Universiti Malaysia PAHANG
Engineering • Technology • Creativity

Principles of Communication Systems

Chapter 4 (Part 1): Introduction to Digital Modulation

by
Nurulfadzilah Hasan
Faculty of Electrical & Electronics Engineering
nurulfadzilah@ump.edu.my

Learning Outcomes

Å By the end of this topics you should be able to:

- ï Explain basic operation digital modulation
- ï Explain the concept of analog to digital conversion
- ï Explain the different types of pulse modulation

Why go Digital?

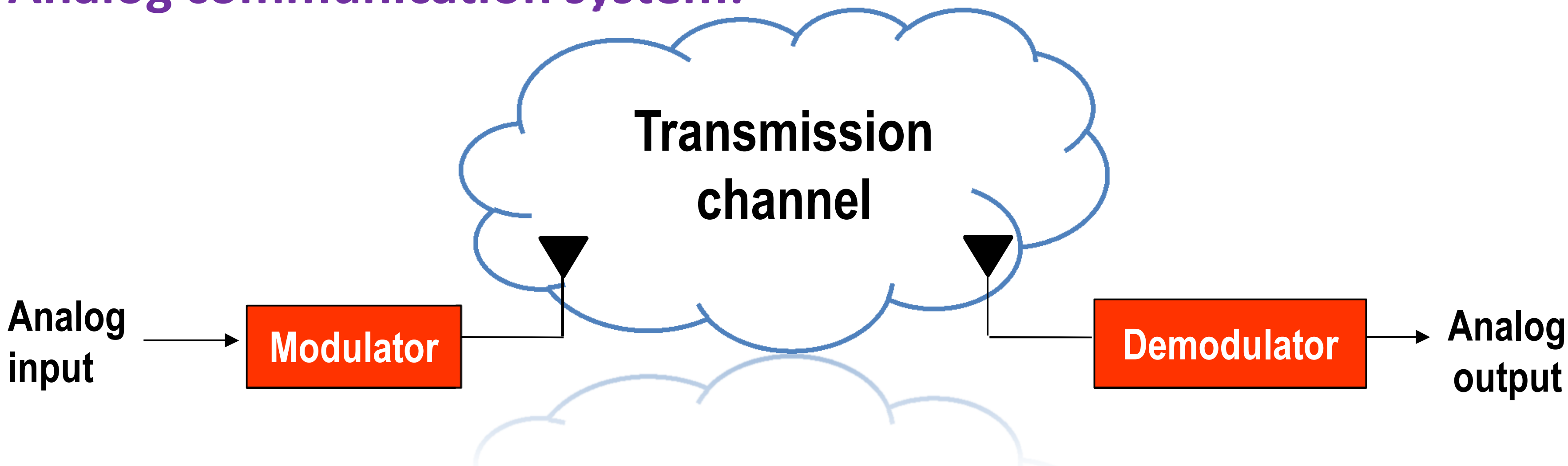
Å Demand for communications services increases, but RF spectrum is limited.

ï Need more efficient way to convey data through RF.

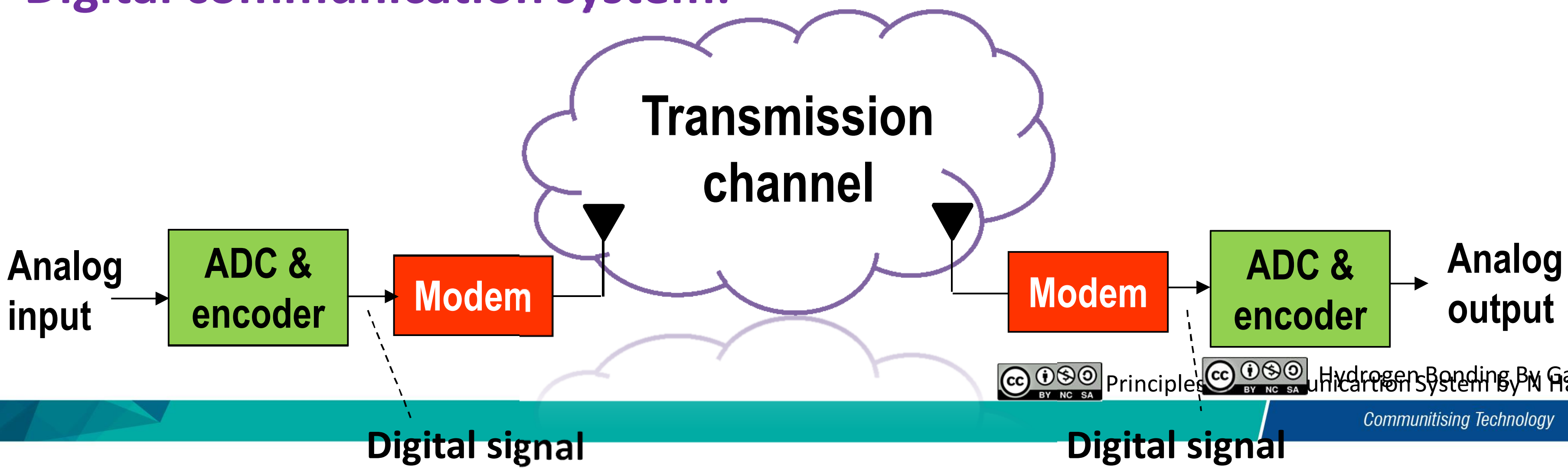
Å Digital modulation schemes have greater capacity to convey large amounts of information than analog modulation schemes

Comparison with analog system:

Analog communication system:



Digital communication system:



Digital Modulation, **Advantages**

Å Immunity to noise (due to its finite process)

Å Easy storage and processing:

Å Regeneration

Å Easy to measure

Å Enables encryption

Å Data from several sources can be integrated and transmitted using the same digital communication system

Å Error correction detection can be utilized

Digital Modulation, **Disadvantages :**

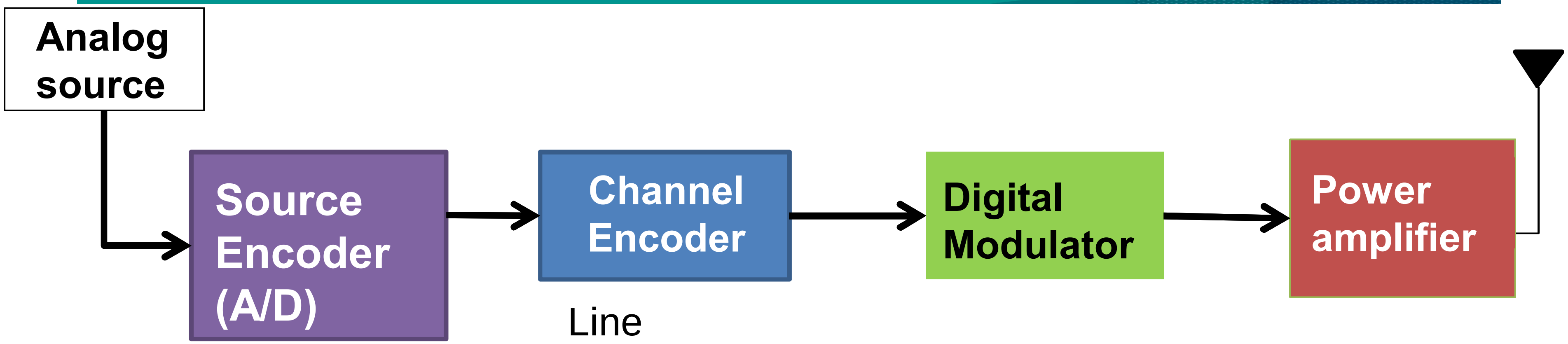
Å Requires a bigger bandwidth

Å Analog signal need to be changed to digital first

Å Not compatible to analog system

Å Need synchronization

Closer look at digital transmission system



Source Encoder (A/D)	Channel Encoder	Digital Modulator
1. Pulse modulation:	Line Coding	1. ASK
Å PWM	1. RZ	2. FSK
Å PPM	2. NRZ	3. PSK
Å PAM	3. AMI	4. QAM
2. Pulse code Modulation	4. etc	
3. Delta modulation		

Analog to Digital Conversion

The first step to digital communication is to convert information from continuous analog into digital form.

The continuous signals are changed into a series of binary numbers

At the receiver, digital data must usually be reconverted to analog form before used by the user.

Analog to Digital Conversion

Å Translating an analog signal into a digital signal is done by a device known as analog-to-digital converter or ADC.

Å Digital-to-analog (D/A) converter or DAC or a decoder performs the opposite operation of converting digital signal to analog signal.

ADC Specifications

Å **Resolution** : the smallest input voltage recognized by the converter.

Å **Dynamic range:** a measure of the range of input voltages that can be converted.

Å **signal-to-noise *(S/N)* ratio (SNR):** The ratio of the input signal voltage to the total noise in the system.

ADC Specifications: M-ary Encoding

- Bi-nary represent digit that has 2 level/ condition/ combination.
  - E.g: 2-bits (1 and 0)
- M-ary represents a digit that has M level/ condition/ combination.

$$N = \log_2 M$$

$$2^N = M$$

N = number of bits necessary

M = number of conditions, levels, or combinations possible with N bits

For binary M = 2 $\rightarrow$ N = 1

Exercise:

- Find the number of bits, N if
- (a) M= 2
- (b) M = 4

- Find the number of conditions, M for 3 bits system.

ADC Specifications: Baud / Symbol Rate

Å Baud is a measure of the rate of change of a signal on the transmission medium after encoding and modulation have occurred

Å A way of measuring the quality of the signal at the transmitter, just before it is transmitted.

Å Also known as symbols per seconds

$$\text{baud} = f_s = \frac{1}{t_s}$$

- f_s = symbol rate (baud per second)
- t_s = time interval of one signaling element (second)

- symbol = one signaling element

ADC Specifications: Bitrate ï channel capacity

Bit is number of symbol change/processes at the input to the Modulator (bits per second, bps).

$$f_b = f_s N = 2BN = 2B \log_2 M$$

f_b = bitrate: bit per second (bps)
f_s = baud (symbols per second)
B = minimum Nyquist bandwidth (hertz)
M = number of discrete signals or voltage levels
N = number of bits encoded into each symbol

Minimum Bandwidth (Nyquist bandwidth)

- The minimum Nyquist bandwidth is minimum theoretical bandwidth necessary to propagate signal. For binary system:

$$f_b = 2B$$

f_b is bit rate (bps)

B is ideal Nyquist bandwidth

- For N bits system, it's possible to propagate a bit at a rate grater than 2B

Bandwidth

Å For M-ary system, we know that

$$f_b = f_s N = 2BN = 2B\log_2 M$$

Å Thus, bandwidth:

$$B = \left(\frac{f_b}{2\log_2 M} \right) = \frac{f_b}{2N}$$

ADC Specifications: **Information capacity**

- Represents the number of independent symbols that can be carried through the system in a given unit of time.

- By using Shannon limit for information capacity, the relationship between Information capacity to the signal bandwidth and SNR is defined below:

$$I = B\log_2\left(1+\frac{S}{N}\right) = 3.32B\log_{10}\left(1+\frac{S}{N}\right)$$

I = information capacity (bit/second)

B = system bandwidth (Hertz)

S/N =signal-to-noise power ratio (dimensionless)

EXAMPLE 1 :

A standard voice-band communication channels have a SNR power of 1000 (30 dB) and signal Bandwidth of 2.7 kHz. Determine the information capacity.

Solution :

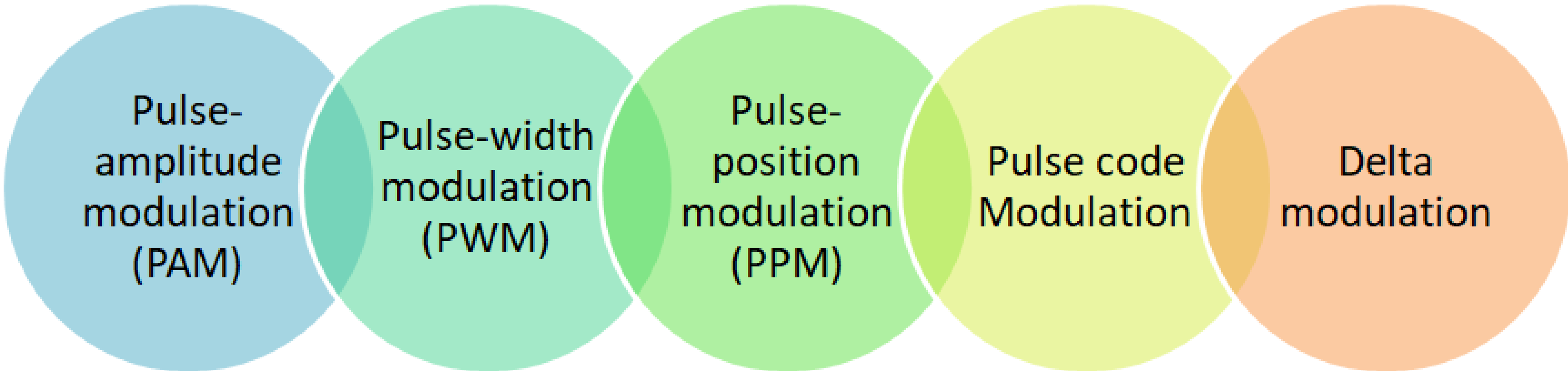
By using Shannon's Limit, information capacity is defined as:

$$I = (2.7\ \text{kHz})(3.32)\log10\ (1 + 1000) = \mathbf{26.9\ \ kbps}$$

A/D Conversion: Steps

1. A/D conversion starts with a process of **sampling** or measuring the analog signal at regular time intervals.
2. The samples are then rounded off to a discrete voltage values, closest to it. This process is known as quantization
   - ÅErrors associated with this process are known as quantizing errors.
3. Then the quantized voltage are coded into predetermined binary numbers

Analog to Digital Conversion Methods



PAM (Pulse Amplitude Modulation)

It's used to describe the conversion of analog signal to pulse-type signal in which the amplitude of the pulse denotes the analog information.

It's a series of pulses in which the amplitude of each pulse represents the amplitude of the information signal at a given time.

Pulse Modulation

PWM (Pulse Width Modulation)

- It is a pulse duration modulation (PDM) or pulse length modulation. The width of pulse is varied proportional to the Amplitude of the analog signal at the time signal is sampled.

PPM (Pulse Position Modulation)

- It is a series of pulses in which the timing of each pulse represents the amplitude of the information signal at a given time.

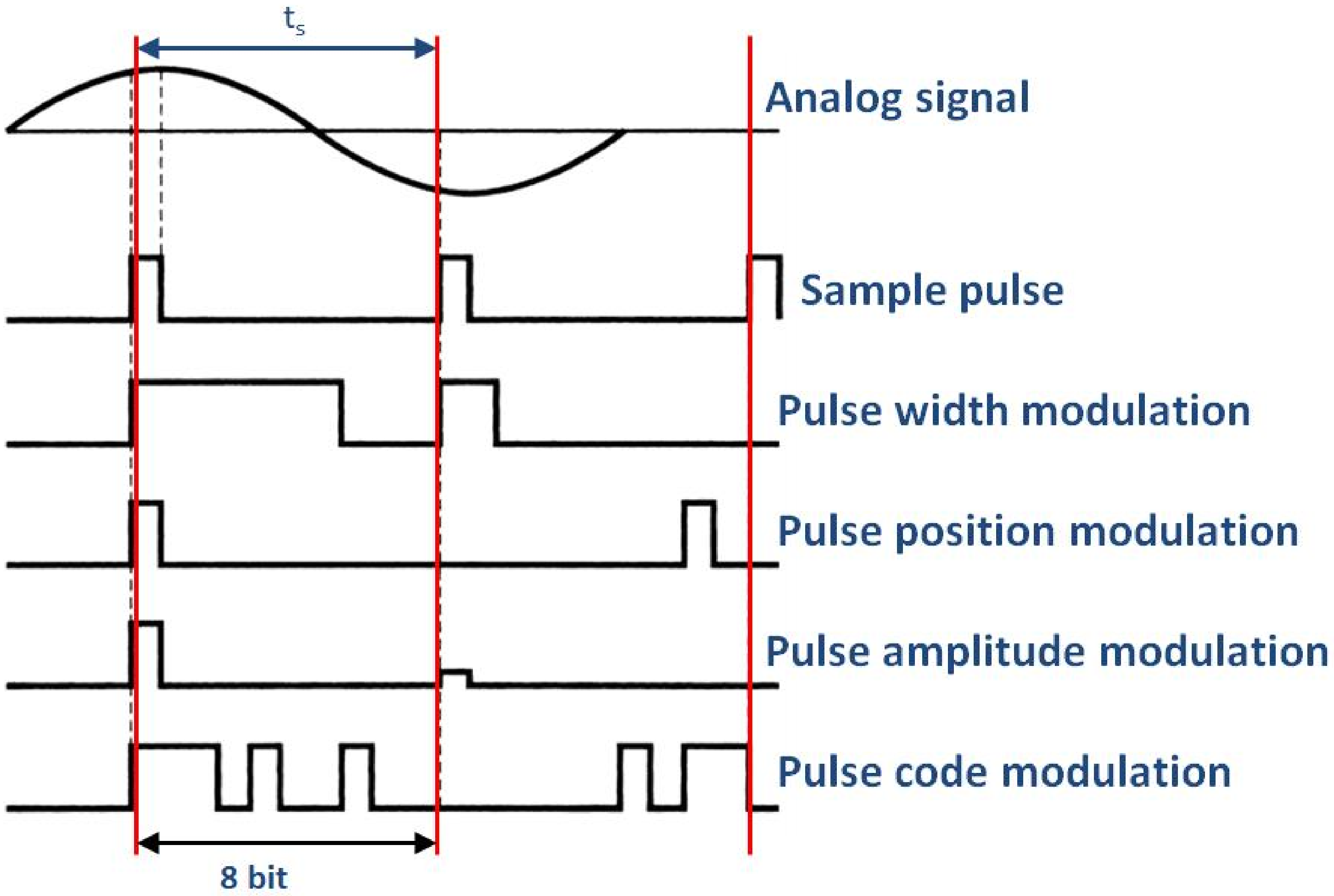
PCM (Pulse Code Modulation)

It is a series of pulse in which the amplitude of the information signal at a given time is coded as a binary number. The pulses are of fixed length and fixed amplitude. Refer to Figure 10-1 in the textbook for PWM, PPM, PAM & PCM.

PCM is generated by 3 processes; Sampling, Quantization & Encoding.

An Integrated circuit that perform PCM encoding and decoding function is called CODER OR DECODER.

Pulse Modulation



Comparing Pulse-Modulation Methods

- The PAM signal is a series of constant-width pulses whose amplitudes vary in accordance with the analog signal.
- The PWM signal is binary in amplitude (has only two levels). The information signal varies the width or time duration of the pulse.
- In PPM, the pulses change position according to the amplitude of the analog signal.
- Of the four types of pulse modulation, PAM is the simplest and least expensive to implement.

Collaborative authors:

Nurulfadzilah Binti Hasan
Noor Zirwatul Ahlam Binti Naharuddin
Norhadzfizah Binti Mohd Radi
Mohd Hisyam Bin Mohd Ariff

Faculty of Electrical & Electronics Engineering, UMP