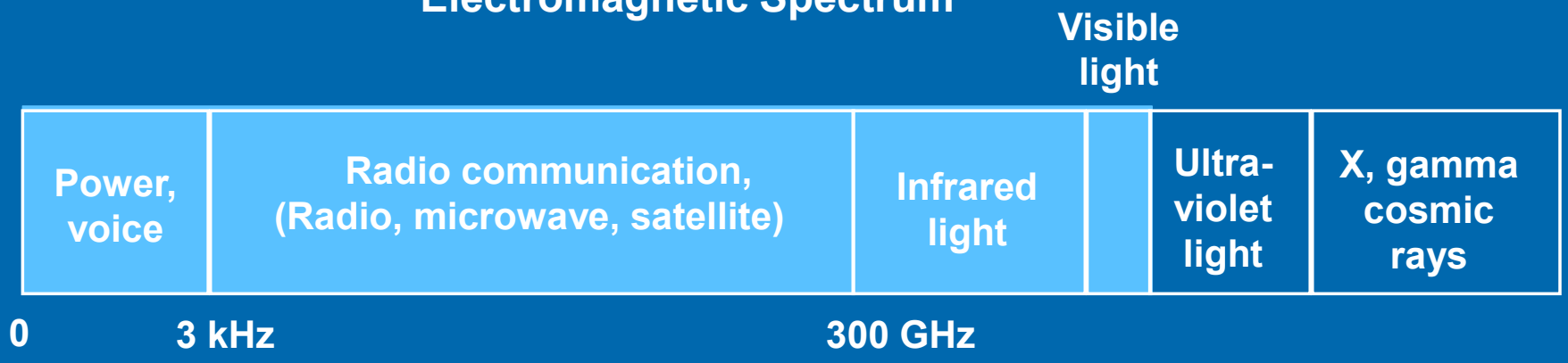
- **Type of signals employed:** **analog / digital**
- **Transmission channels:** **wired / wireless**
- **Signal transmission methods:** **baseband / passband transmission**

4.1 Electromagnetic frequency spectrum

- **Communication systems transmit information in form of electromagnetic energy:**

- voice-band frequencies	Signal transmission via over metal cables, e.g. twisted-pair or coaxial cable.
- radio frequencies	Signal transmission via air or space.
- infrared light	
- visible light	Signal Transmission via fiber-optic cable

Electromagnetic Spectrum



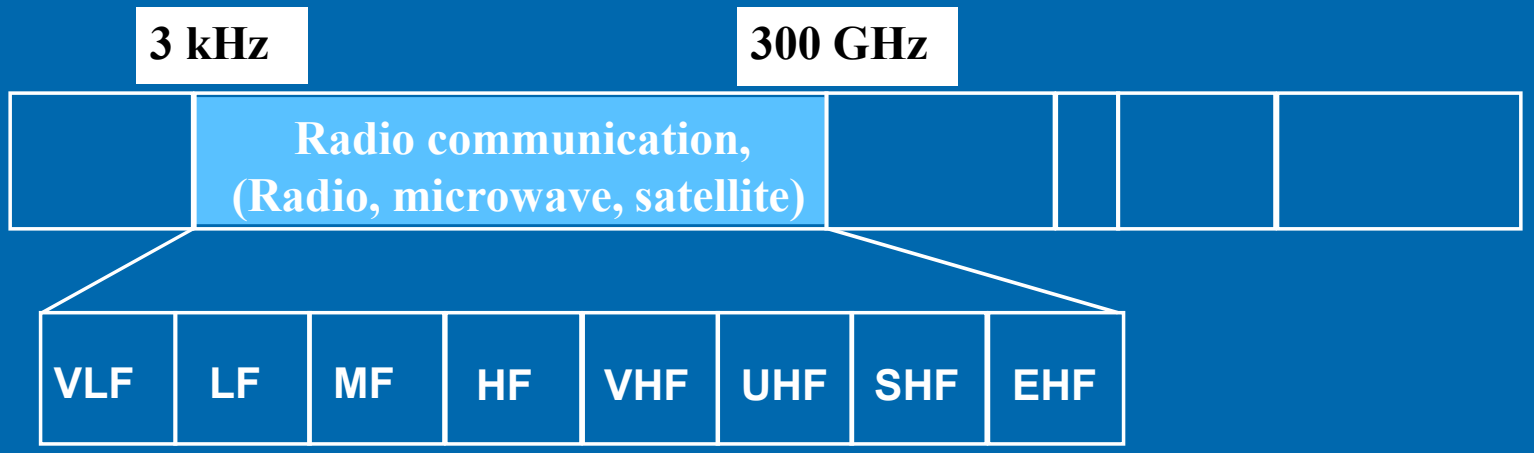
4.1 Electromagnetic frequency spectrum

Radio transmission channels

- The electromagnetic spectrum used for **radio communication** is divided into eight ranges, known as:

Radio frequency bands

VLF - Very Low Frequency	VHF - Very High Frequency
LF - Low Frequency	UHF - Ultra High Frequency
MF - Medium Frequency	SHF - Super High Frequency
HF - High Frequency	EHF - Extremely High Frequency



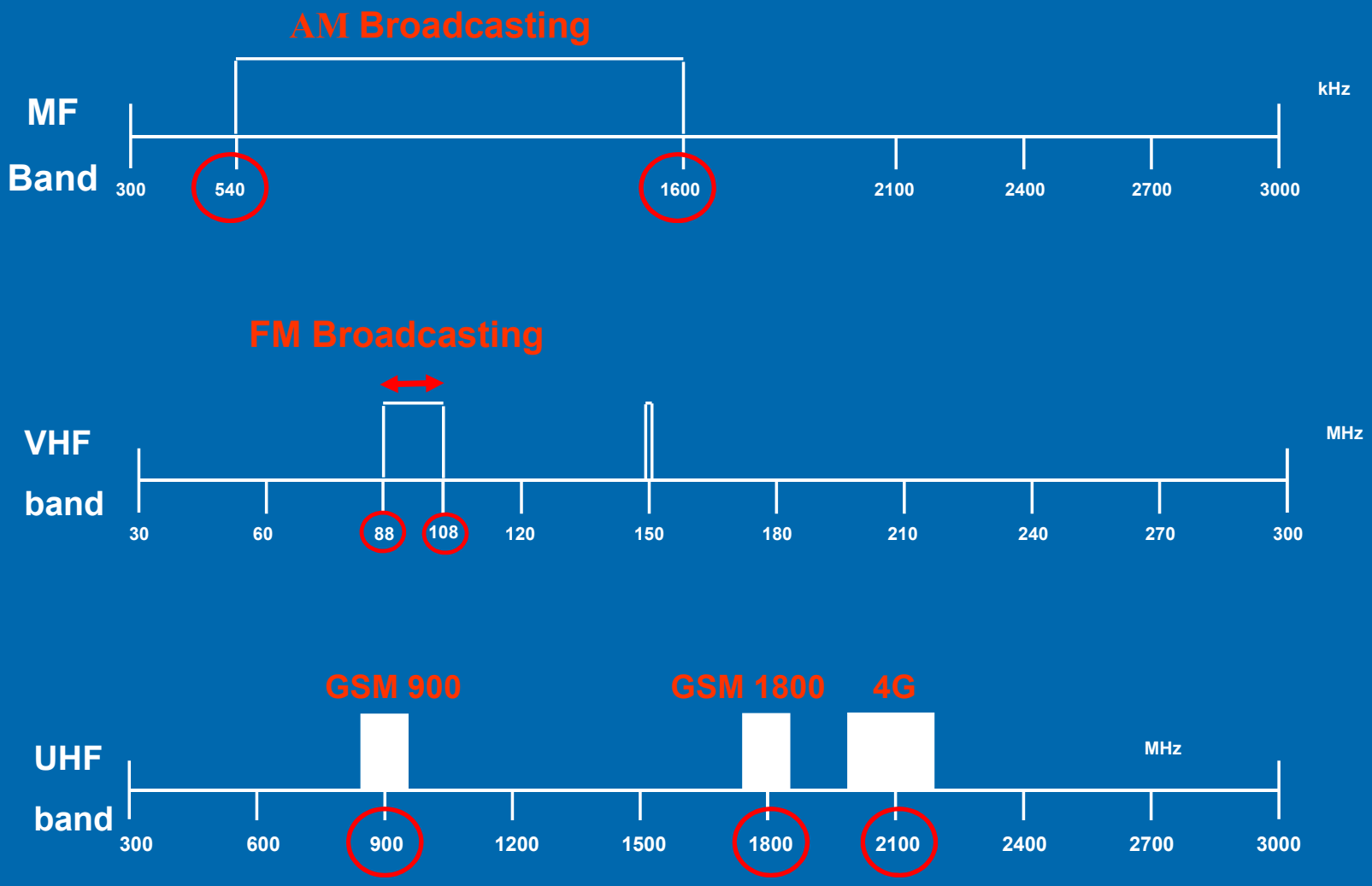
4.1 Electromagnetic frequency spectrum

Table 4.1 RF Bands

Frequency Range	Name of Band	Other Names
30 kHz - 300 kHz	Low Frequency (LF)	Long Wave (LW)
300 kHz - 3 MHz	Medium Frequency (MF)	Medium Wave (MW)
3 MHz - 30 MHz	High Frequency (HF)	Short Wave (SW)
30 MHz - 300 MHz	Very High Frequency (VHF)	-
300 MHz - 3 GHz	Ultra High Frequency (UHF)	-
3 GHz - 30 GHz	Super High Frequency (SHF)	Microwave
30 GHz - 300 GHz	Extremely High Frequency (EHF)	Millimetre Wave
300 GHz - 3 THz	-	Infrared

4.1 Electromagnetic frequency spectrum

Common Users of Radio Frequencies allocated by ITU



4.1 Electromagnetic frequency spectrum

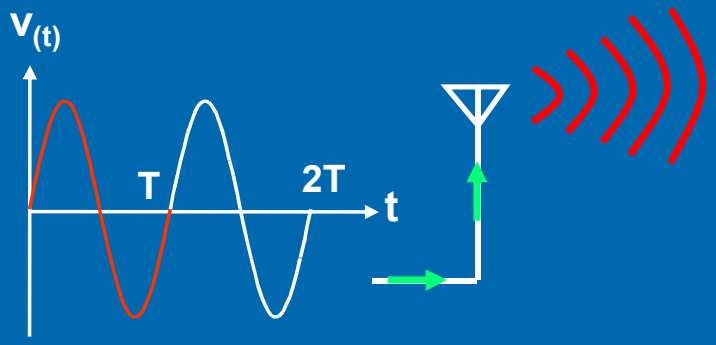
Relationship between frequency and wavelength

Wavelength, λ — **Distance travelled by radio wave in one period, T**

$\lambda = v_{(prop)} \times T$ metres $\Rightarrow$ $\lambda = \frac{v_{(prop)}}{f}$

$v_{(prop)}$ = velocity of propagation

Max $v_{(prop)}$ = speed of light (3×10^8) m/s



Signals travel through a transmission channel at a certain velocity dependent on the transmission medium.

e.g. Faster in outer space
Slower on earth.

4.1 Electromagnetic frequency spectrum

Example 4.1

(a) A radio station is transmitting at 20 MHz. What is the wavelength of this transmission?

(b) A 20 MHz signal travels along a certain length of co-axial cable at 2×10^8 m/s. What is the wavelength of this transmission?

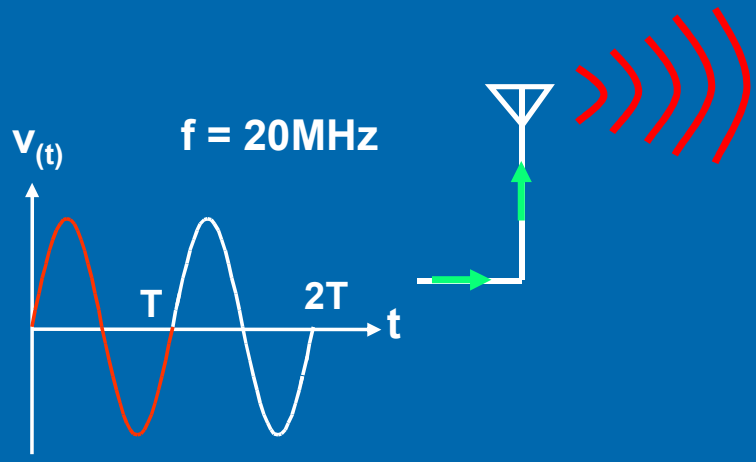
4.1 Electromagnetic frequency spectrum

Solution

(a) A radio station is transmitting at 20 MHz. What is the wavelength of this transmission?

Assume $v_{(prop)} = c$ = speed of light, for simplicity

$$\lambda = \frac{v_{(prop)}}{f} \Rightarrow \lambda = \frac{3 \times 10^8}{20 \times 10^6} = 15 \text{ m}$$



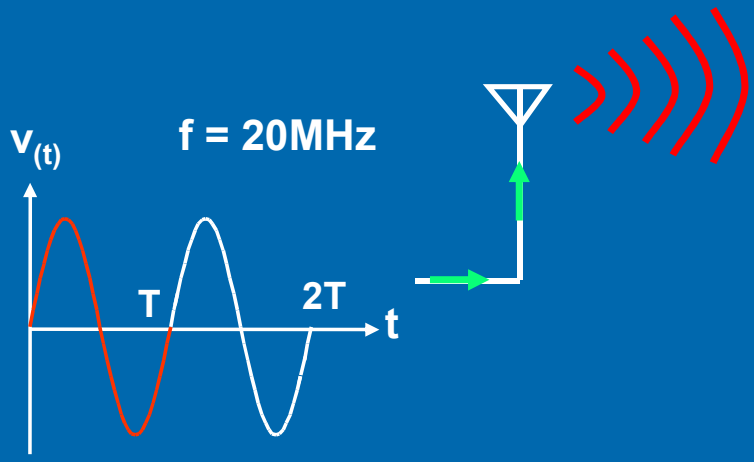
4.1 Electromagnetic frequency spectrum

Solution

(b) A 20 MHz signal travels along a certain length of co-axial cable at 2×10^8 m/s. What is the wavelength of this transmission?

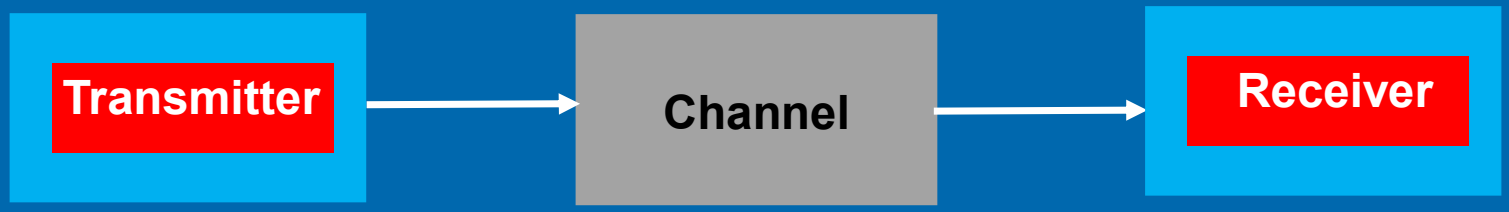
$v_{(prop)} = 2 \times 10^8$ m/s

$$\lambda = \frac{v_{(prop)}}{f} \Rightarrow \lambda = \frac{2 \times 10^8}{20 \times 10^6} = 10 \text{ m}$$



4.2 Transmission channels

- The transmission channels, connecting the transmitters and receivers, take a variety of forms:



Wired channels

- Twisted-pair wires
- Coaxial cable
- Optical fibre

Wireless channels.

- Air
- Vacuum

4.2 Transmission channels

Wired channels

Wired channel includes twisted-pair, coaxial cable, fiber-optic cable and a combination of these.

Twisted-pair wires

- Speech transmission — e.g. voice transmission in telephone networks.
- Digital data transmission from computers

- Provide a bandwidth of a few hundred kHz
- Suffer from cross-talk and sharp attenuation with frequencies above 100 kHz.

4.2 Transmission channels

Wired channels

Coaxial cable

Signal transmission of frequency range from a few hundred kHz to about 1 GHz.

e.g. cable TV systems,
data transmission in LANs.

4.2 Transmission channels

Wired channels

optical fiber — **for backbone networks**

Dielectric waveguide that transports light signals

- Information is transmitted by varying the intensity of the light source.
- Provides very large bandwidth
- Suffer very little attenuation
- Immune to interferences and induced noise

4.2 Transmission channels

Wireless channels

Transport radio waves without using a physical conductor.

- **Information bearing radio wave propagates through the air or vacuum.**

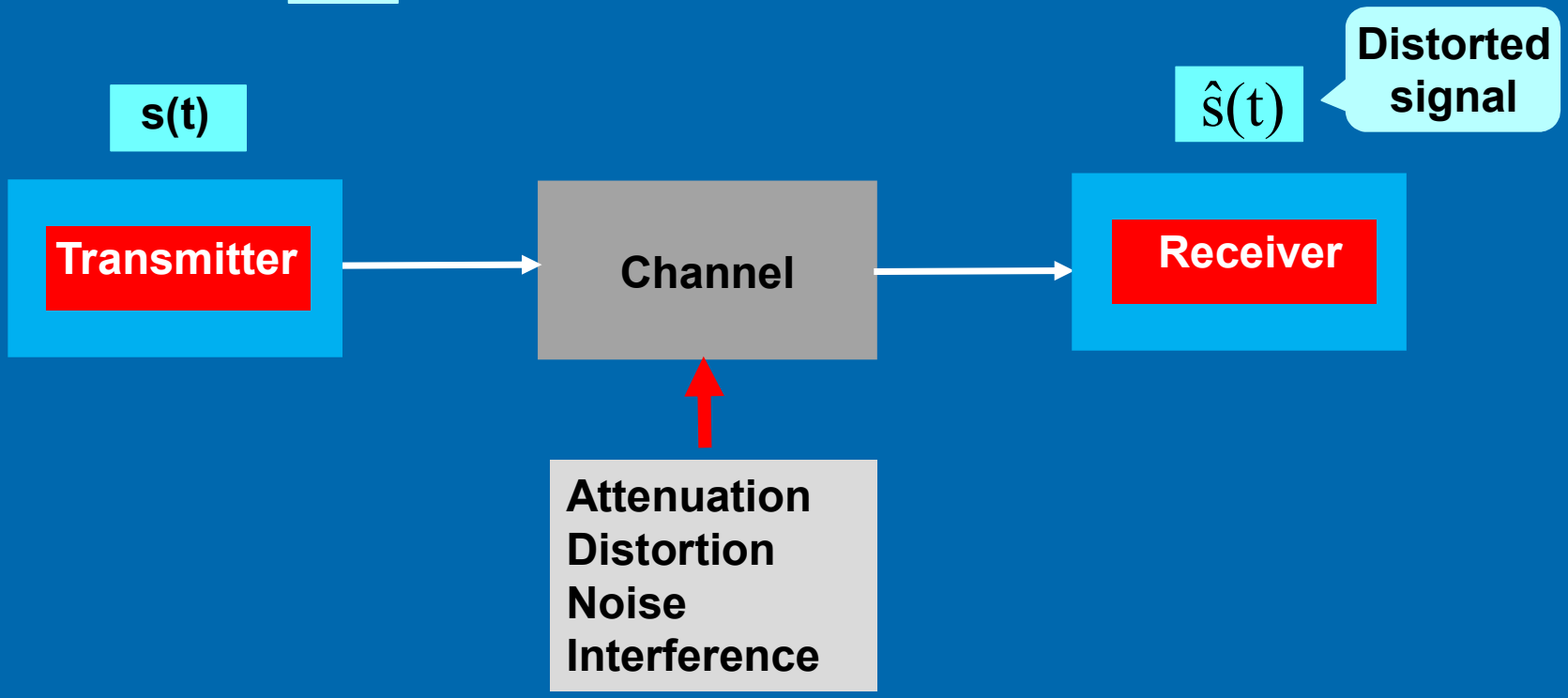
Radio propagates as
Surface wave (below 3 MHz),
Sky wave (3MHz to 30MHz) or
Space wave (above 30MHz).

Advantages	Disadvantages
Suitable for signal broadcasting and mobile communication	Channel characteristics highly dependent on • Transmission frequency • Channel noise • Bandwidth

4.2 Transmission channels

Transmission impairments

- Signals at transmitter and receiver are not the same due to transmission impairment.
- There are mainly **four** types of transmission impairment.



4.2 Transmission channels

Transmission impairments

Attenuation — Loss of transmission signal strength as the signal travels through the channel.

Wired channels: Attenuation (dB) increases linearly with the distance.

Wireless channels: Attenuation (dB) increases logarithmically with the distance.

4.2 Transmission channels

Transmission impairments

Distortion

Changes in signal in form or shape | **Linear or nonlinear**

Linear distortion	Nonlinear distortion
• Amplitude distortion when the magnitude response of the channel is not constant (flat). • Phase distortion when the phase response of the channel is not linear (i.e. different frequency components suffer different amount of delay)	• Nonlinear distortion occurs when the relationship between the transmitted signal and received signal is not linear.

4.2 Transmission channels

Transmission impairments

Noise

Unwanted and unavoidable random waves added to signal by the channel or the receiver

Sources of noise
Thermal noise
Noise from semiconductor
Noise from lighting and the sun, etc.

- **Common type of noise considered: Additive white Gaussian noise (AWGN)**

Gaussian distribution
Uniform power spectral density
Additive to signals

- **Noise limits the performance of communication systems**

Cause errors in digital signals
Degrade the quality of analog signals

4.2 Transmission channels

Transmission impairments

Interference

Random man-made signals that appear at the receiver from other sources.

Caused by other communication systems or electrical devices.

- **Alters, modifies or disrupts a signal as it travels along a channel.**
- **Wireless communication systems are particularly vulnerable to interference because of the wide difference in the transmitted and received signal levels.**

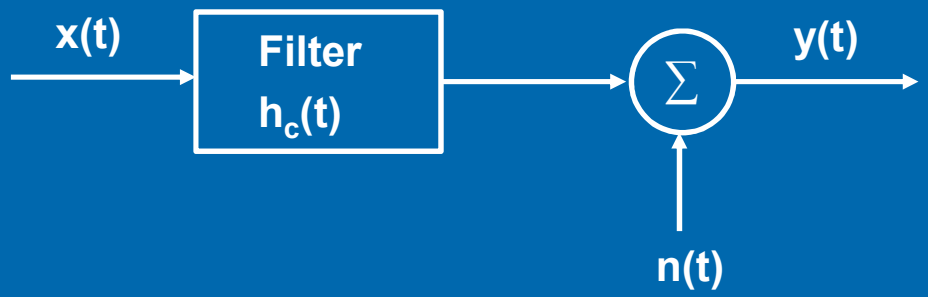
4.2 Transmission channels

Channel models

- System model incorporated the most important characteristics of channel.

Filters with additive noise, n(t)

Model parameters:
- deterministic or random
- time-invariant or variant
- linear or nonlinear



Only linear AWGN channel is considered in this module.

4.3 Baseband and passband signal transmission

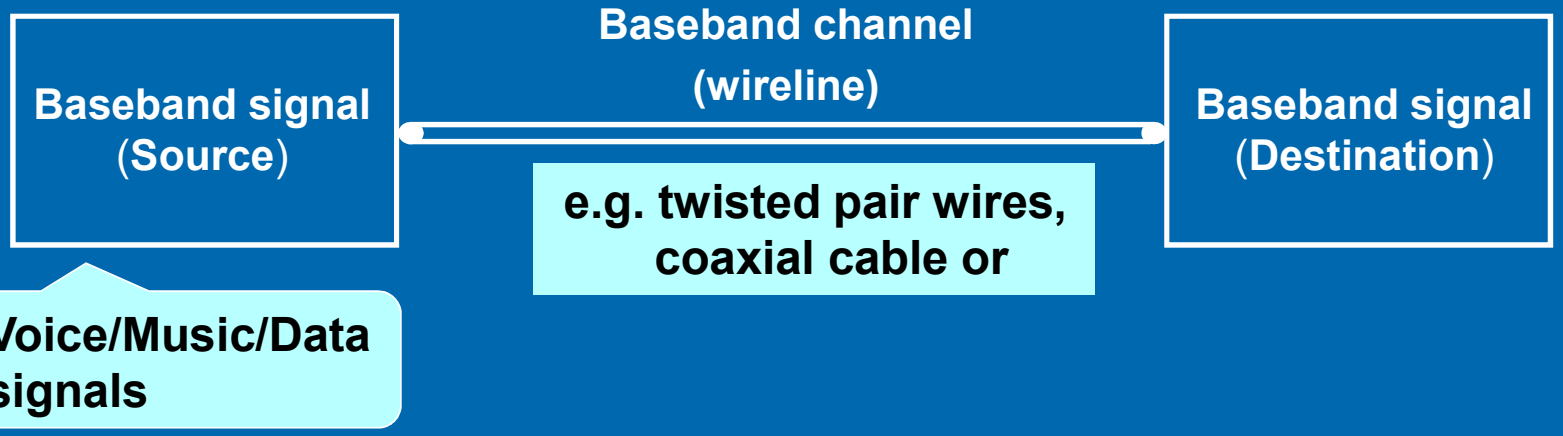
Baseband signal transmission

Transmitting baseband signals directly over transmission channels.

Baseband signals
Natural speech (0.1-5 kHz)
Video signal (0-5 MHz)
etc.

- **Preferred for low frequency and short distance dedicated communication, usually over wiredline**

Baseband signal is sent as it is without modulation

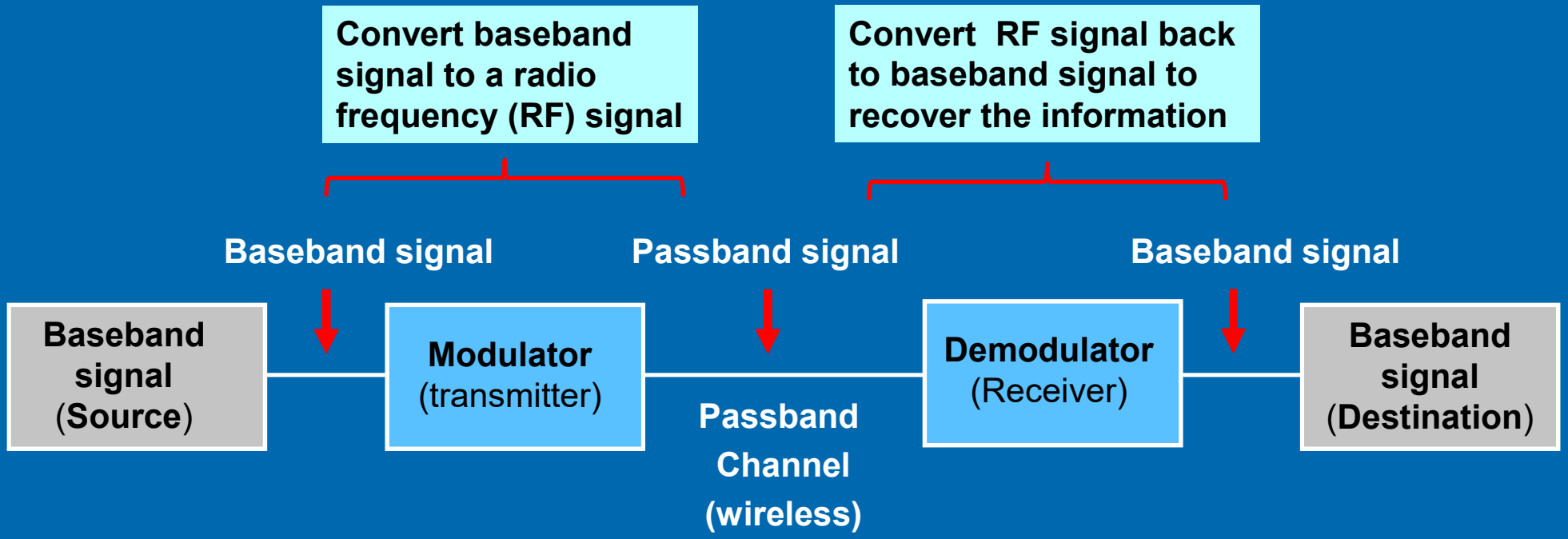


4.3 Baseband and passband signal transmission

Passband signal transmission

Impressing a baseband signal upon a radio frequency sinusoidal signal through modulation for transmission

- **Suitable for wireless, long- distance communications or shared channel.**



End

CHAPTER 4

(Part 1 of 2)