Al-Mustaqbal University
College of Engineering & Technology
Computer Techniques Engineering Department

Digital Communication

Lecture 9
Bandpass Waveform Modulation

Dr. Ahmed Hasan Al-Janabi
PhD in Computer Network
Email: Ahmed.Janabi@uomus.edu.iq

Introduction to Bandpass Waveform Modulation

- **What is Bandpass Modulation?**
- 🔹 Digital signals require **high-frequency carrier waves** for long-distance transmission.
  - 🔹 Modulation allows the **signal to travel efficiently** through the medium.
  - 🔹 Instead of starting from 0 Hz, the signal is transmitted in a **bandpass frequency range**.
- ✅ **Key requirements for good modulation:**
  ✓ High data transmission rate
  ✓ Resistance to noise and interference
  ✓ Efficient bandwidth usage
  ✓ Low power consumption

Types of Digital Modulation

- **Amplitude Shift Keying (ASK):** Amplitude of carrier changes based on input data.
  - **Frequency Shift Keying (FSK):** Carrier frequency changes based on data.
  - **Phase Shift Keying (PSK):** Carrier phase changes with data.
  - **Binary Phase Shift Keying (BPSK):** Special type of PSK using two phase shifts (0° and 180°).

Binary Phase Shift Keying (BPSK)

What is BPSK?

- **BPSK** changes the **phase of a carrier wave** depending on digital data (0 or 1).
- Mathematical representation:

$$s(t) = A\cos(2\pi f_0 t)$$

- If bit = **1**, phase remains **unchanged**.
- If bit = **0**, phase shifts by **180°** (adds π to the phase).

$$s(t) = A\cos(2\pi f_0 t), \quad \text{for bit} = 1$$

$$s(t) = -A\cos(2\pi f_0 t), \quad \text{for bit} = 0$$

- Where A is the amplitude,
- f0 is the frequency of the carrier,
- t is the time.

BPSK Generation (How to Generate BPSK?)

✔ **Steps to generate a BPSK signal:**

1. The input **binary data (0s and 1s)** controls the phase of the carrier signal.
2. A **balanced modulator (Multiplier Circuit)** is used to switch phase.
3. The **BPSK waveform** is generated with two possible phase values: **0° or 180°**.

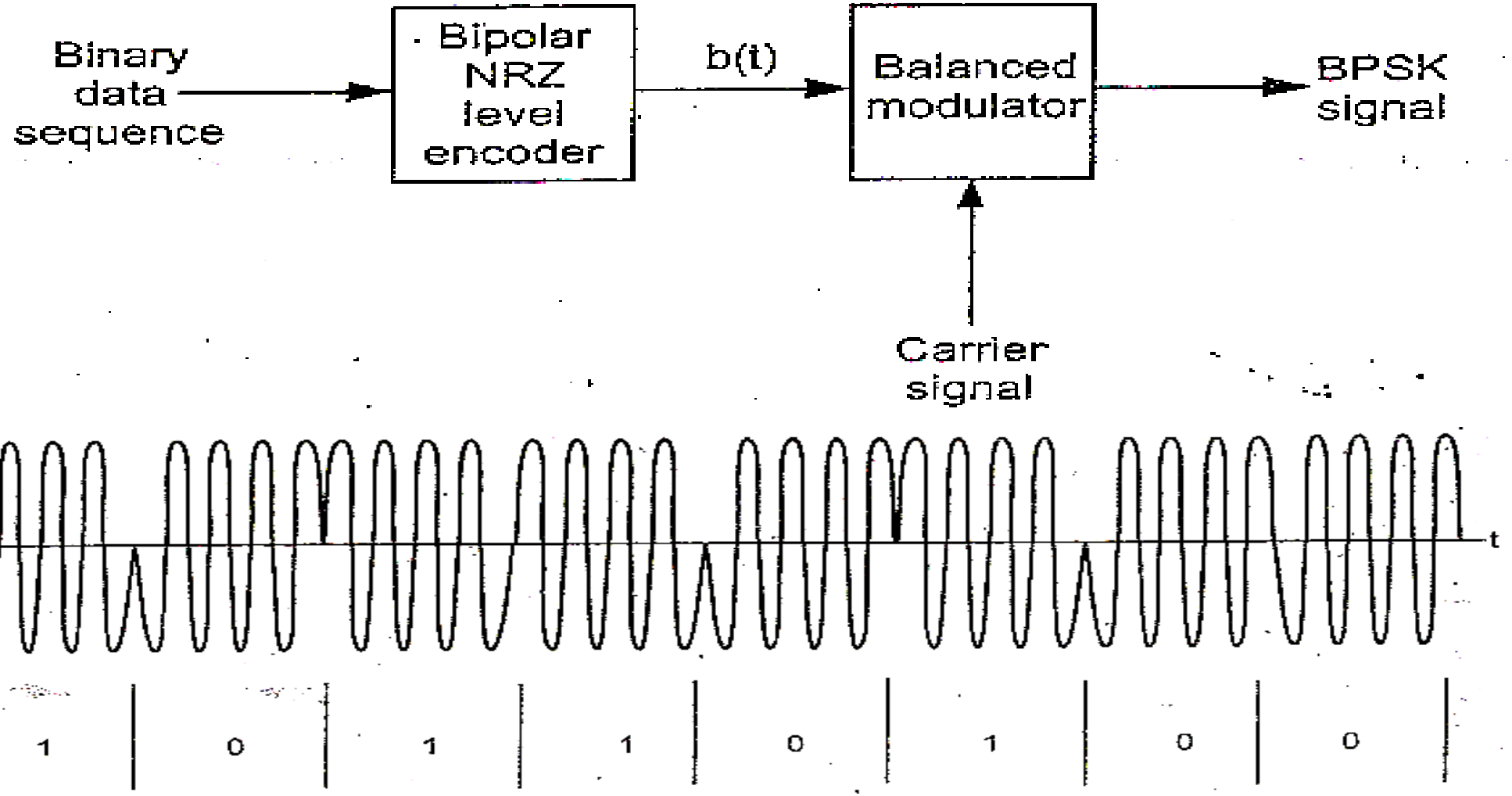
✔ **Mathematical Representation:**

$$s(t) = b(t) \cdot A\cos(2\pi f_0 t)$$

where:

- $b(t) = +1$ for bit **1**
- $b(t) = -1$ for bit **0**

BPSK Generation (How to Generate BPSK?)



Spectrum and Bandwidth of BPSK

- **The Fourier Transform of the Modulating Signal (NRZ bipolar signal):**

$$X(f) = V_b T_b \frac{\sin(\pi f T_b)}{\pi f T_b}$$

  - V_b: Voltage of the binary signal,
  - T_b: Bit period,
  - f: Frequency.

- **Power Spectral Density (PSD):**

$$S(f) = \frac{|X(f)|^2}{T_s}$$

The PSD shows the distribution of power across frequencies:

- **Bandwidth Calculation:**

$$BW = f_0 + f_b - (f_0 - f_b) = 2f_b$$

Where f_b is the bit rate (frequency).

BPSK Coherent Detection (Receiver Side)

- ✓ **How do we recover the original signal from BPSK?**
  1 The received signal enters a **bandpass filter** to remove unwanted noise.
  2 It is **multiplied by a reference carrier signal** to eliminate phase shifts.
  3 The resulting signal is **passed through an integrator** and then sampled.
- ✓ **Mathematical Derivation for Detection:**
  - The received signal $r(t)$ at the receiver is: $r(t) = b(t)\sqrt{2P}\cos(2\pi f_0 t + \theta)$
  - **The output after sampling is:** $S_o(kT_b) = b(kT_b)\sqrt{P/2}\,[1 + \cos(2\pi f_0 t + \theta)]$

This method is known as coherent detection, as it requires synchronization between the transmitter and receiver.

Advantages and Disadvantages of BPSK

- ✅ **Advantages:**

  ✓ **High noise resistance** compared to ASK and FSK

  ✓ **Efficient bandwidth usage**

  ✓ **Used in satellite and military communication**

- ❌ **Disadvantages:**

  ✕ **Requires accurate synchronization** at the receiver

  ✕ **Not as bandwidth-efficient as QPSK (Quadrature PSK)**

Applications of BPSK

- ✓ **Satellite Communication:**

  Used for **long-distance, low-noise transmission**.

- ✓ **Military Communication:**

  Provides **secure and reliable** data transmission.

- ✓ **5G and Wireless Networks:**

  BPSK is the foundation of **advanced digital modulation techniques**.

Summary and Conclusion

- 📌 **Key takeaways:**
  ✅ Digital signals require **carrier modulation** for efficient transmission.
  ✅ Different modulation techniques (**ASK, FSK, PSK, BPSK**) have advantages and trade-offs.
  ✅ **BPSK** is highly noise-resistant but needs **accurate synchronization**.
  ✅ Used in **satellite, military, and wireless communication**.
- 📢 **Any questions?** 🎤

Thank You