

Tutorial 6 Digital Modulation

Problem 1 (Binary PAM)

A baseband analog signal with **bandwidth 3kHz** is sampled with **Nyquist sampling rate** and applied to a **4-bit quantizer**. The bit stream is then sent out using **binary PAM**.

- 1) Determine the minimum channel bandwidth required for **90% in-band power**;
- 2) Determine the amplitudes of the pulses if the **transmission power** is 16W.

Problem 2 (M-ary PAM)

Suppose a **4-ary PAM** system is adopted to transmit the bit stream. The bit rate and the transmission power are the same as that given in Problem 1.

- 1) Determine the minimum channel bandwidth required for **90% in-band power**;
- 2) Determine the amplitudes of the pulses.
- 3) What is the minimum amplitude difference between those pulses?

Problem 3 (PCM)

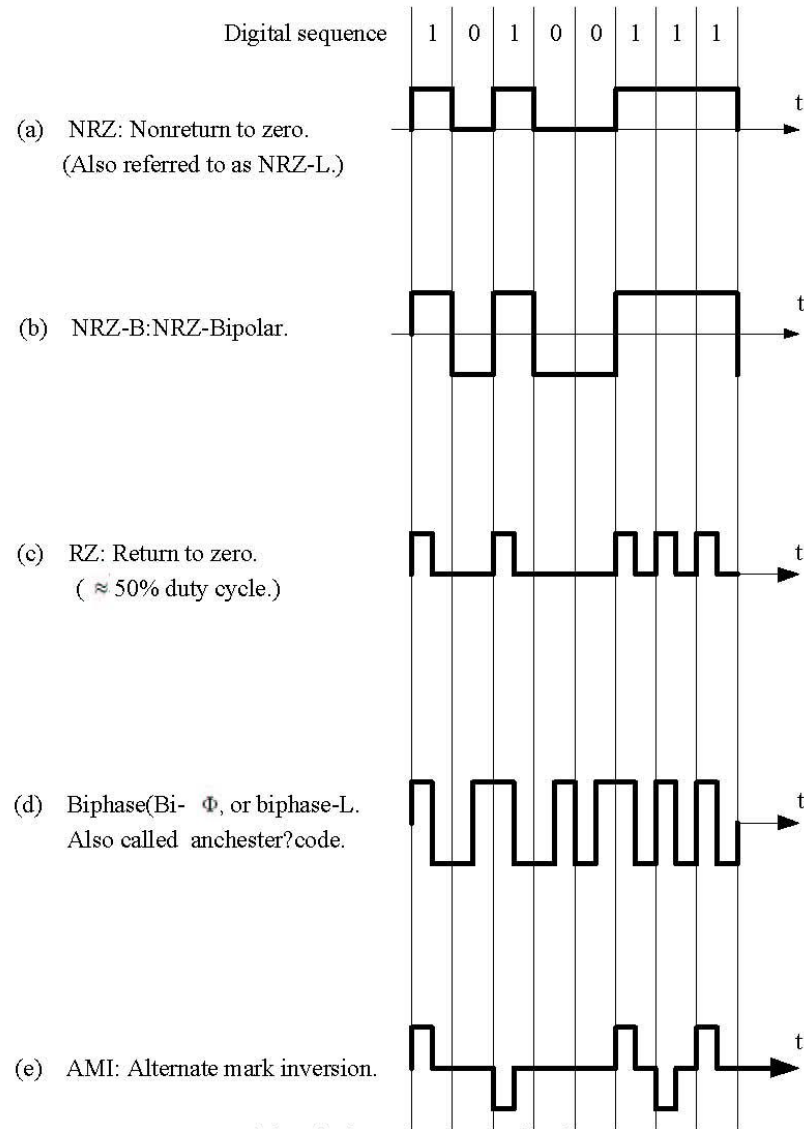
Pulse-code modulation (PCM) is referred to a three-step process, as the following figure illustrates.



Now consider an analog signal with bandwidth **5 kHz** transmitted using a PCM system. Suppose that it is sampled at the **Nyquist rate**, quantized via a **5-bit μ -law** quantizer, and encoded by the NRZ waveform (which is shown in the figure on next page). Determine the minimum channel bandwidth required for **90% in-band power**.

PCM Encoder

To represent the binary data
in the form of digital wave



Problem 4 (PCM)

A TDM system is used to multiplex several PCM signals over a single communication channel. It is found that **a minimum interval of $1\mu\text{s}$ must be allowed for reliable identification of bits** at the receiving end. Suppose that each input analog signal has the bandwidth of **3kHz**, sampled at **the Nyquist sample rate**, and **the number of quantization levels is 16**. How many PCM signals can be multiplexed?

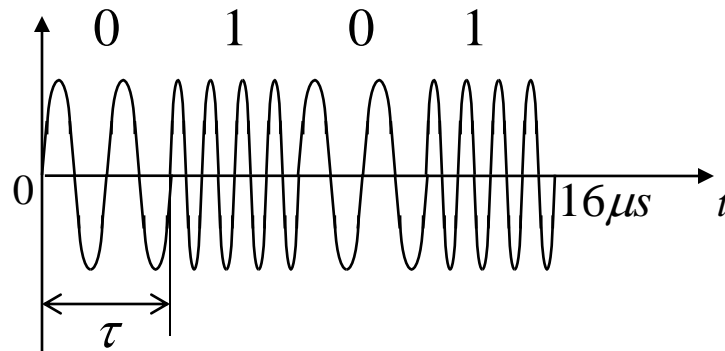
Problem 5 (Bandpass Modulation)

Digital data is to be transmitted over a bandpass channel with bandwidth **1MHz**. Determine the maximum bit rate that can be supported by the channel with 90% in-band power if the data is modulated using the following techniques:

- 1) BASK
- 2) BFSK (suppose that **the frequency offset is set to be half of the bit rate**)
- 3) BPSK

Problem 6 (BFSK)

A binary sequence $\{0101\}$ is applied to a **BFSK** system producing the waveforms shown below.



- 1) Determine the bit interval τ and the carrier frequencies for bit “1” and “0”, respectively.
- 2) Determine the required channel bandwidth with 90% in-band power.

Problem 7 (QPSK)

Design a QPSK modulator to map the information symbols into the carrier phase θ according to the following rule:

Information Symbol	(1 1)	(0 1)	(0 0)	(1 0)
Phase θ	$\pi/4$	$3\pi/4$	$5\pi/4$	$7\pi/4$