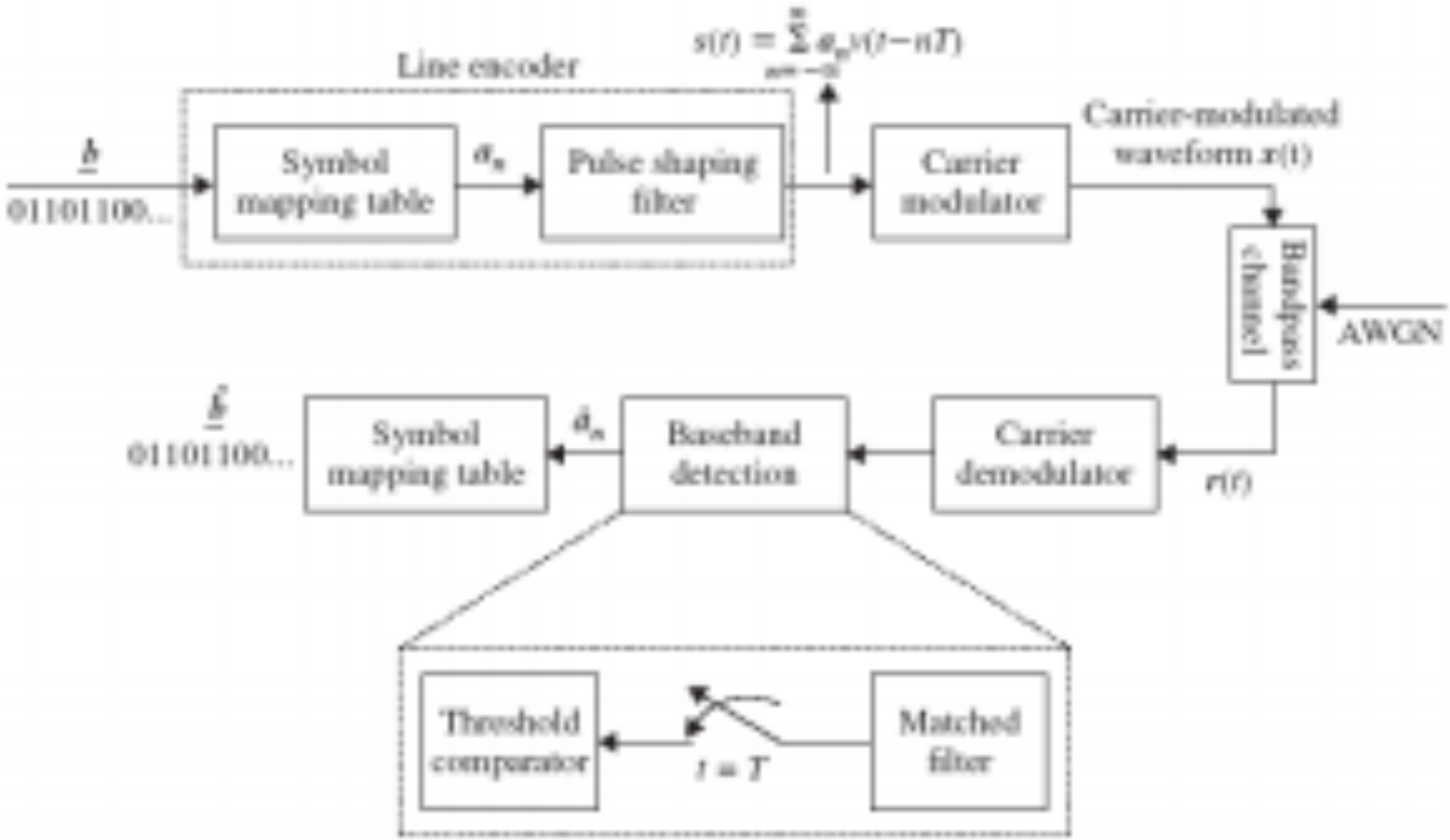
# Digital Baseband Modulation

# Outline

- Later

# Digital Carrier Transmission System

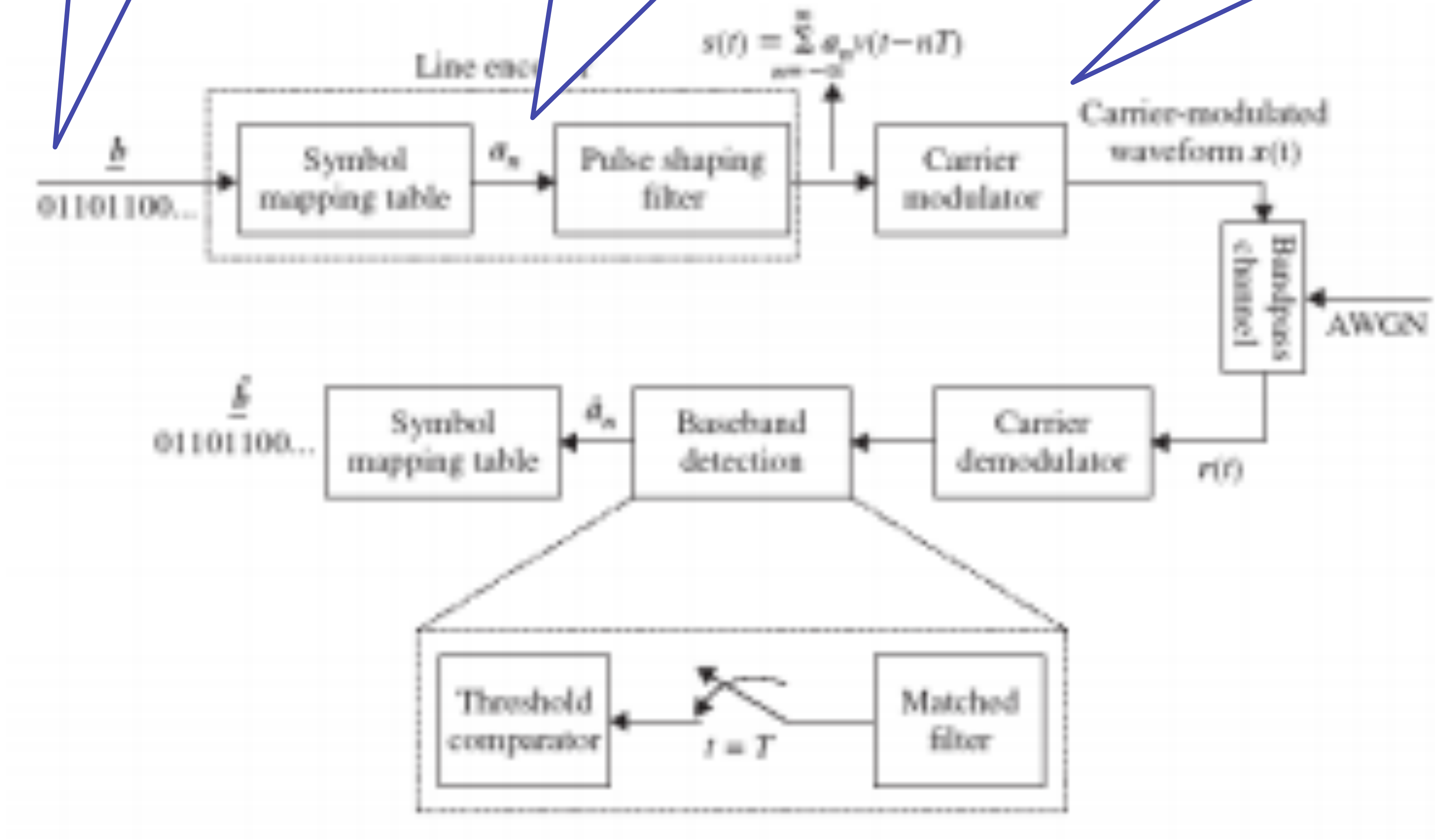


# Digital Carrier Transmission System

Bit rate,Rb

Symbol rate, Rs=Rb/k; M=2^K

PM, AM, FM



# Quadrature representation of the BP signals

- For bandpass signals

$$x(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t)$$

- Often in digital communications the baseband signals I(t) and Q(t) are independent, **linearly** modulated pulse trains

$$\boldsymbol{I}(t) = \sum_n \boldsymbol{a}_n^I v(t - nT)$$

$$\boldsymbol{Q}(t) = \sum_n \boldsymbol{a}_n^Q w(t - nT)$$

- Such modulation methods are called quadrature schemes

# Alternative Representation of BP Signals

- See notes

# Example (1)

- Notes

# Binary Amplitude-Shift Modulation

- Also known as Binary Amplitude-Shift Keying (B-ASK)
- In BASK, every Tb seconds the modulator transmits a carrier burst only if the binary information bit is 1. There is no transmission if the information bit is 0

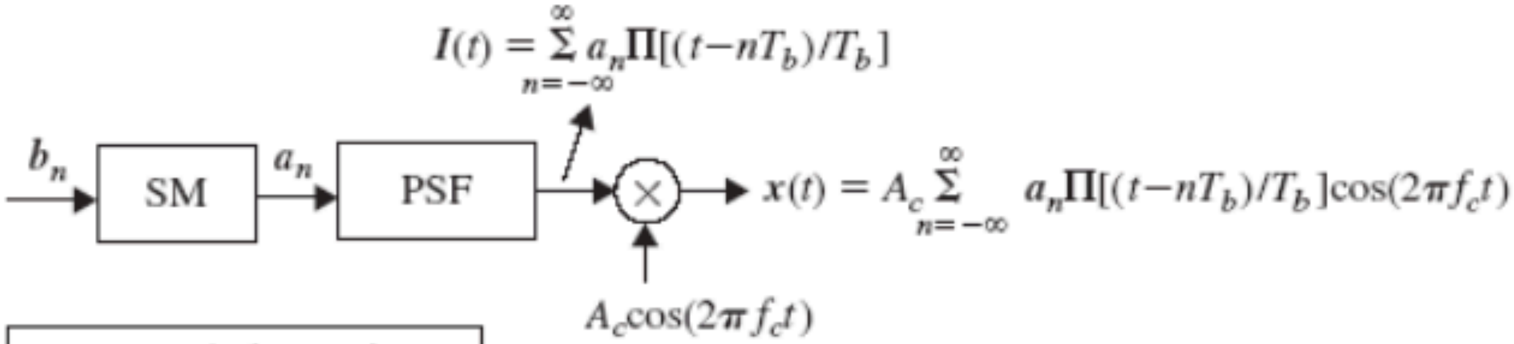
$$\text{Binary 1: } s_1(t) = A_c \cos(2\pi f_c t), \qquad 0 \le t \le T_b$$

$$\text{Binary 0 : } s_2(t) = 0, \qquad 0 \le t \le T_b$$

- The resultant BASK signal can be expressed as

$$\boldsymbol{x}(t) = A_c \underbrace{\sum_{n=-\infty}^{\infty} \boldsymbol{a}_n \Pi\left[\left(t - nT_b\right)/T_b\right]}_{\boldsymbol{I}(t)} \cos\left(2\pi f_c t\right), \quad \boldsymbol{a}_n \in \mathscr{A}_2 = \{1, 0\}$$

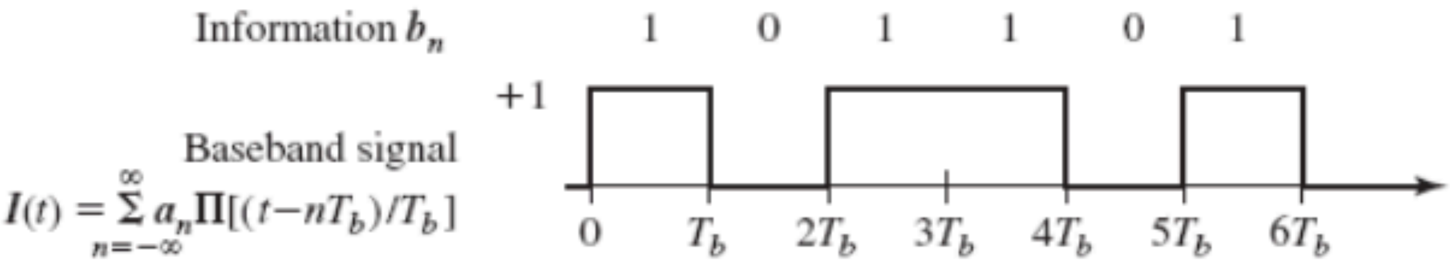
- The quadrature component Q(t) is zero



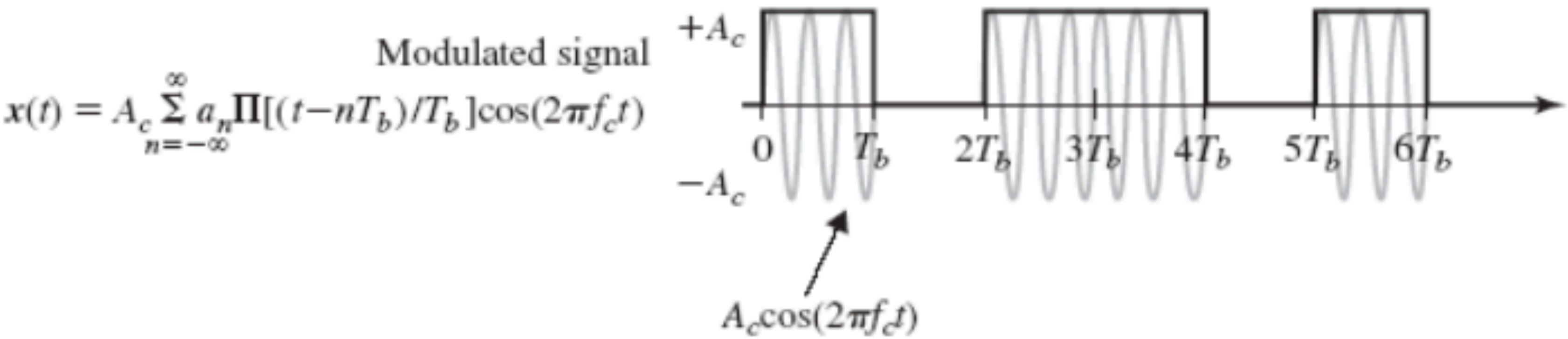

SM = Symbol mapping
PSF = Pulse shaping filter

Binary 1: $s_1(t) = A_c \cos(2\pi f_c t), \quad 0 \le t \le T_b$

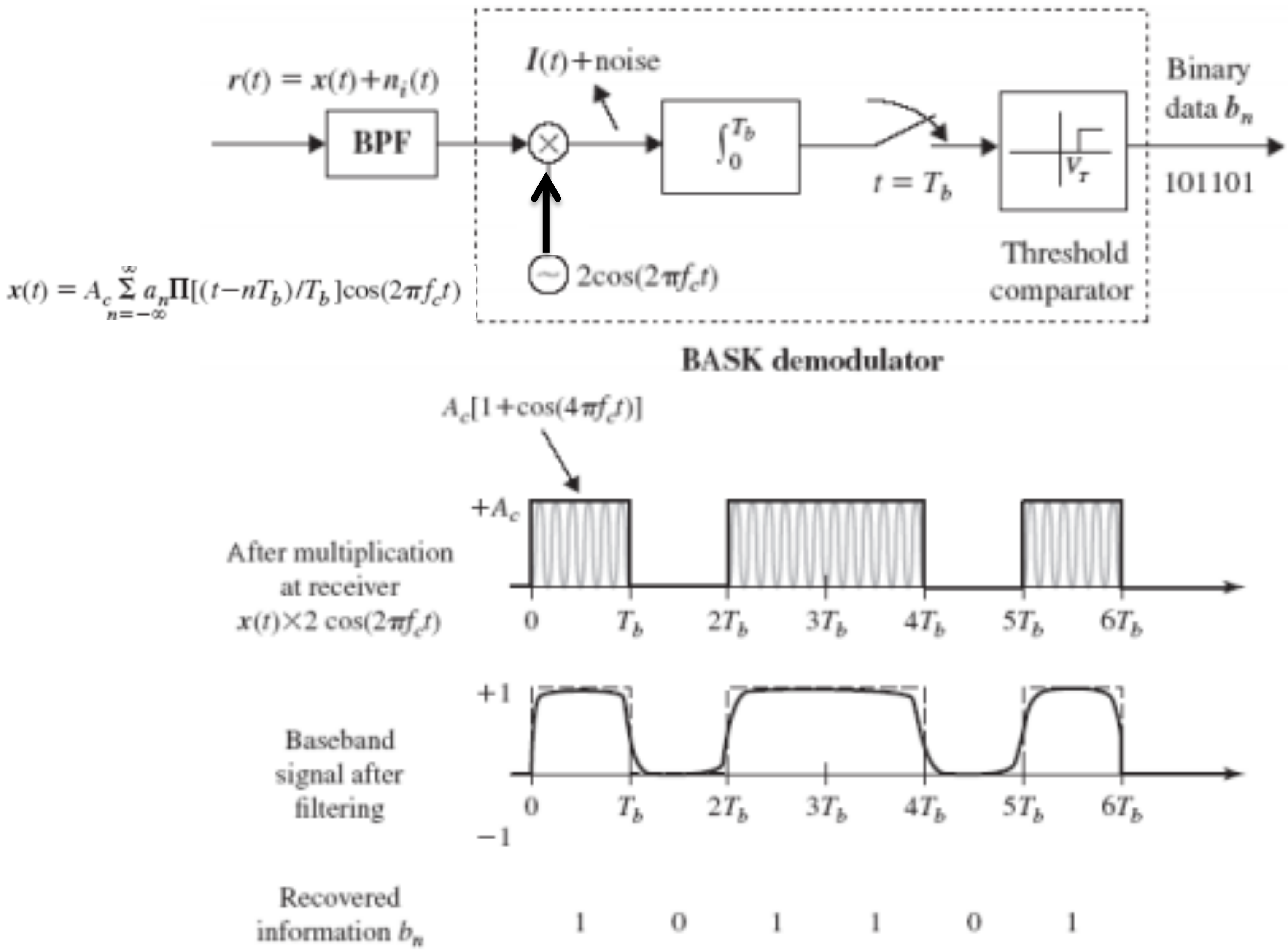
Binary 0 : $s_2(t) = 0, \quad 0 \le t \le T_b$




SQUARE PUSE SIGNAL



# Coherent Demodulation



# Error Performance

# BPSK

- In BPSK, the symbol mapping table encodes bits ($b_n$) 1 and 0 to transmission symbols ($a_n$) 1 and −1, respectively
- Every $T_b$ seconds the modulator transmits one of the two carrier bursts that corresponds to the information bit being a 1 or 0

Binary 1: $s_1(t) = A_c \cos(2\pi f_c t), \qquad 0 \le t \le T_b$

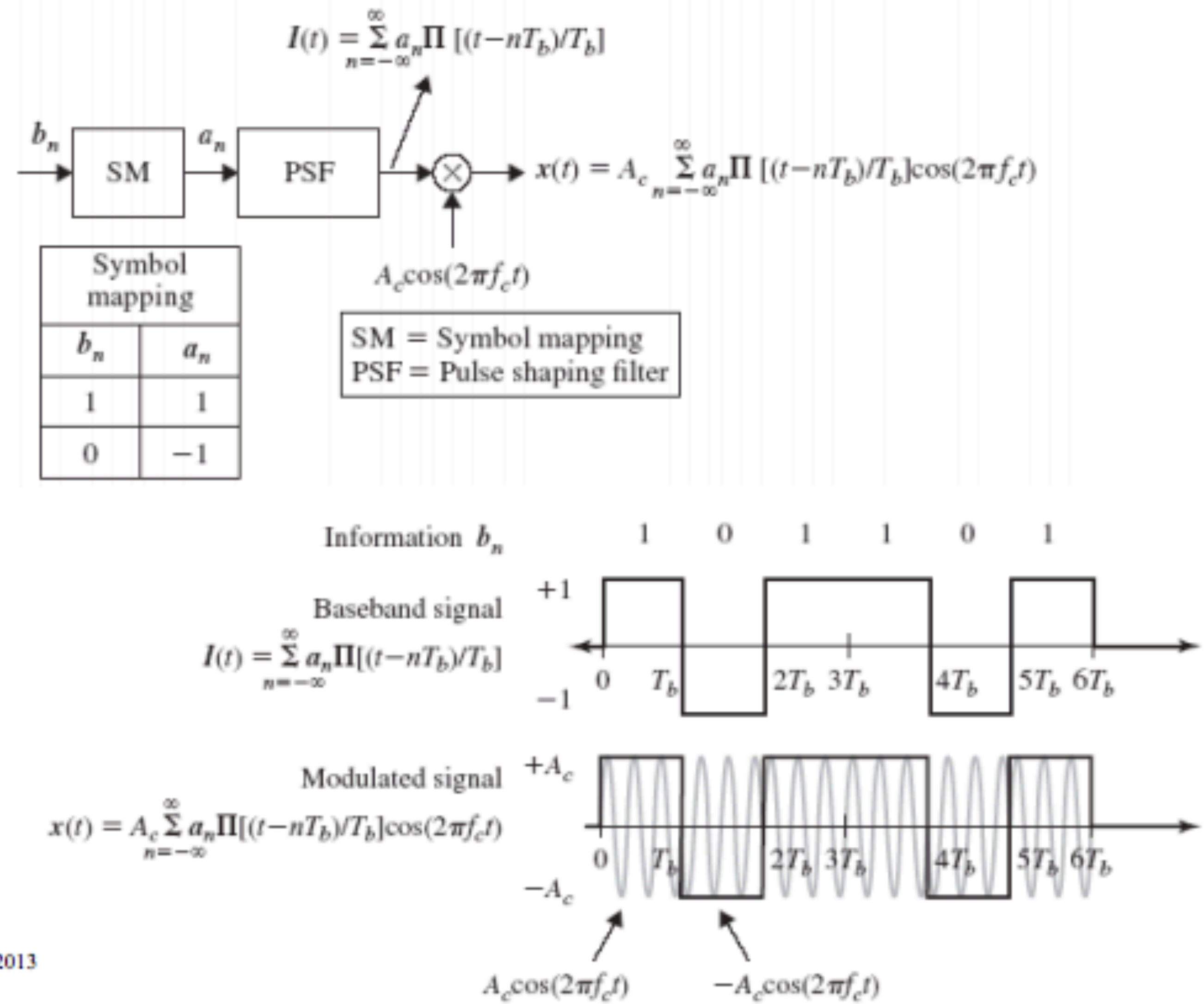
Binary 0: $s_2(t) = A_c \cos(2\pi f_c t + \pi) = -A_c \cos(2\pi f_c t)$

- The resultant BPSK signal can be expressed as

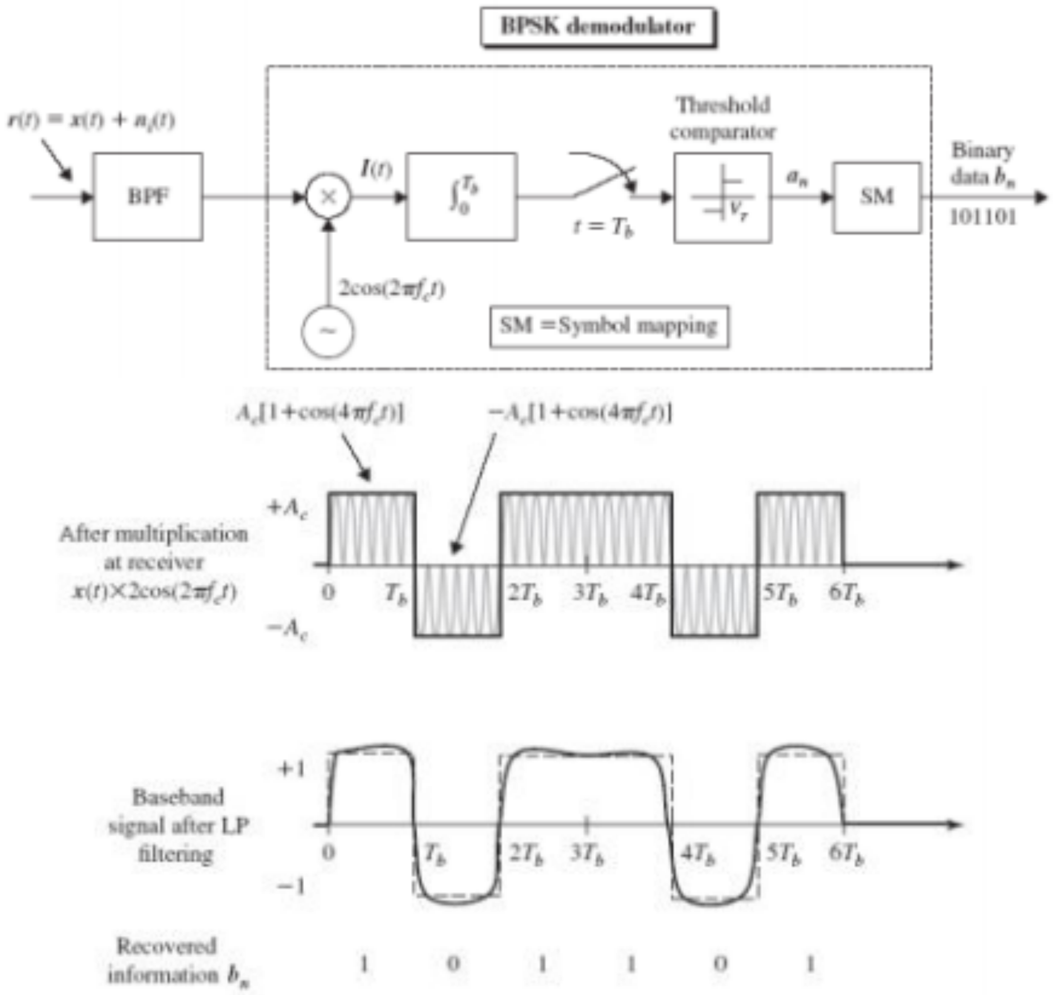
$$\boldsymbol{x}(t) = A_c \underbrace{\sum_{n=-\infty}^{\infty} \boldsymbol{a}_n \Pi\left[\left(t - nT_b\right)/T_b\right]}_{I(t)} \cos\left(2\pi f_c t\right), \quad \boldsymbol{a}_n \in \mathcal{A}_2 = \{1 -1\}$$

- $\boldsymbol{x}(t)$ contains only the in-phase component $\boldsymbol{I}(t)$; $\boldsymbol{Q}(t)$ is zero

# BPSK Modulation



# BPSK Coherent Demodulation




The BER performance of BPSK is, therefore, identical to that of polar NRZ signaling

$$BER_{BPSK} = Q\left(\frac{d_{\min}}{\sqrt{2N_o}}\right) = Q\left(\sqrt{\frac{2E_b}{N_o}}\right)$$

# Binary Frequency Shift Keying (BFSK)

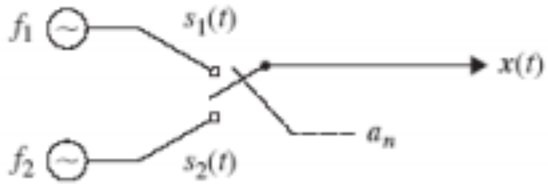
- In BFSK, information is transmitted by sending carrier bursts of two different frequencies, $f_1 = f_c + \Delta f/2$ and $f_2 = f_c - \Delta f/2$, to transmit binary data. $\Delta f$ is called the *frequency deviation*

$$\text{Binary 1: } s_1(t) = A_c \cos(2\pi f_c t + \pi \Delta f t + \phi_1), \qquad 0 \le t \le T_b$$

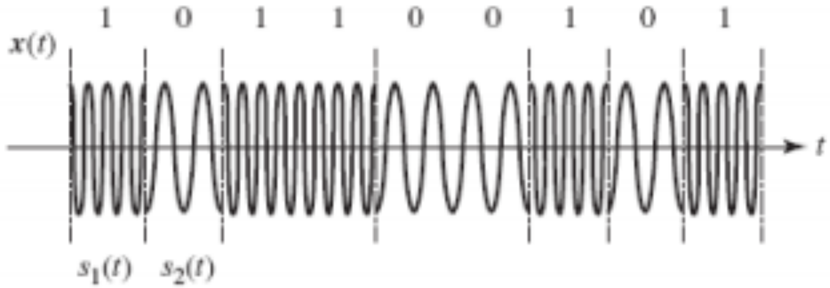
$$\text{Binary 0 : } s_2(t) = A_c \cos(2\pi f_c t - \pi \Delta f t + \phi_2), \qquad 0 \le t \le T_b$$

- A simple way to generate a BFSK signal is to use two separate oscillators tuned to frequencies $f_1$ and $f_2$ and switch between their outputs in accordance with the amplitude of the random data bit during that bit interval
- $\phi_1$ and $\phi_2$ are arbitrary phases of two frequency bursts generated by separate oscillators

# FSK




(a)



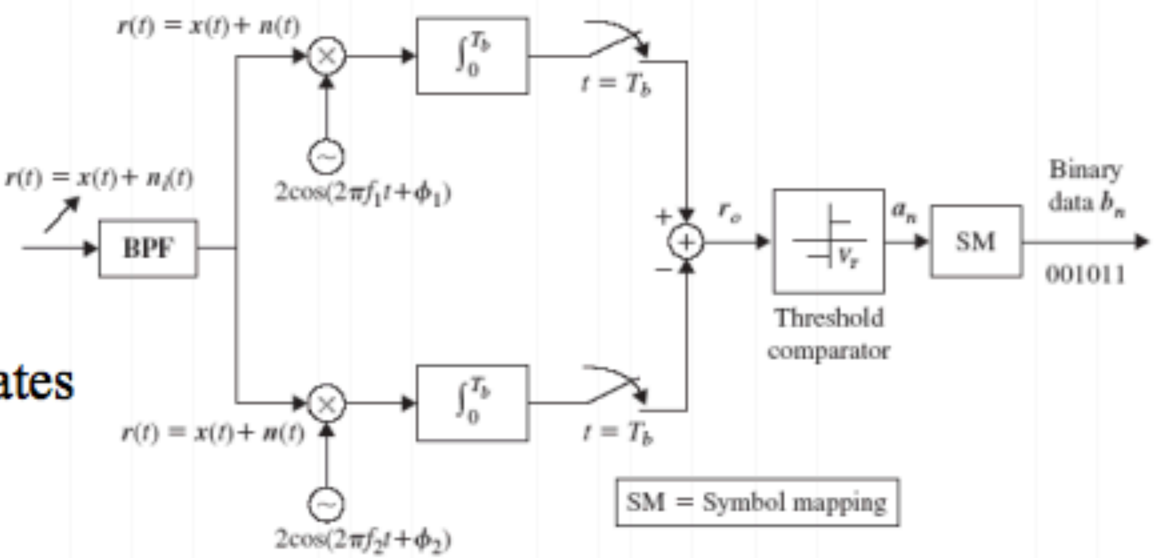

- Because there is no requirement for the phase to be continuous in an FSK signal, the change to different frequencies can be quite abrupt as we switch from one oscillator output to another in successive symbol periods

- The BER performance of BFSK is, therefore, given by

$$BER_{BFSK} = Q\left(\sqrt{\frac{E_b}{N_o}}\right)$$

# Coherent Demodulation of BFSK signals

- BFSK waveform can be viewed as consisting of two interleaved BASK signals with the same amplitude but different carrier frequencies $f_1 = f_c + \Delta f/2$ and $f_2 = f_c - \Delta f/2$
- If the frequencies of two FSK carriers are chosen so that the waveforms are orthogonal, then interleaved ASK signals can be coherently demodulated and detected without mutual interference.




Each branch of the demodulator replicates ASK demodulator

# References


- Leon W. Couch II, Digital and Analog Communication Systems, 8th edition, Pearson / Prentice, Chapter 3-5
- "M. F. Mesiya, ”Contemporary Communication Systems”, 1st ed./2012, 978-0-07-. 338036-0, McGraw Hill. Chapter 11