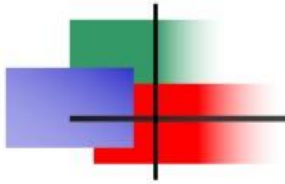
数字通信
Digital Communications
(620101)

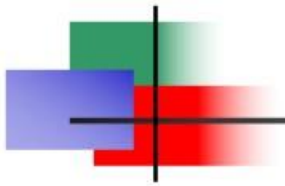
李晓峰 教授
Prof. Xiaofeng Li
信息与通信工程学院
School of Info & Comm Engineering



Chapter 1

Introduction

—— by Prof. XIAOFENG LI
SICE, UESTC



Examples of communication Sys

Diagram and elements of Comm. Sys

Digital Comm. Sys.

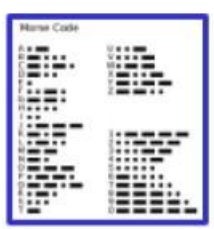
Channels and their characteristics

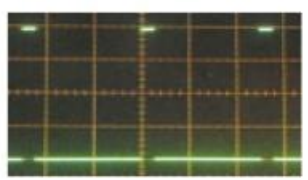
Examples of communication

Mobile phone= **Telephone**+**SMS**+
Radio+TV+Internet+...

- **SMS** (**QQ**，**WeChat**)= Short Message Sys
  =Telegraphy
- **Telegraphy**: oldest communication sys

- **Morse code** (1837) uses DASH and DOT (**0**/**1**), representing long and short pulses respectively, to code a letter in a text.





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Radio+TV+Internet+...

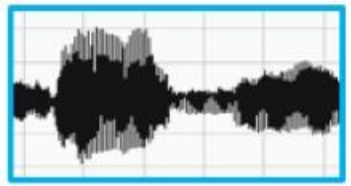
- **SMS** (**QQ**，**WeChat**)= Short Message Sys
  =Telegraphy
- **Telegraphy**: oldest communication sys

The idea of using 0 and 1 (**binary digits ,** bits) to code information symbols and then transmit the **sequence of bits** is the standard way of modern communication systems.

Examples of communication

Mobile phone= **Telephone**+**SMS**+
Radio+TV+Internet+...

- **Telephony** (1870s): the most important analog communication system
- Alexander Graham Bell
- Carbon microphone, speaker, triode amplifier, automatic switching, networks, PCM and digital techniques, fiber optical cables are important advances in its development.



Examples of communication

Mobile phone= **Telephone**+**SMS**+
Radio+TV+Internet+...

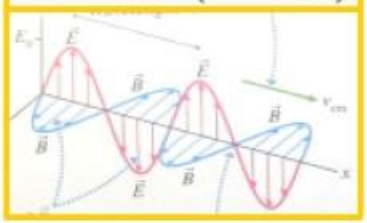
- **Wireless communications**
- The theory of electromagnetic waves (radiation) was formulated by James C. Maxwell in 1864.
- G. Marconi patented a wireless telegraphy system in 1897.
- Radio broadcasting were important application in old days. AM radio was initiated in Pittsburgh in 1920. Then Edwin Armstrong invented super-heterodyne receiver and demonstrated FM radio.

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

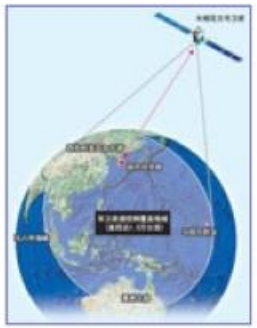
$$\nabla \times \mathbf{B} = \mu_0\left(\mathbf{J} + \varepsilon_0\frac{\partial \mathbf{E}}{\partial t}\right)$$



Examples of communication

Mobile phone= **Telephone**+**SMS**+
Radio+TV+Internet+...

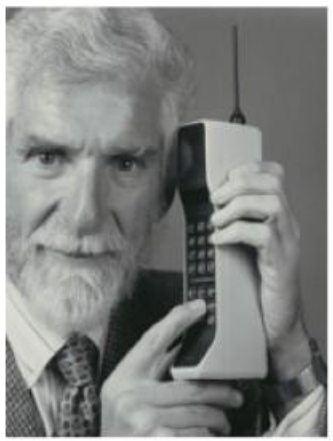
- **Wireless communications**
- The 1st communication satellite, Telstar I, relays TV signals in 1962.
- Motorola demonstrated cellular phone in 1972.
- Global positioning system (GPS) developed in 1989.



Examples of communication

Mobile phone= **Telephone**+**SMS**+
Radio+TV+Internet+…

- **Evolution of global mobile communication**



1G: Analog phone

1980

2G: Digital phone
GSM+cdmaOne

1990

3G: Mobile internet
WCDMA/TD-SCDMA
/CDMA2000

2000

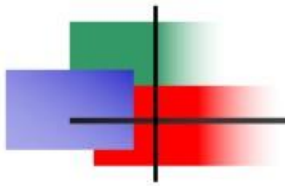
4G: Broadband
LTE-Adv/WiMAX

2010

?

5G: ?
"New radio"

201x



Examples of communication

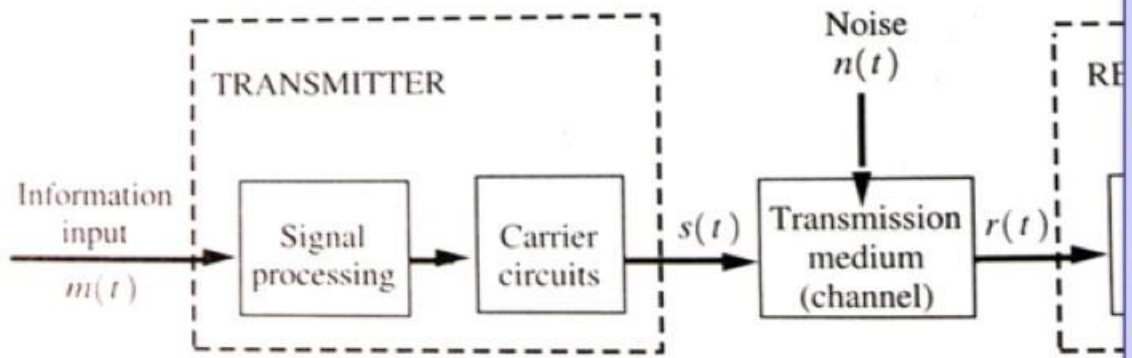
Diagram and elements of Comm. Sys

Digital Comm. Sys.

Channels and their characteristics

Elements of Comm. Sys

Communication systems are electronic systems designed to transmit information



In general, the infor/msg is said to be generated by a information/msg **source.**

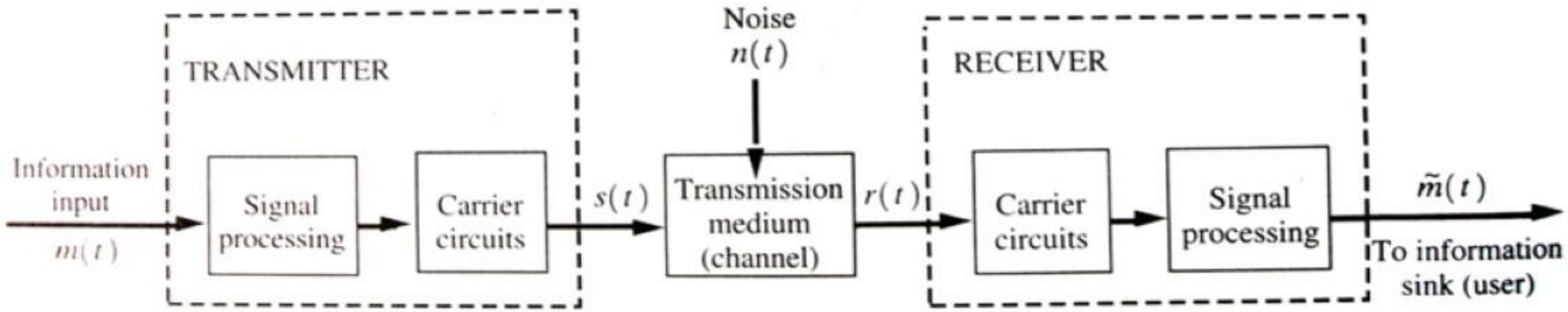
Info must be something unknown and mathematically described by **random** signals, also called random **processes**.

- The information or massage may be voic
  text, or a file.
1. **Voice**: in telephony, a microphone is us
2. **Text**: in mobile SMS, a keypad system i
3. **Video**: in network, a video-camera is ...

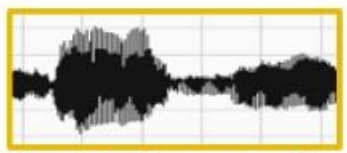
- **Information/message signal**: to represent the information or message.
- **Transmission signal**: to go through the channel

Elements of Comm. Sys

Communication systems are electronic systems designed to transmit information



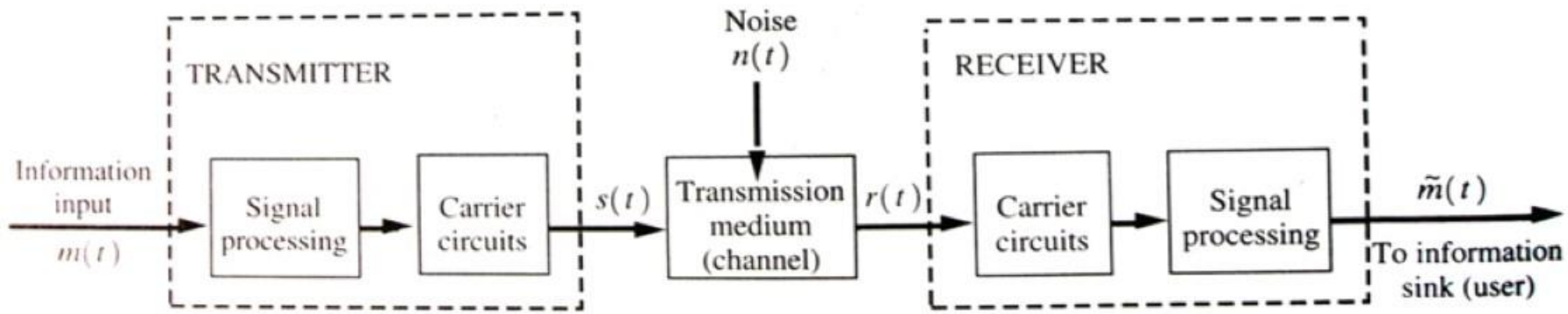
- **A waveform** is basically a time-continuous signal, called **analog signal**.



- **A seq of data** is basically a time-discrete signal with finite values, called **digital signal**.

Elements of Comm. Sys

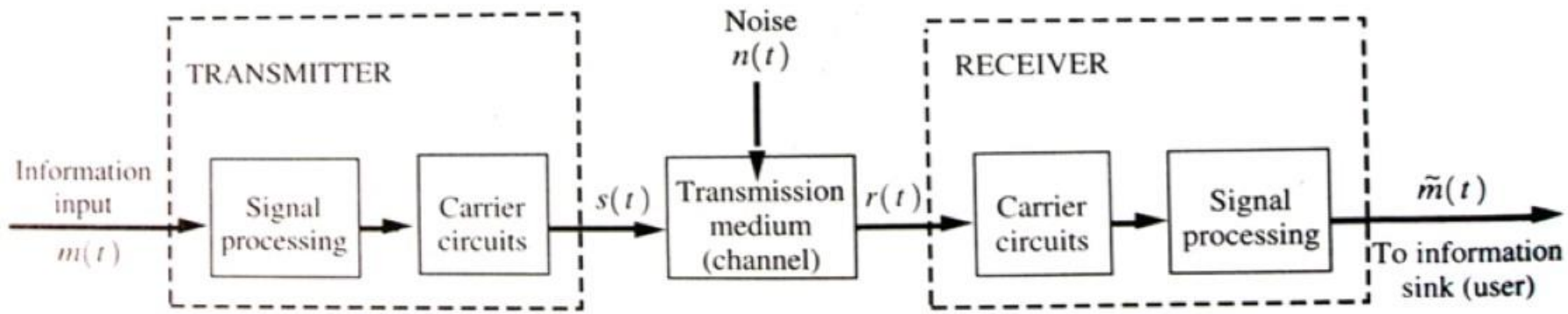
Communication systems are electronic systems designed to transmit information



- **Channel:** the physical media to transmit
- Say, wire-lines, cables, open space and optical fiber cables
- Channel is often non-ideal, introducing **distortion** and **noise**.

Elements of Comm. Sys

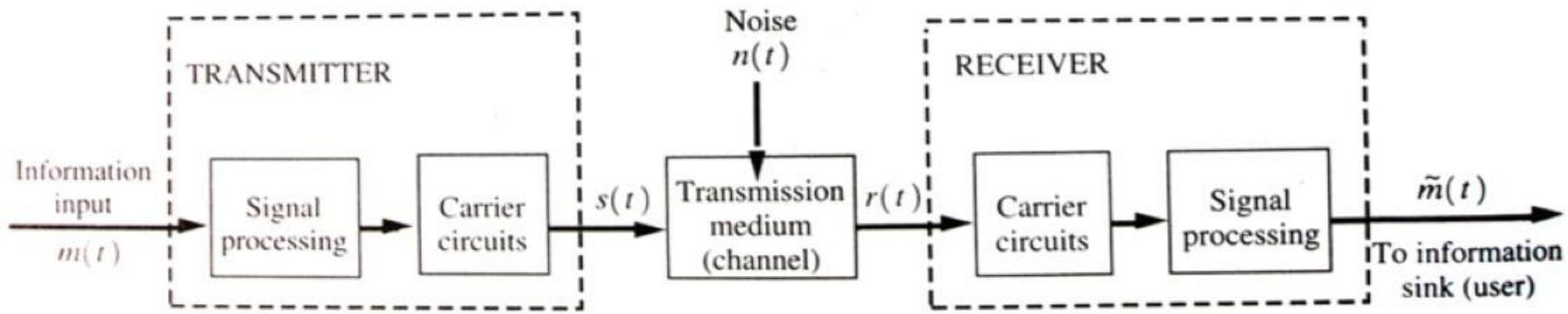
Communication systems are electronic systems designed to transmit information



- **Transmitter:** A device that converts the infor into a signal that matches the channel.
- Eg. To send an AM radio signal, you have to move the voice into the band at some freq, say 1000kHz.

Elements of Comm. Sys

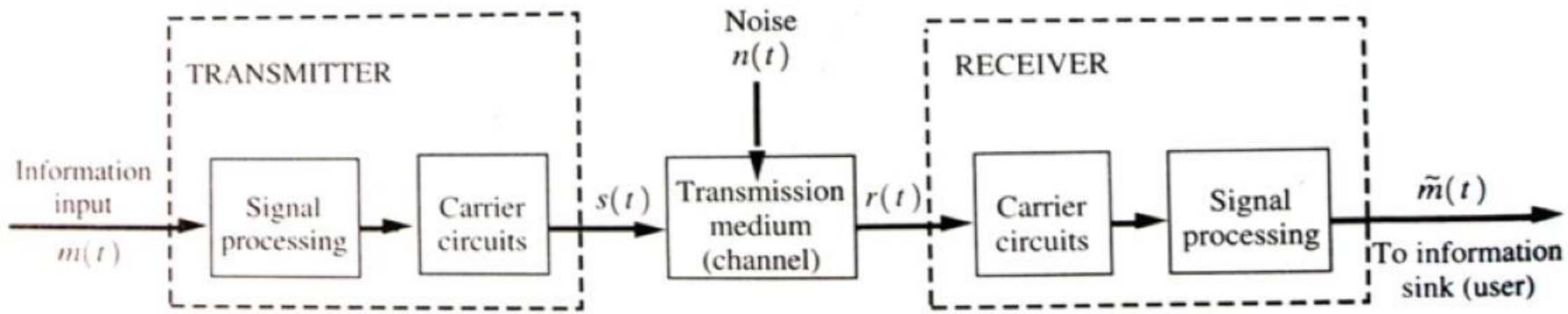
Communication systems are electronic systems designed to transmit information



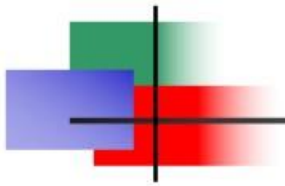
- A basic process of many transmitters is to convert a baseband signal into a bandpass form, call **modulation**. Say, AM, FM and PM using sinusoid waves, called **carriers**, of some freqs, often denoted by fc's.

Elements of Comm. Sys

Communication systems are electronic systems designed to transmit information



- **Receiver:** picks up signals in the channel and recovers information; then delivers it to user.
- The process of extracting information from the modulated signal is called **demodulation**.
- **signal-correction and noise-suppression** are important work in the receiver.



Examples of communication

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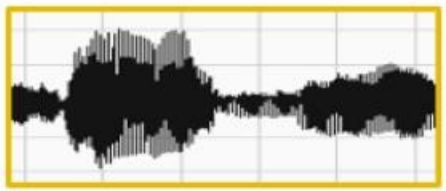
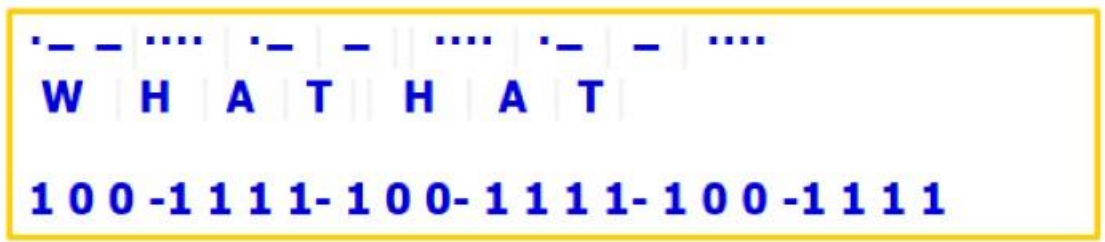
Digital Comm. Sys.

- A **analog** communication system transfers analog msg signals.
- For analog info, we measure the **difference** of the restored signal and the src signal, or the **SNR** (ratio of the signal pwr to the pwr of the difference).



- A **digital** communication system transfers digital msg signals.
- The performance is often evaluated in term of rate of error in bits (**BER**), equivalent to the probability of the bit error, **Pb.**



Digital Comm. Sys.

- A **analog** communication system transfers analog msg signals.
- A **digital** communication system transfers digital msg signals.

- **Advantages** of digital comm.

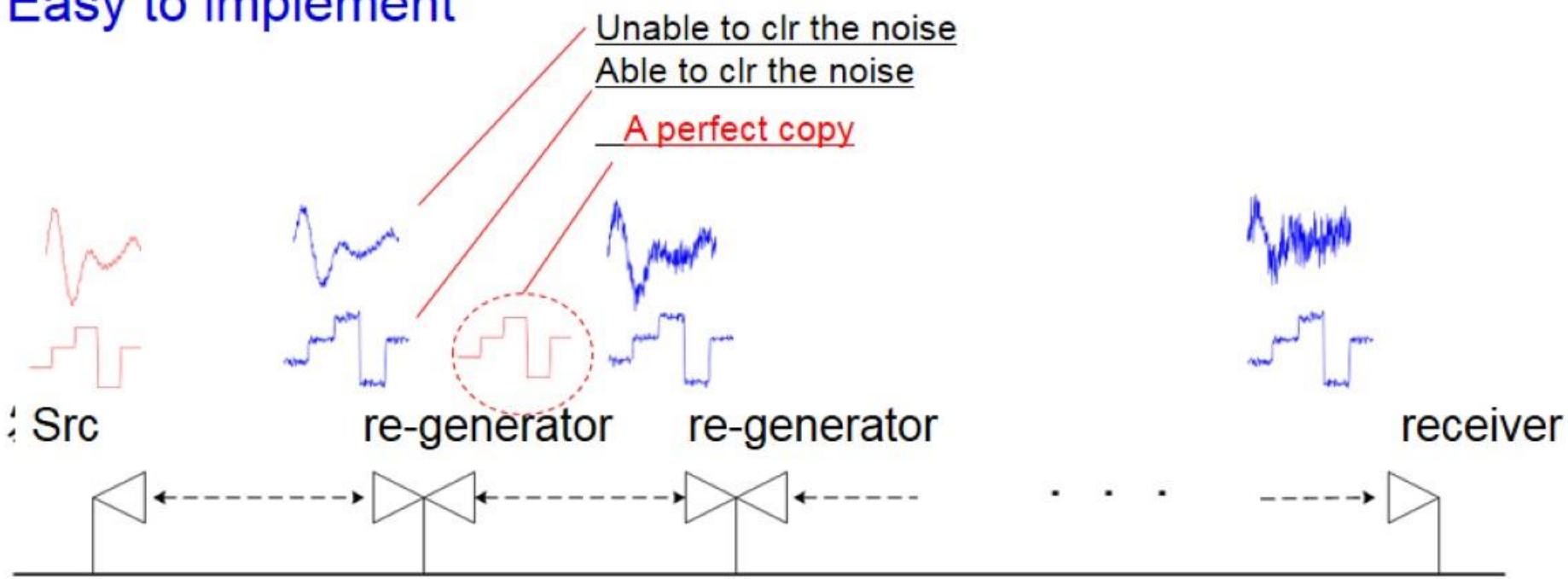
1. In long-distance transmission, we may **regenerate** the signal to clear the noise periodically
2. It is very easy to **compress** the digital msg signal.
3. It works well for **different msg** and support **networking**.
4. Digital system are **cheap and easy** to implement with the development of VLSI and DSP

- So, **analog msgs are often converted** to digital form, then transferred by a digital sys.

Digital Comm. Sys.

3 inherent advantages:

- ✓ Noise immunity
- ✓ Unified format
- ✓ Easy to implement



Digital Comm. Sys.

3 inherent advantages:

- ✓ Noise immunity
- ✓ Unified in format
  (all are in bits or bytes)
- ✓ Easy to implement

Like standard-containers, text, voice, video, data,... all can be packed in one, so that be handled and dispatched simply
--- multimedia, packet switching, internet, all becomes possible

Digital Comm. Sys.

3 inherent advantages:

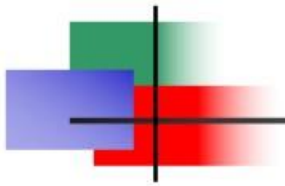
- ✓ Noise immunity
- ✓ Unified format
- ✓ Easy to implement

Simply, handling integers are much more easer than handling real numbers.
So, digital circuits and algorithms are prevalent.

Digital Comm. Sys.

- **Transmitter** = src encoder, channel encoder and digital mod.
- **Receiver** is expanded accordingly.

1. **Source encoder:** represent the info in an efficient way, called **compression**. **ADC** for analog info.
2. **Channel encoder**: introduce some rule such that the receiver can detect or even correct errors
3. **Digital modulator**: converts the information into signals suitable for channel.
   - ✓ **Binary** modulation maps a bit 1 or 0 into s1(t) or s0(t) respectively.
   - ✓ **M-ary** modulation sends k bits at a time ($M=2^k$) using M waveforms.



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Channels and their characteristics

Physical channel includes:

1. a pair of wires carrying electrical waveforms
2. an optical fiber passing light beam
3. free space for microwave propagation
4. water for acoustic signals
5. storage media, like magnetic tape, optical disk.



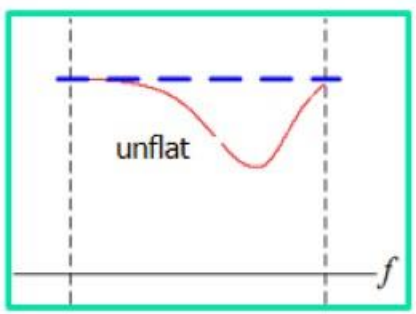




Channels and their characteristics

Channel effects are:

1. Signal **attenuation** is due to loss in the media
2. **Additive noise** is essential for electronic systems. Electronic components such as resistors introduce noise, which often called thermal noise.
3. **Bandwidth** reflects how fast the media can follow the change of signals
4. **Interference** may be generated by nature and other systems, like thunders, signals of other users, spikes due to nearby car ignitions, etc.
5. **Distortion** of signal in amplitude or phase



Channels and their characteristics

Channel effects are:

1. Signal **attenuation**
2. **Additive noise**
3. **Bandwidth**
4. **Interference**
5. **Distortion**

Two fundamental limits for communication:

- **SNR**---Increasing **power** of transmitting signal may less the effect of noise and interference.
- Channel of large **bandwidth** supports transmission of much information.

Models for channels

- For the convenience of design and study of sys, we often use models instead of real physical channels.

- The most simple and useful model for a channel is the **additive noise channel**.

$$r(t) = a \times s(t)+n(t)$$

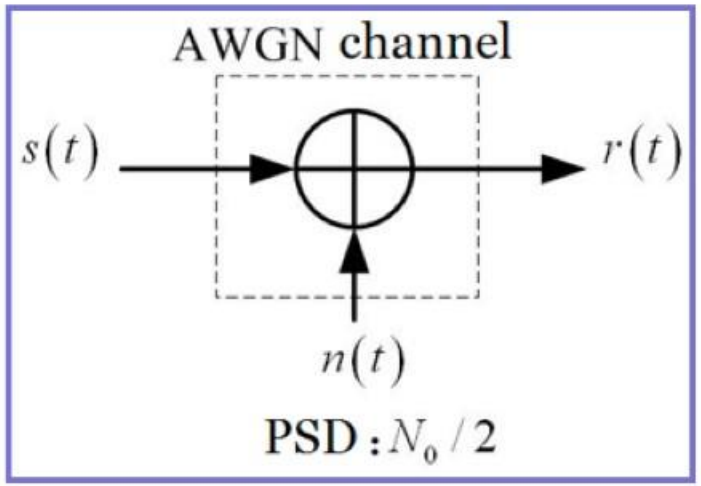
where a is the attenuation factor and n(t) is the noise.

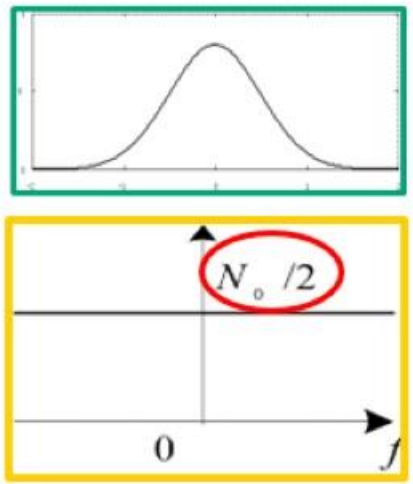
For convenience, we often normalize the expression as,

$$r(t)=s(t)+n(t)$$

where r(t) and n(t) represent the equivalent received signal and noise.

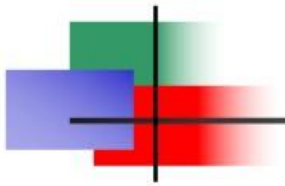
Models for channels---AWGN channel





The noise may be characterized stochastically by a white Gaussian process with zero mean.

1. Gaussian = arbitrary RVs in the process have a joint Gaussian distribution.
2. white = PSD is flat, denoted by N0/2
3. RVs are fully independent.



End of this chapter

Thank you