Al-Mustaqbal University
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Digital Communication

Lecture 5

Examples for PAM, PDM & PPM and Time Division Multiplexing (TDM)

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Aims of this Lecture

By the end of this lecture, students will **be able** to:

- **Calculate** the required Bandwidth for PAM, PDM & PPM.
- **Understand** Time Division Multiplexing (TDM).
- **Identify** the Challenges of TDM.

Example 1

The voice signal with maximum frequency of 3kHz, is to be transmitted using sampling frequency fs = 8kHz, and pulse duration r = 0.1 Ts, determine the required PAM, PWM and PPM if the rise time tr = 1% of pulse duration. The pulse **width** changes based on the amplitude of the input signal x (t), while the **leading edge** is fixed.

Given Data

1. Maximum frequency of the voice signal:

$$f_{\max} = 3\,\text{kHz}$$

2. Sampling frequency:

$$f_s = 8\,\text{kHz}$$

Sampling period:

$$T_s = \frac{1}{f_s} = \frac{1}{8 \times 10^3} = 0.125\,\text{ms}$$

3. Pulse duration:

$$r = 0.1T_s = 0.1 \times 0.125 = 0.0125\,\text{ms}$$

4. Rise time:

$$t_r = 1\%\,\text{of pulse duration} = 0.01 \times r = 0.01 \times 0.0125 = 0.000125\,\text{ms} = 125\,\text{ns}$$

Step 1: PAM Bandwidth Calculation

For **PAM**, the bandwidth B_{PAM} is inversely proportional to the pulse duration:

$$B_{\text{PAM}} \geq \frac{1}{2r}$$

Substitute $r = 0.0125\,\text{ms} = 0.0125 \times 10^{-3}\,\text{s}$:

$$B_{\text{PAM}} \geq \frac{1}{2 \times 0.0125 \times 10^{-3}} = \frac{1}{0.025 \times 10^{-3}} = 40\,\text{kHz}$$

Conversion to MHz: 1 kHz = $10^{-3}\,\text{MHz}$:

$$40\,\text{kHz} = 40 \times 10^{-3} = 0.04\,\text{MHz}$$

Result:

$$B_{\text{PAM}} = 40\,\text{kHz or } 0.04\,\text{MHz}$$

Step 2: PWM Bandwidth Calculation

For **PWM**, the bandwidth depends on the rise time (t_r):

$$B_{\text{PWM}} \geq \frac{1}{2t_r}$$

Substitute $t_r = 125\,\text{ns} = 125 \times 10^{-9}\,\text{s}$:

$$B_{\text{PWM}} \geq \frac{1}{2 \times 125 \times 10^{-9}} = \frac{1}{250 \times 10^{-9}} = 4\,\text{MHz}$$

Result:

$$B_{\text{PWM}} = 4\,\text{MHz}$$

Step 3: PPM Bandwidth Calculation

For **PPM**, the bandwidth also depends on the rise time (t_r) and is calculated the same way as PWM:

$$B_{\text{PPM}} \geq \frac{1}{2t_r}$$

Using $t_r = 125\,\text{ns}$:

$$B_{\text{PPM}} = 4\,\text{MHz}$$

Result:

$$B_{\text{PPM}} = 4\,\text{MHz}$$

What is TDM?

- **Definition**:
  Time Division Multiplexing (TDM) is a technique where multiple signals are transmitted over the same communication channel by allocating separate time slots for each signal.
- **Key Idea**:
  The time between pulses is utilized efficiently to allow pulses from multiple channels to occupy the free space.

How TDM Works

- Signals from N input channels are sampled at the **Nyquist rate**.
- Each sample is assigned a specific time slot within a frame duration Ts.
- The combined signal is transmitted, with one frame containing N samples.
- Synchronization is critical between the transmitter and receiver to identify frames.

Key Formulas for TDM

1. **Signaling Rate r:**

$$r = 2NW$$

Where N is the number of channels, and W is the highest frequency component of the signal.

2. **Bandwidth Requirement B_T:**

$$B_T = NW$$

The total bandwidth is proportional to the number of channels N and the highest frequency W

.

3. **Receiver Bandwidth B_b:**

$$B_b = \frac{r}{2} = NW$$

Example

- Twenty-four voice signals are sampled uniformly and time-division multiplexed. Each voice signal has a maximum frequency of W=3.4kHz. Calculate the minimum channel bandwidth required.

Solution:

1. Number of channels, $N = 24$
2. Bandwidth for one channel, $W = 3.4\,\text{kHz}$
3. Total Bandwidth:

$$B_T = NW = 24 \times 3.4 = 81.6\,\text{kHz}$$

Answer:

The minimum channel bandwidth required is **81.6 kHz**.

Challenges of TDM

- Requires precise synchronization between transmitter and receiver.
- Overhead from synchronization pulses reduces the number of available channels.
- Vulnerable to time delay when channels increase.

Homework

Q) If the bandwidth of PAM system not exceed 4kHz is used to transmit voice signal sampled at Nyquist frequency. Calculate the bandwidth required to transmit the same signal using PPM system with rise time of 2% of pulse duration.

Thank you