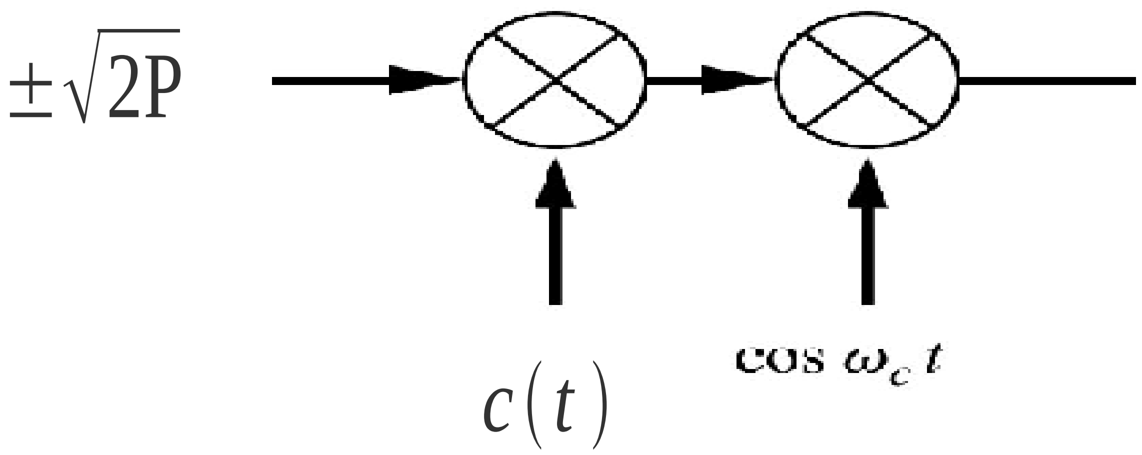
ELC 406A Advanced Digital Communication

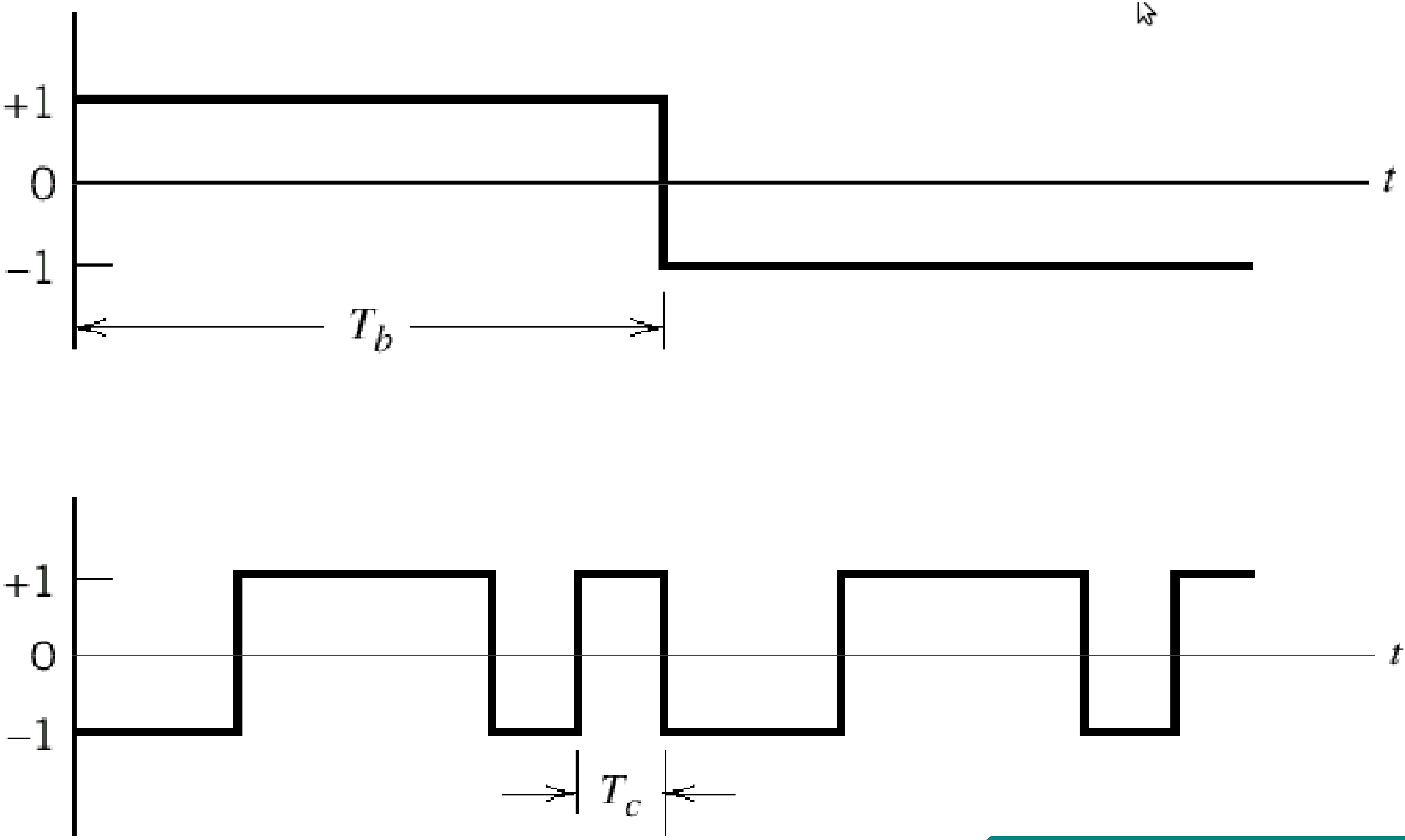
Lecture 2

DS-SS and FH-SS

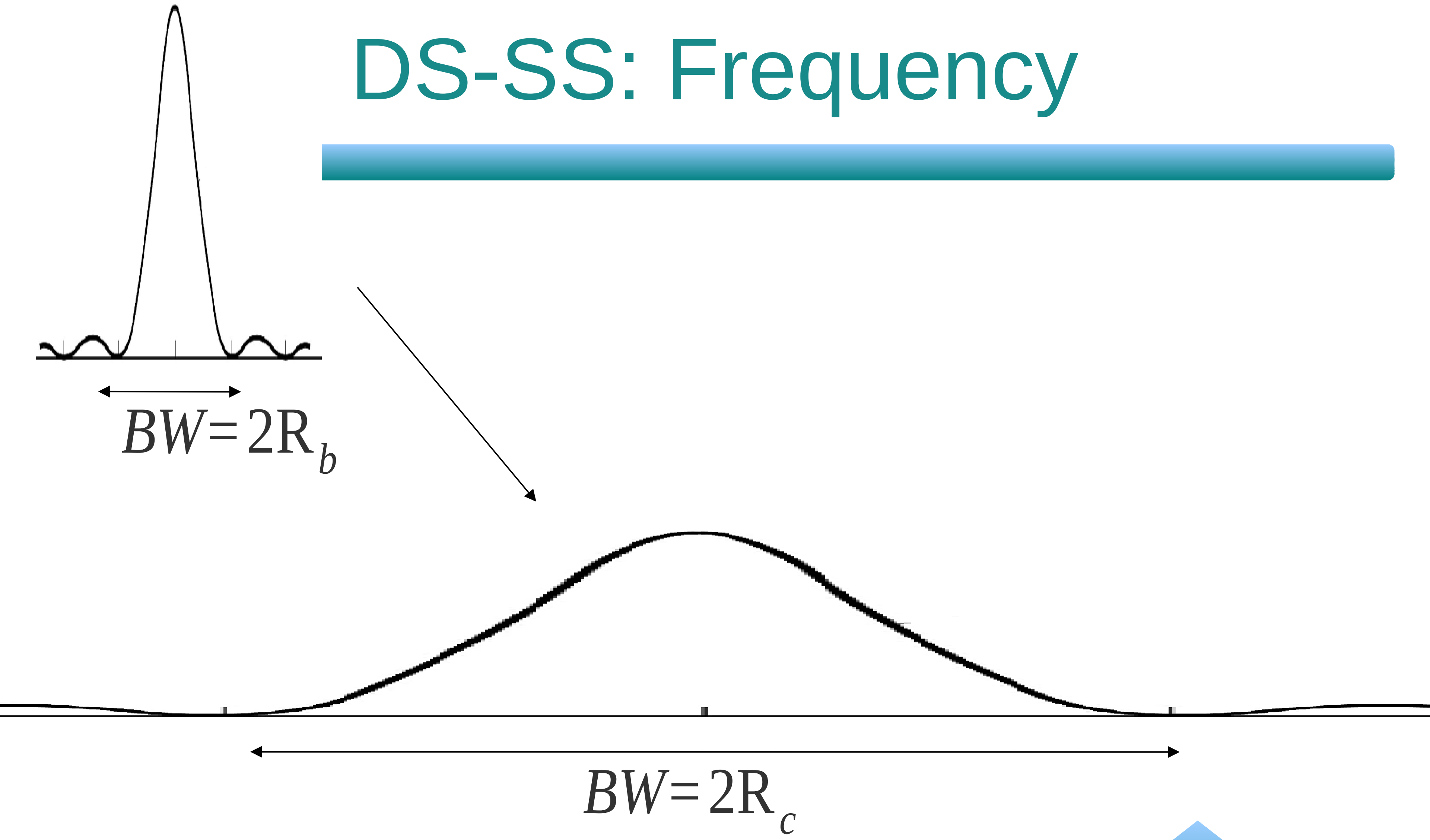
DS-SS : Transmitter



DS-SS: Time



DS-SS: Frequency



DS-SS : Equations

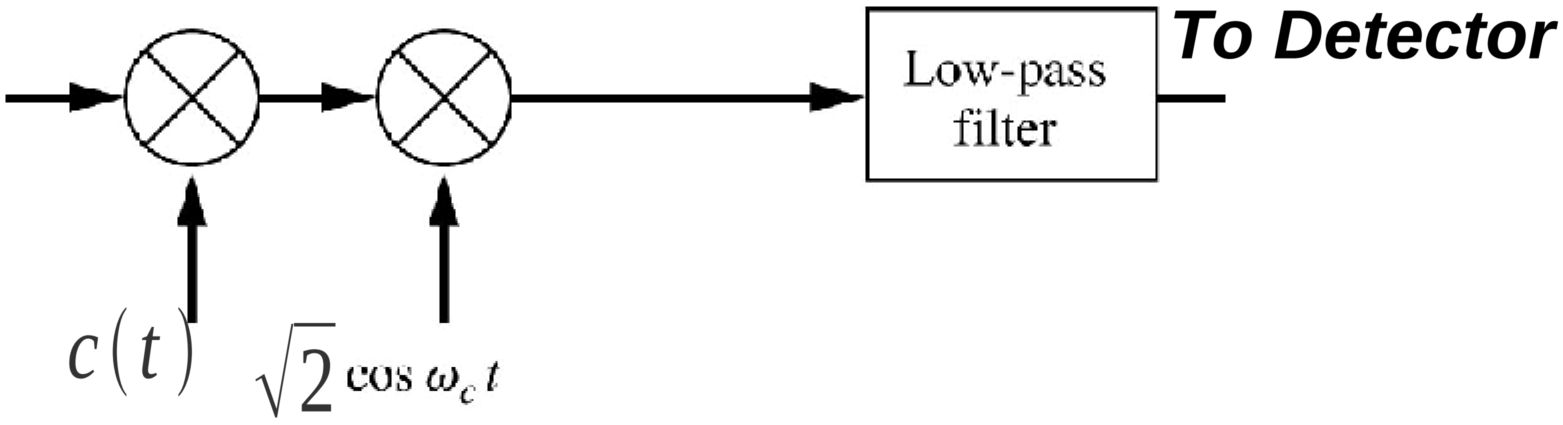
- Transmitted :

$$s_i(t) = \pm\sqrt{2P}\,.\,c(t)\cos(\omega_c t)$$

- Received

$$r_i(t) = \pm\sqrt{2P}\,.\,c(t)\cos(\omega_c t) + n_c(t)\,.\cos(\omega_c t) - n_s(t)\,.\sin(\omega_c t)$$

DS-SS : Demodulator



DS-SS : Demodulator equations

$$r_i(t).c(t).\sqrt{2}\cos(\omega_c t) = \pm 2\sqrt{P}.c^2(t)\cos^2(\omega_c t)$$
$$+\sqrt{2}n_c(t).c(t)\cos^2(\omega_c t) - \sqrt{2}n_s(t).\sin(\omega_c t).c(t)\cos(\omega_c t)$$

DS-SS : Demodulator equations

$$d_i = \frac{\sqrt{2}}{T_b} \int r_i(t).c(t)\cos(\omega_c t).dt$$

$$= \frac{\pm 2\sqrt{P}}{T_b} \int \cos^2(\omega_c t).dt$$

$$+ \frac{\sqrt{2}}{T_b} \int n_c(t).\cos^2(\omega_c t).c(t)dt$$

$$- \frac{\sqrt{2}}{T_b} \int n_s(t).\sin(\omega_c t).c(t)\cos(\omega_c t).dt$$

DS-SS : Demodulator equations

$$d_i = \frac{\sqrt{2}}{T_b} \int r_i(t) . \cos(\omega_c t) . dt$$

$$= \pm\sqrt{P} + \frac{1}{\sqrt{2} . T_b} \int n_c(t) . dt + \text{zero}$$

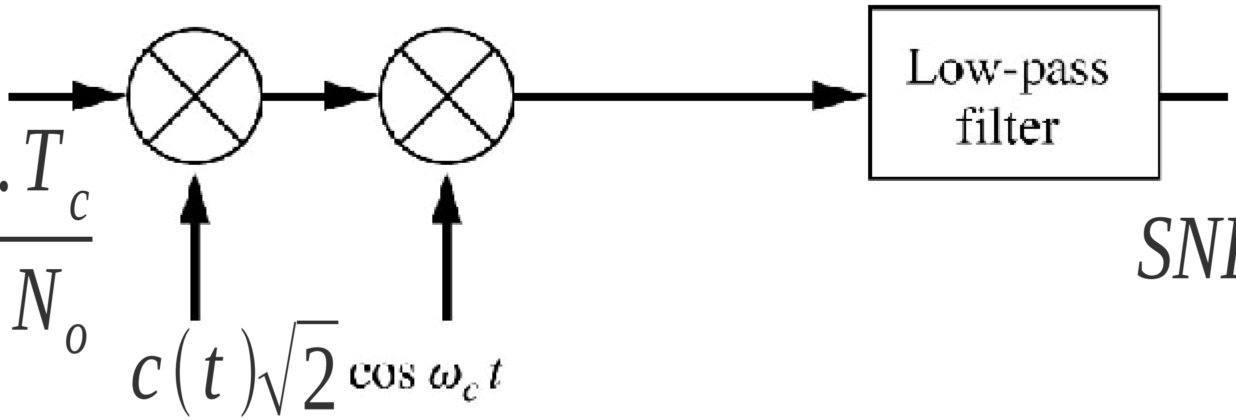
2PSK : Demodulator

- $r_i(t) = \pm\sqrt{2\text{P}}.c(t)\cos(\omega_c t) + n(t)$ $\qquad SNR_i = \dfrac{P.T_c}{2.N_o}$

- $d_i == \pm\sqrt{P} + \dfrac{1}{\sqrt{2}.T_b}\int n_c(t).dt$ $\qquad SNR_o = \dfrac{P.T_b}{N_o}$

DS-SS : Demodulator

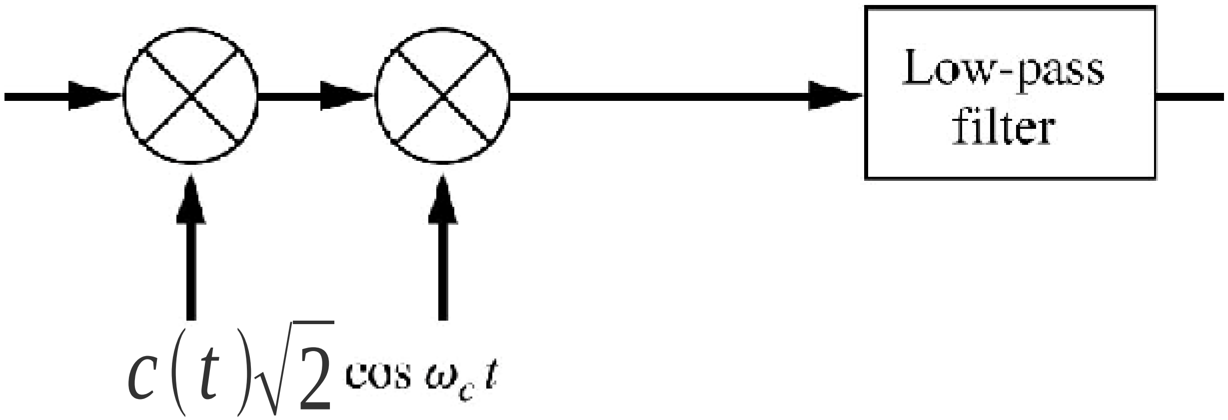
$$SNR_i = \frac{P.T_c}{2.N_o}$$



$$SNR_o = \frac{E_b}{N_o}$$

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_o}}\right) = Q\left(\sqrt{\frac{2E_b}{N_o}}\right)$$

DS-SS : Demodulator



$$SNR_o = 2.\frac{T_b}{T_c}\,\mathrm{SNR}_i$$

$$PG = \frac{T_b}{T_c}$$

FH-SS

FH-SS

- Hedy Lamarr (under her then-married name of Hedy Kiesler Markey) and composer George Antheil developed a Secret Communication System in 1942.
- This early version of frequency hopping used a piano roll to change between 88 frequencies and was intended to make radio-guided torpedoes harder for enemies to detect or jam.
- The technology was not implemented until 1962, when it was used by U.S. military ships during a blockade of Cuba.

FH-SS : Types

- Slow-FH: symbol rate is an integer multiple of hop rate many symbols are transmitted over the same hop
- $R_s = n.R_h$ $T_h = n.T_s$

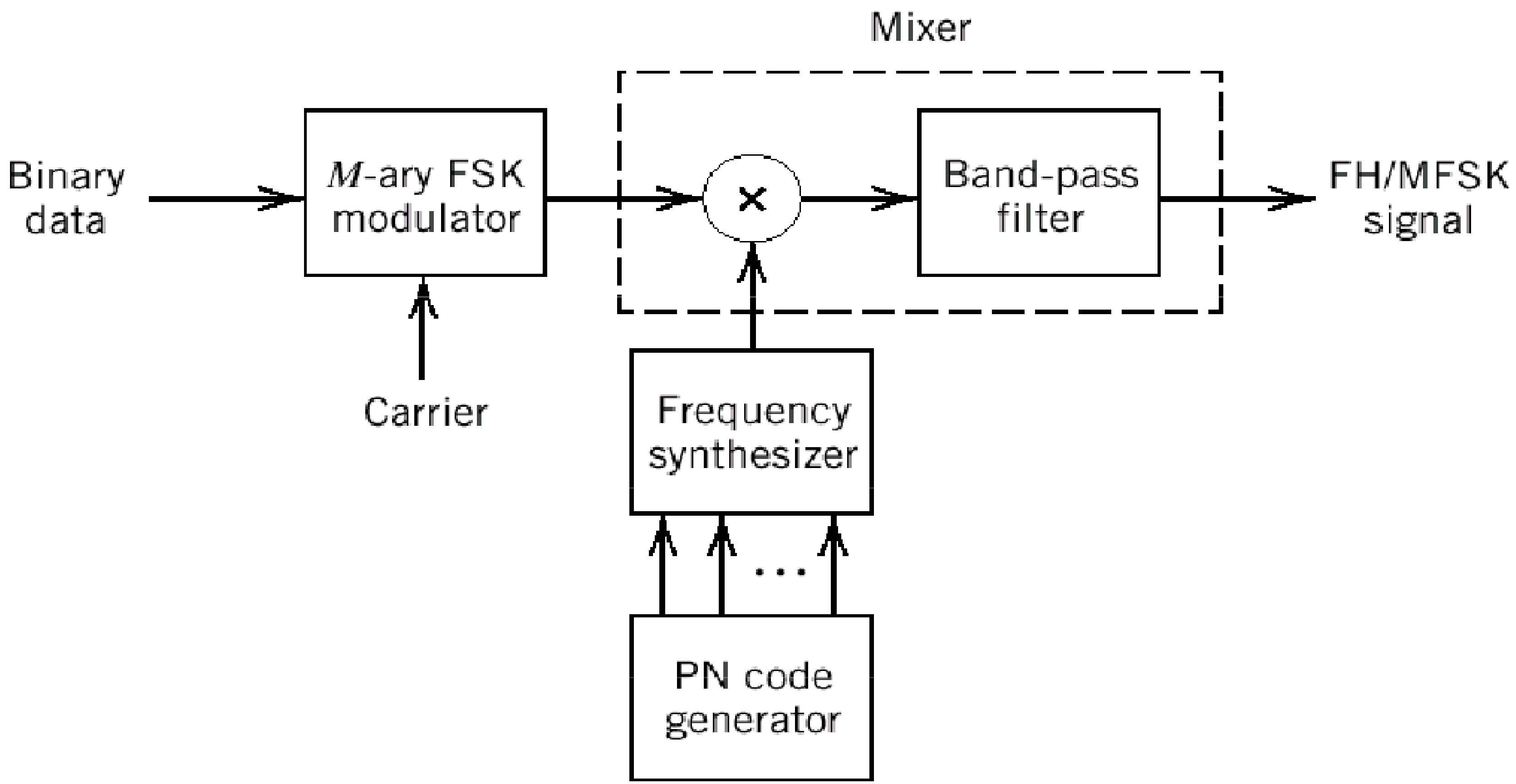
FH-SS : Types

- Fast-FH: hop rate is an integer multiple of the symbol rate carrier frequency will hop many times during the same symbol
- $R_h = n.R_s$ $T_s = n.T_h$

FH-SS : Types

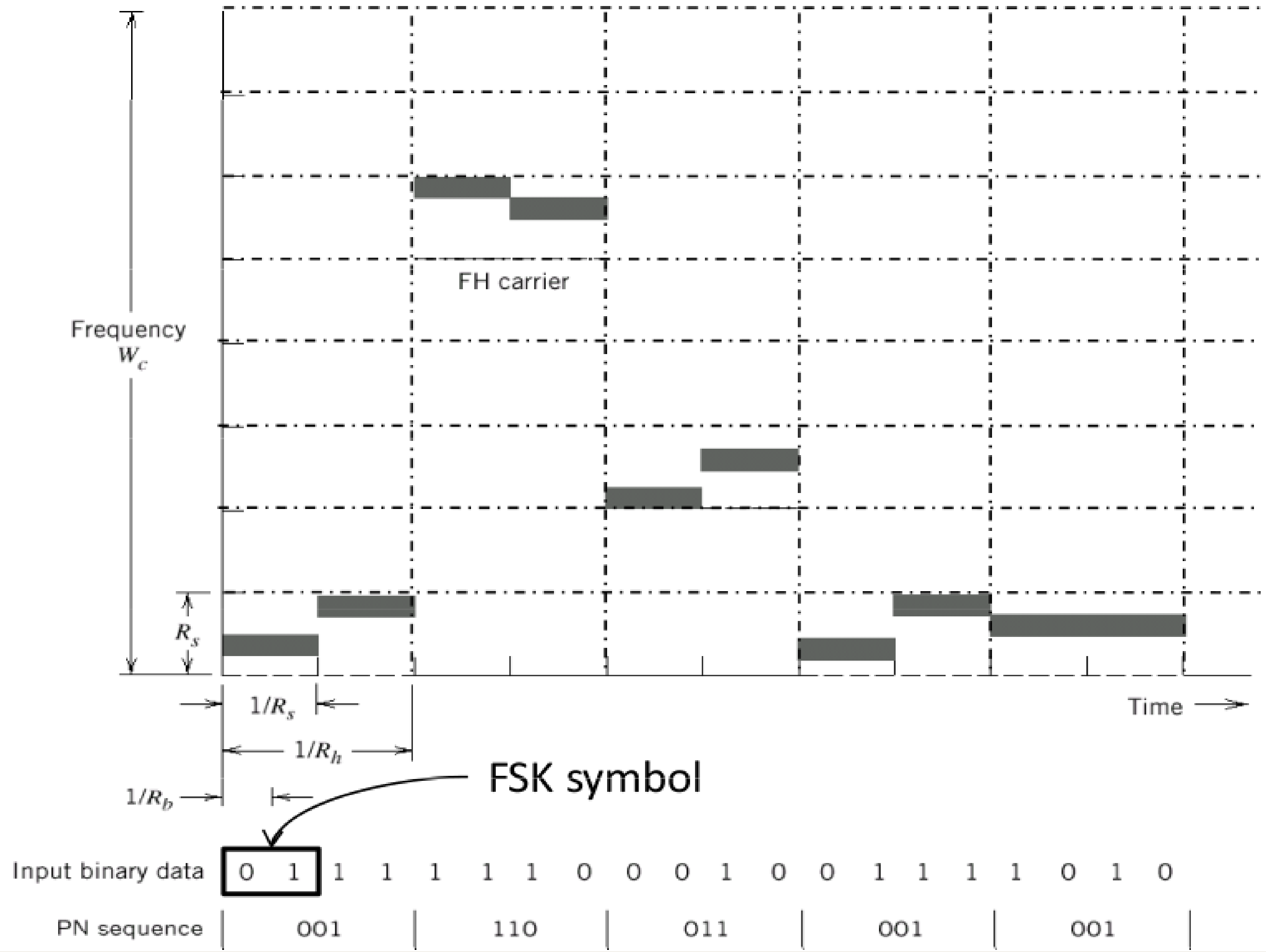
- Slow-FH: symbol rate is an integer multiple of hop rate many symbols are transmitted over the same hop
- $(R_s = n.R_h)$
- Fast-FH: hop rate is an integer multiple of the symbol rate carrier frequency will hop many times during the same symbol $(R_h = n.R_s)$

FH-SS : Transmitter

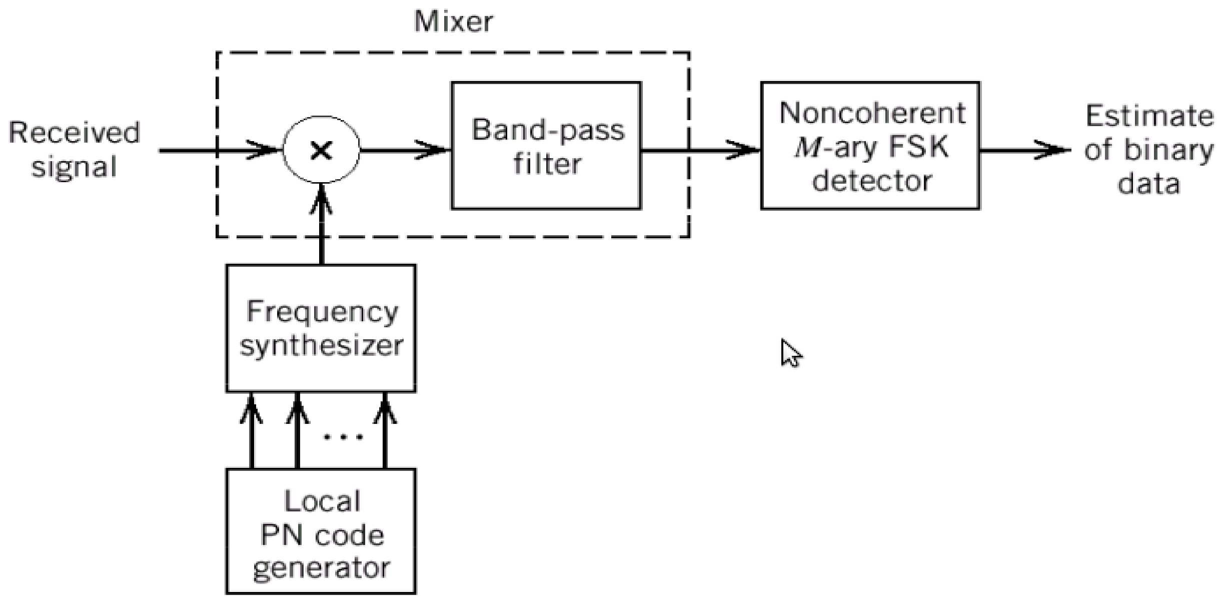


FH-SS : Example

- Binary Input : 011111110001001111010
- Modulation : 4FSK
- PN sequence : 001110011001001
- Total number of frequencies: 8
- $R_s = 2.R_h$


FH carrier
Frequency
W_c
R_s
$1/R_s$
$1/R_h$
$1/R_b$
Time
FSK symbol
Input binary data 0 1 1 1 1 1 1 0 0 0 1 0 0 1 1 1 1 0 1 0
PN sequence 001 110 011 001 001

FH-SS : Receiver



FH-SS: Bandwidth

The chip duration (T_c) is defined as:

$$T_c = \min (T_h , T_s)$$

The bandwidth is then calculated as:

$$BW = N_f * M * R_c$$

FH-SS: Performance

Same as the M_{ary}-FSK

Slow: $$P_e = \frac{1}{2} exp\left(\frac{-E_b}{2.N_o}\right)$$

Fast : $$P_{eh} = \frac{1}{2} exp\left(\frac{-E_h}{2.N_o}\right)$$

FH-SS: Performance

Fast :

$$P_e = \sum_{i=n}^{N_h} \binom{N_h}{i} . P_{he}^{i} . (1 - P_{he})^{N_h - i}$$

$$P_{eh} = \frac{1}{2} . \exp\left(\frac{-E_h}{2.N_o}\right) = \frac{1}{2} . \exp\left(\frac{-E_b / N_h}{2.N_o}\right)$$

$$\binom{N_h}{i} = \frac{N_h!}{i!(N_h - i)!}$$

$$n = \left\lfloor \frac{N_h}{2} + 1 \right\rfloor$$

Questions ???

Thank You