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

Digital Communication

Lecture 10
Binary Frequency Shift Keying (BFSK)

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

Introduction to BFSK

- BFSK is a digital modulation technique.

- The carrier frequency shifts based on binary input.

- Two frequencies: $f_0 + \frac{\Omega}{2\pi}$ for "1" and $f_0 - \frac{\Omega}{2\pi}$ for "0".

- Used in low-power and noise-resistant communication systems.

Mathematical Representation

- If bit = 1: $s(t) = \sqrt{2P_s} \cos(2\pi f_0 + \Omega)t$

- If bit = 0: $s(t) = \sqrt{2P_s} \cos(2\pi f_0 - \Omega)t$
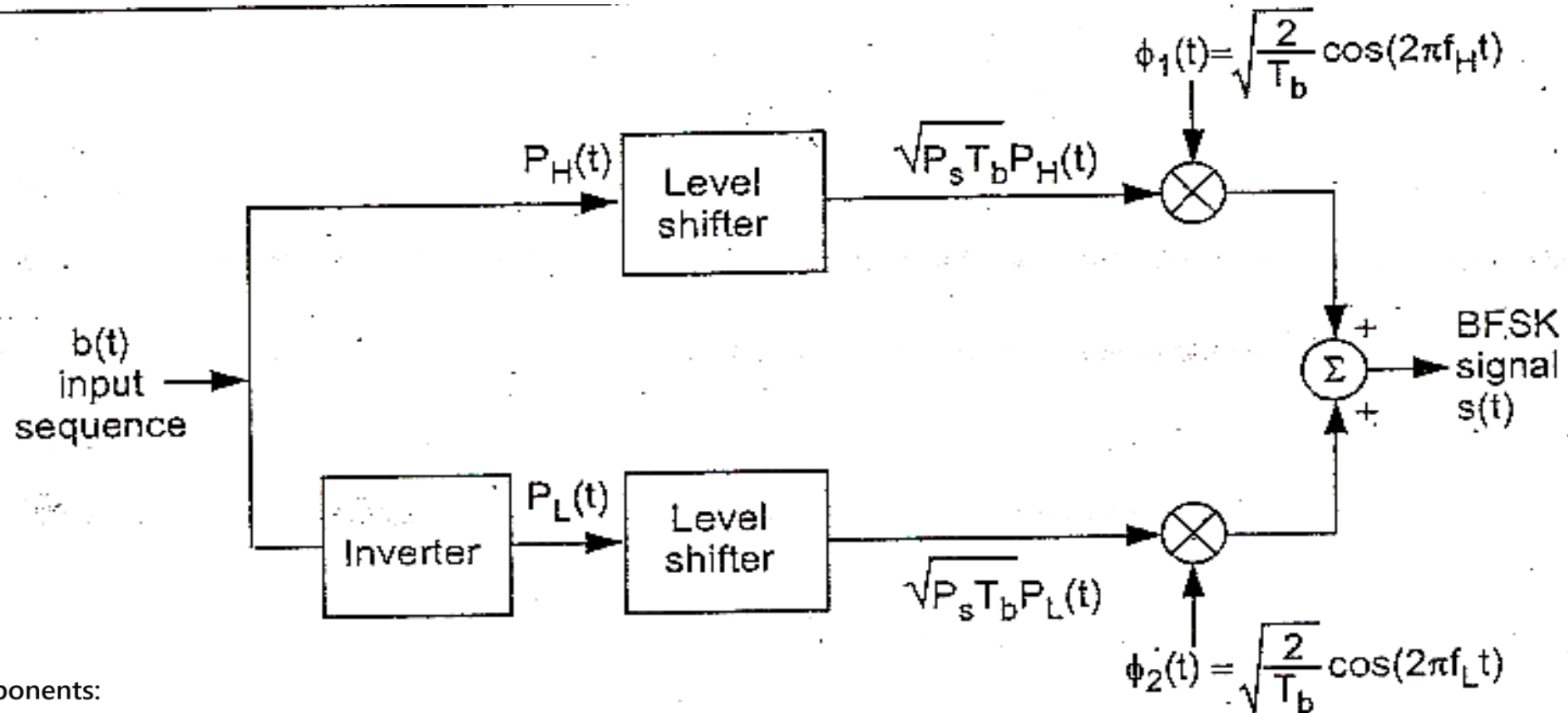
- Combined equation:

$$s(t) = \sqrt{2P_s} \cos(2\pi f_0 + d(t)\Omega)t$$

- $d(t)$ represents the binary data signal.

BFSK Generation

- The BFSK generator consists of:

  1. **Input Sequence** (t)

  2. **Inverter Circuit**

  3. **Level Shifter**

  4. **Two Product Modulators**

- The level shifter maps "1" to $\sqrt{P_s}$ and "0" to 0.

- Modulators generate frequency shifts based on input.

BFSK Block Diagram (Generation)

$$\phi_1(t) = \sqrt{\frac{2}{T_b}} \cos(2\pi f_H t)$$

$P_H(t)$ → Level shifter → $\sqrt{P_s T_b} P_H(t)$ → ⊗

$b(t)$ input sequence →

Inverter → $P_L(t)$ → Level shifter → $\sqrt{P_s T_b} P_L(t)$ → ⊗

$$\phi_2(t) = \sqrt{\frac{2}{T_b}} \cos(2\pi f_L t)$$

Σ → BFSK signal $s(t)$

- **Key Components:**
  - Input sequence $P_H(t)$, inverter to $P_L(t)$.
  - Two orthogonal carriers $\phi_1(t)$ and $\phi_2(t)$.
  - Output signal generated via product modulation.

T_b T_b

1   0   1   1   0   1   0   0

$s_2(t)$ $s_2(t)$ $s_1(t)$ $s_2(t)$ $s_1(t)$ $s_1(t)$
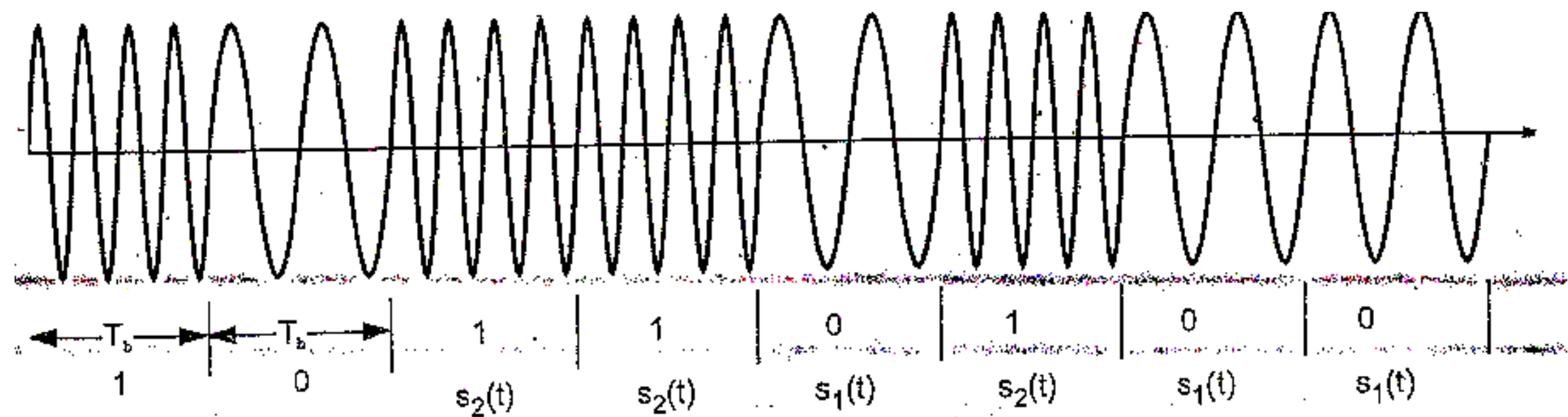
BFSK Spectrum and Bandwidth

- The BFSK signal equation:

$$s_{BP}(t) = \sqrt{2P_b(t)} \cos(2\pi f_0 t)$$

- The spectrum shows two peaks at f_H and f_L.
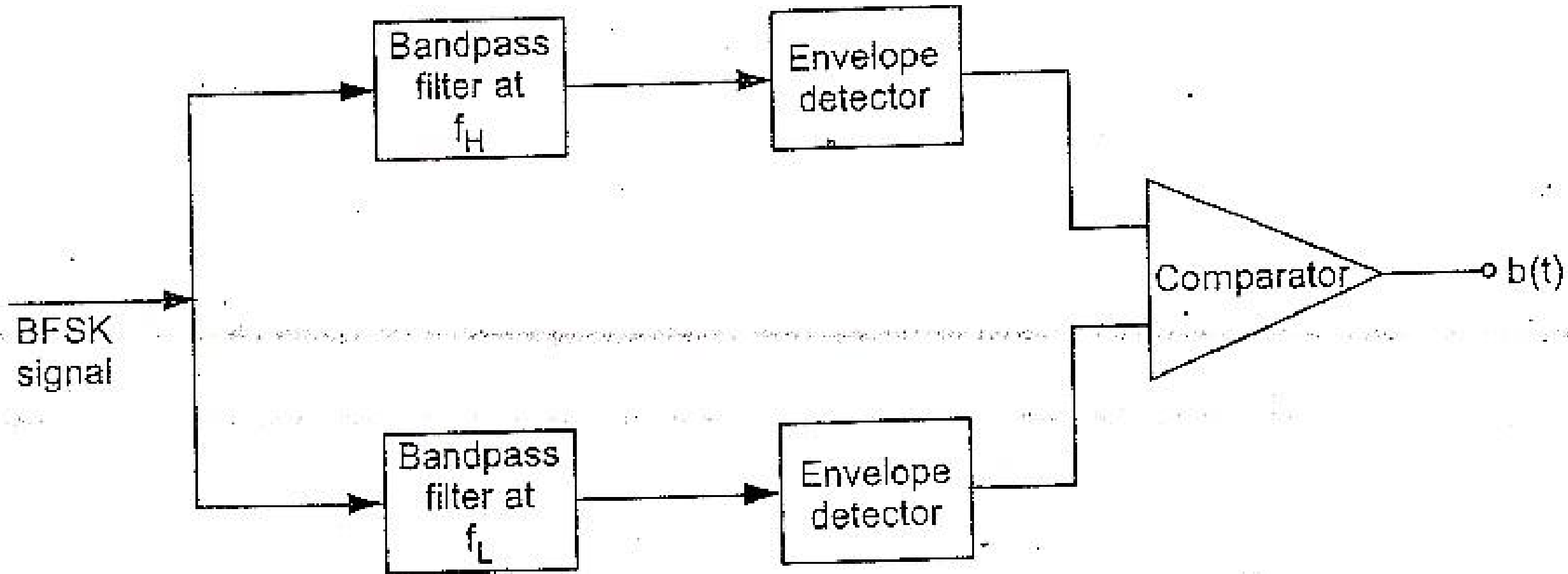
- Bandwidth:

$$BW = 4f_b$$

- BFSK bandwidth is twice that of BPSK.

  - The width of each lobe is $2f_b$.

  - BFSK uses **more bandwidth than BPSK**.

BFSK Detection

- BFSK detection uses:

  1. **Two Bandpass Filters** centered at f_H and f_L.

  2. **Envelope Detectors** to extract the signal.

  3. **Comparator** to decide bit value.

- The frequency separation ensures minimal overlap.

BFSK Block Diagram (Detection)

Advantages of BFSK

1. Simple to implement and generate.

2. More resistant to noise than ASK.

3. Better performance in low-power applications.

Disadvantages of BFSK

1. Requires twice the bandwidth of BPSK.

2. Only half the transmitted energy carries useful information.

3. Not as power-efficient as PSK techniques.

How to Prove Only half the transmitted energy carries useful information.

$$(t) = \sqrt{2P_s} \cos(2\pi f_0 + d(t)\Omega)\, t$$

$$(t) = \sqrt{2\overline{P_s}}co\{d(t)\Omega\} \cos(2\pi f_0 t) - \sqrt{2\overline{P_s}}sin\{d(t)\Omega\} \sin(2\pi f_0 t)$$

Since $(t) = \pm 1$ $\qquad \therefore \qquad co\{\pm\Omega t\} = \cos(\Omega t)$

And $\qquad s\{\pm\Omega t\} = \pm sin(\Omega t) = d(t)\sin(\Omega t)$

$$s(t) = \sqrt{2\overline{P_s}}\cos(\Omega t) \cos(2\pi f_0 t) - \sqrt{2\overline{P_s}}d(t)\sin(\Omega t) \sin(2\pi f_0 t)$$

Form above equation it is clear that only second term carry information, thus

half the transmitted energy carries information signal.

BFSK vs. BPSK

- **Bandwidth**: BFSK requires $2 \times BW(BPSK)$.

- **Power Efficiency**: BPSK transmits more power efficiently.

- **Complexity**: BFSK is simpler but less power-efficient.

Conclusion

- BFSK shifts carrier frequency based on input data.

- Generation involves modulating two separate frequencies.

- Detection uses bandpass filters and envelope detectors.

- BFSK is simple but requires higher bandwidth.

Thank You