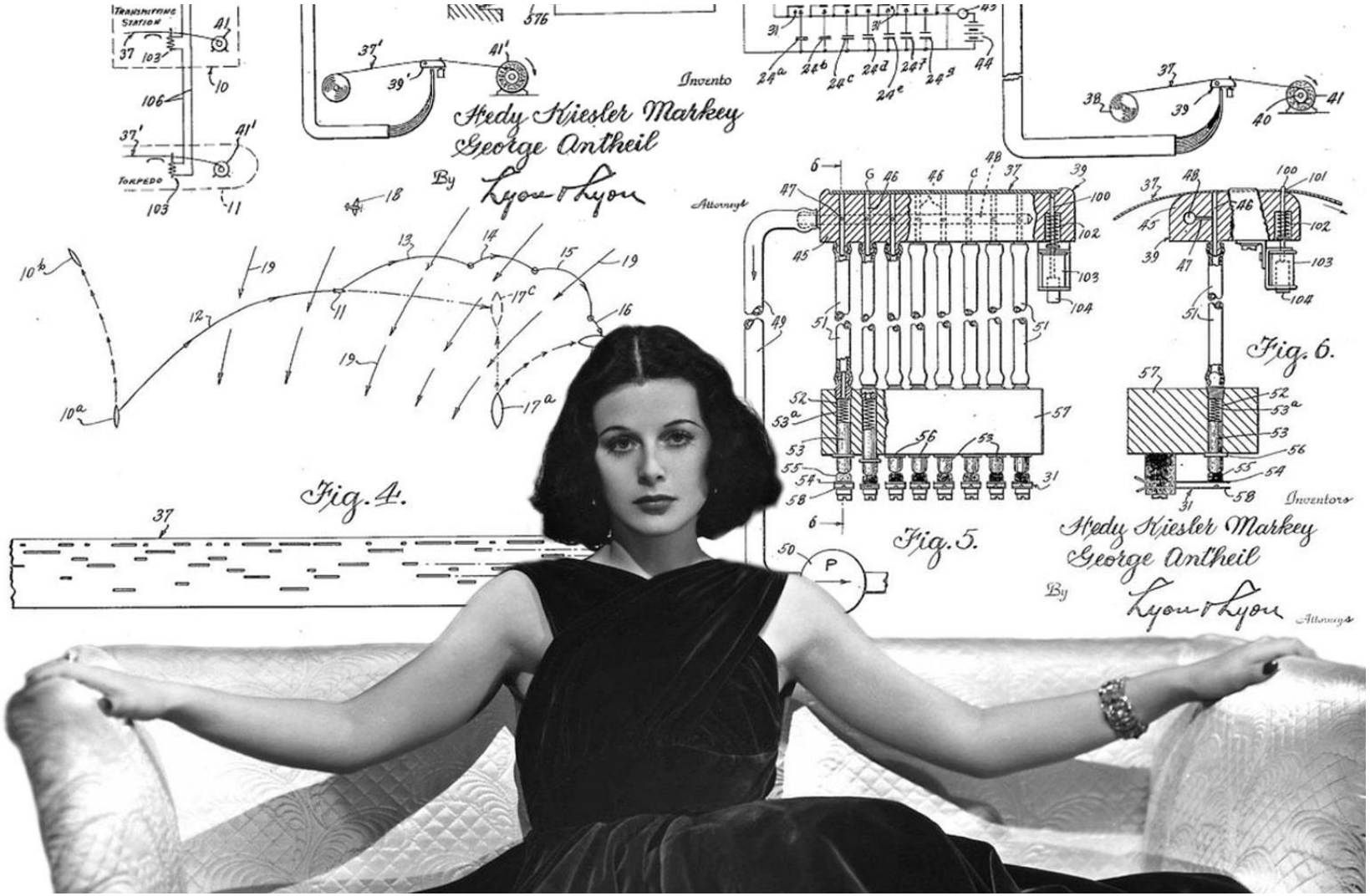
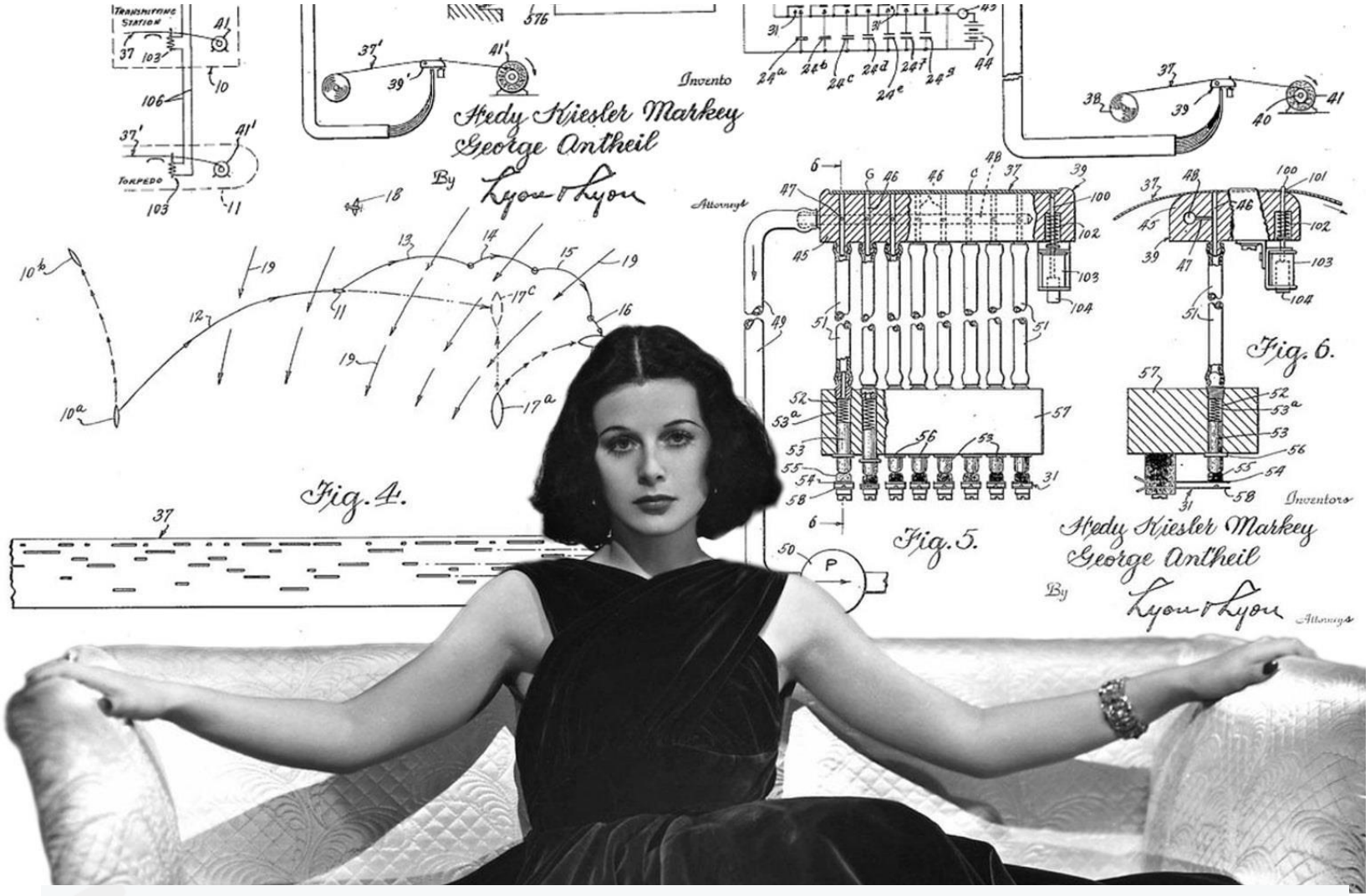

Hedy Kiesler Markey
George Antheil
By Lyon & Lyon
Attorneys
Fig. 4.
Fig. 5.
Fig. 6.
Inventors
Hedy Kiesler Markey
George Antheil
By Lyon & Lyon
Attorneys

Hedy Lamarr, the mother of Wi-Fi

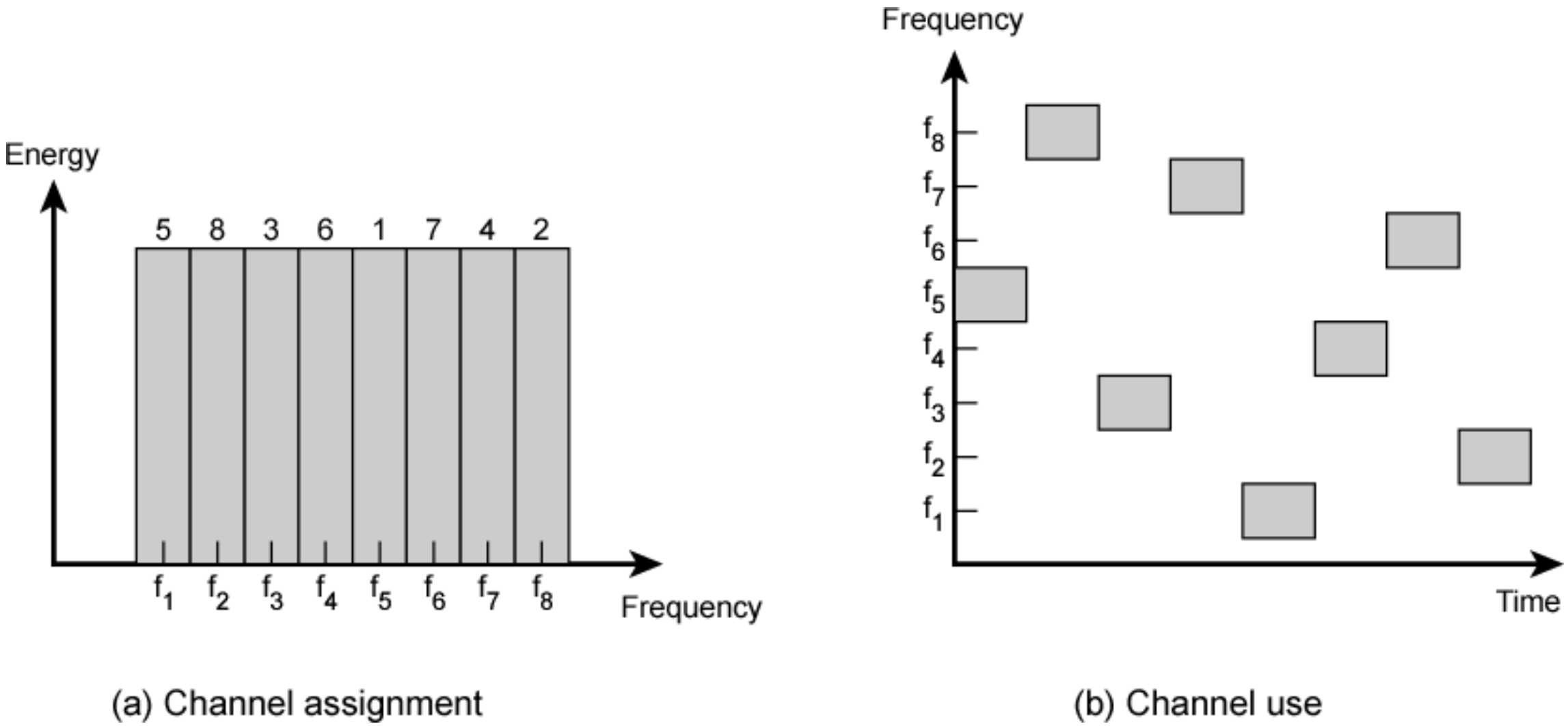


"Inventions are easy for me to do, the Austrian accented LaMarr says in 'Bombshell.' I don't have to work on ideas, they come naturally."

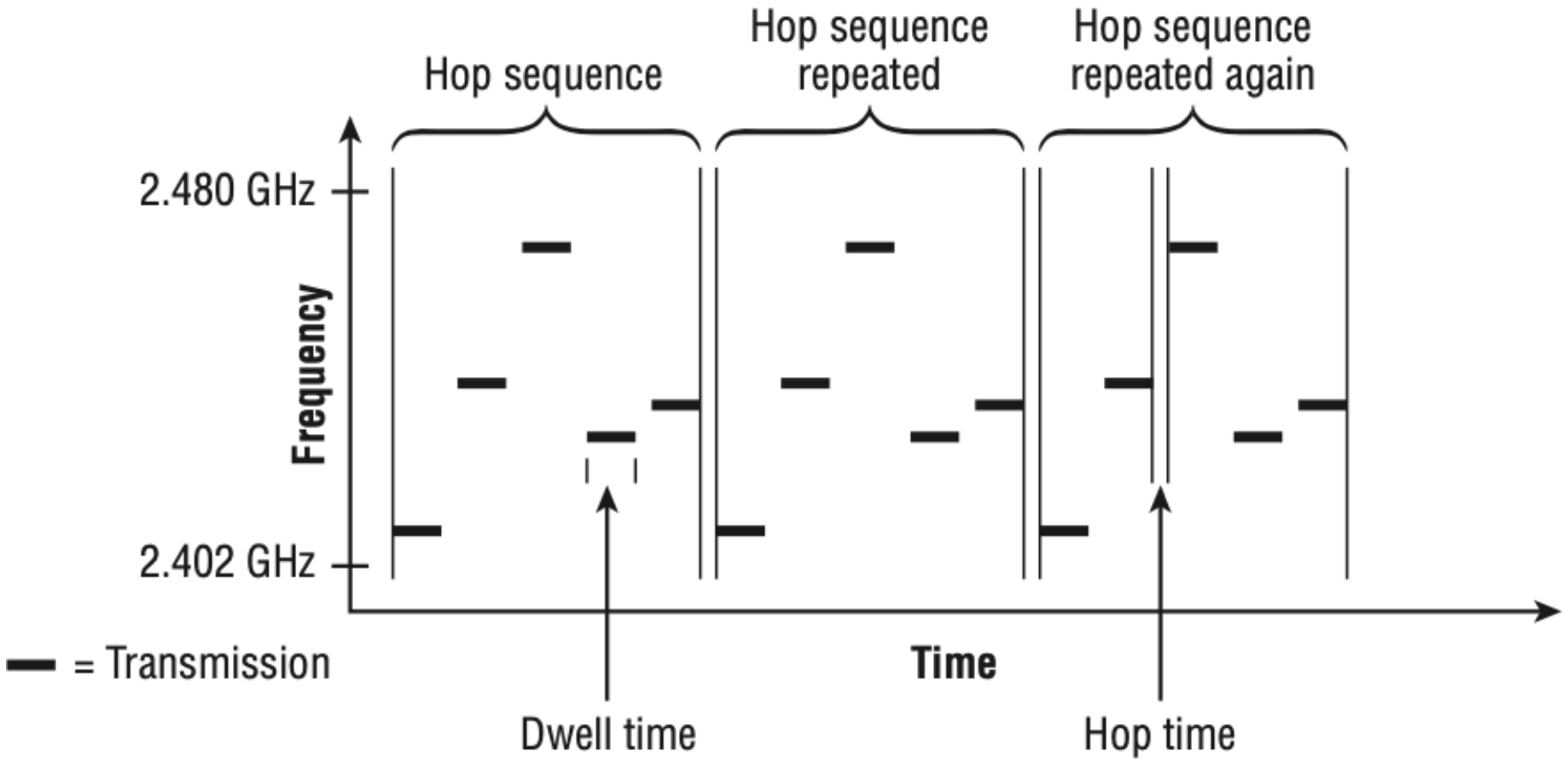
Frequency-Hop Spread Spectrum

- The type of spread spectrum in which the carrier hops randomly from one frequency to another is called *frequency-hop (FH) spread spectrum*
- A common modulation format for FH system is that of a *M-ary frequency-shift keying (MFSK)*
- Since, the hopping does not cover the entire spread spectrum instantaneously, we are led to consider the rate at which the hops occur

Frequency Hopping Example



Frequency Hopping Example



Frequency-Hop Spread Spectrum

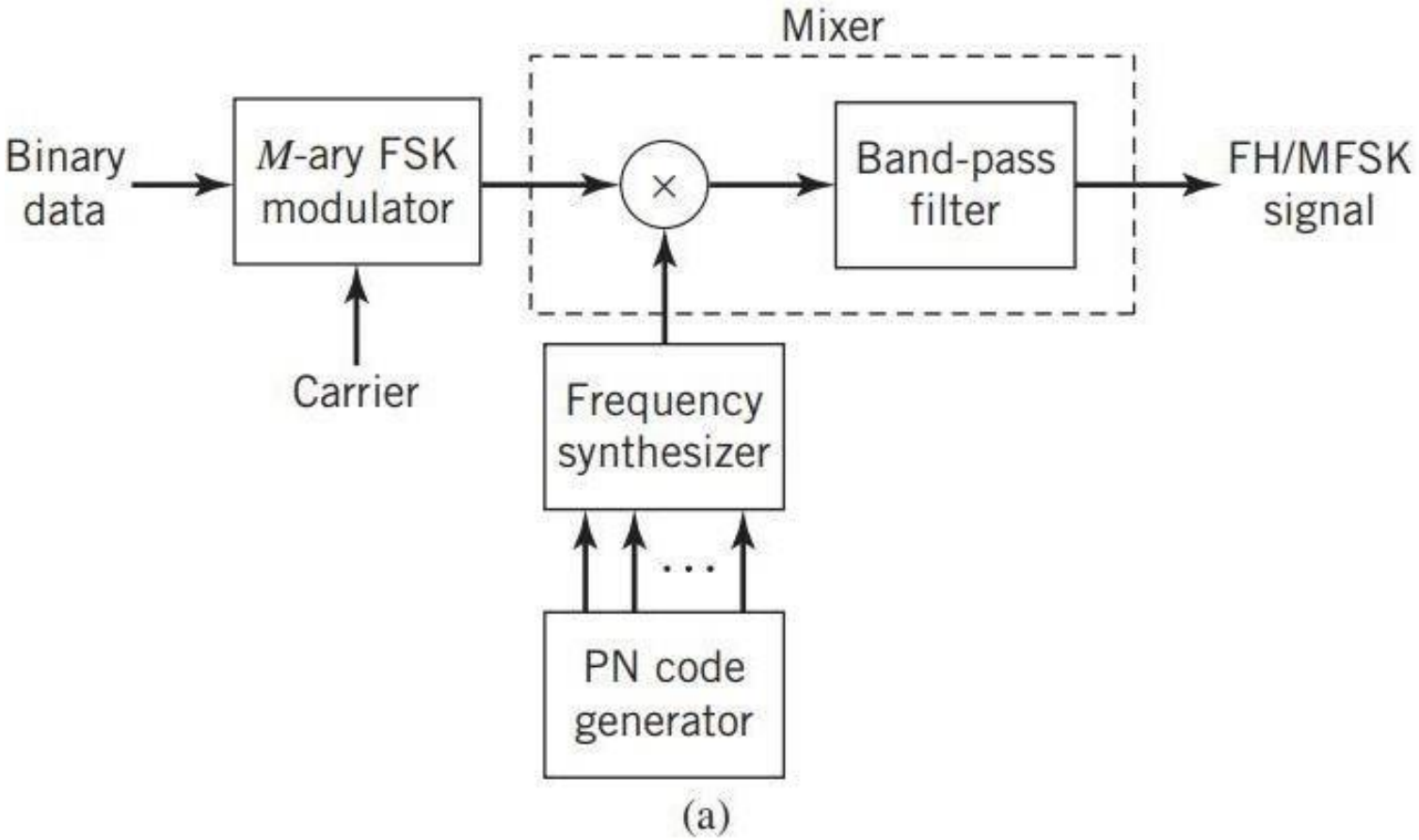
- Two basic (technology-independent) characterization of frequency hopping are identified as:

i. *Slow-frequency hoping*, in which the **symbol rate R_s** of the MFSK signal is an integer multiple of the ***hop rate R_h***

ii. *Fast-frequency hoping*, in which the **hop rate R_h** is an integer multiple of the of the MFSK signal R_s

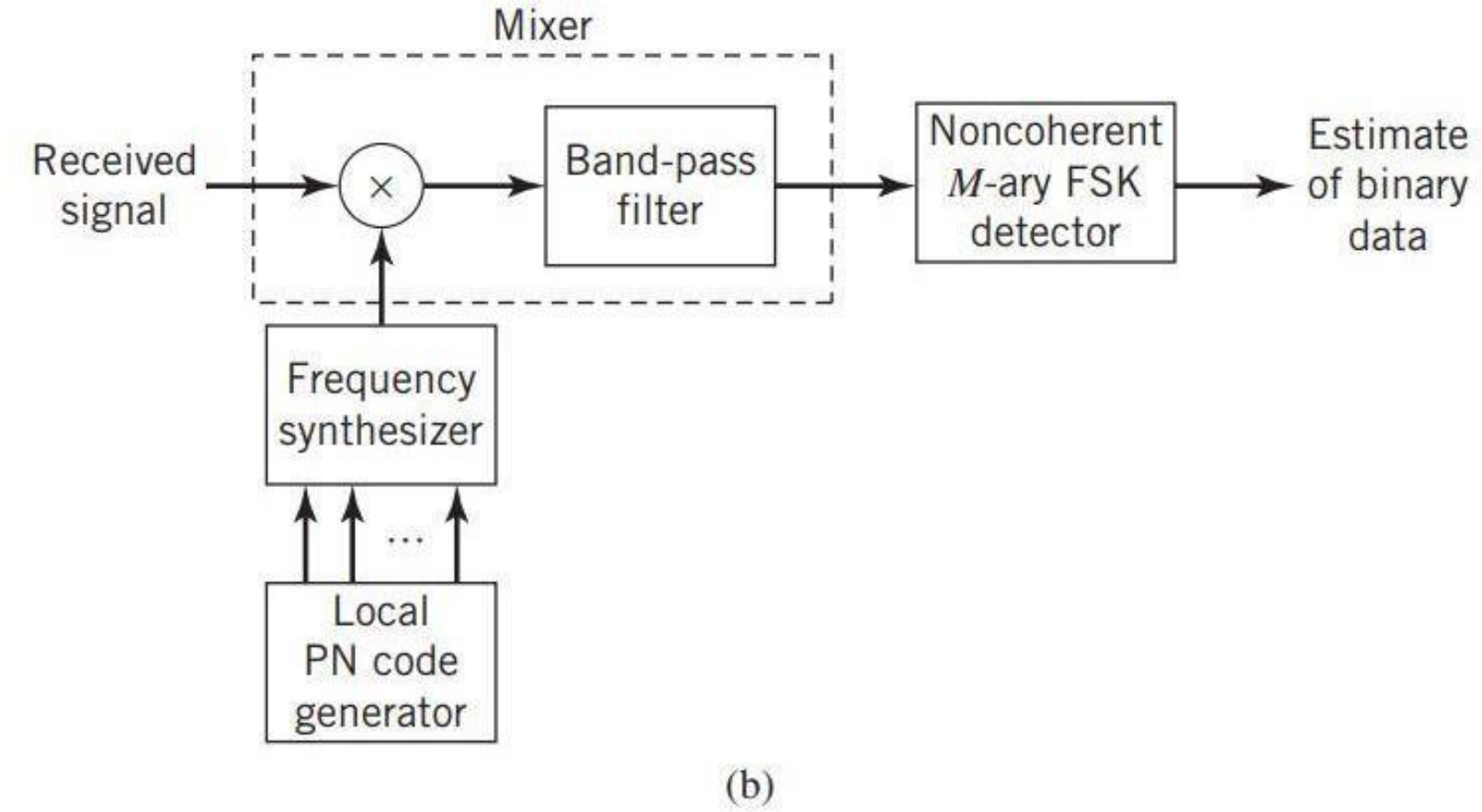
Slow-Frequency Hopping

- Frequency-hop M-ary frequency-shift keying:Transmitter



Slow-Frequency Hopping

- Frequency-hop M-ary frequency-shift keying: Receiver



(b)

Slow-Frequency Hopping

- The fig (a) shows the block diagram of an FH/MFSK transmitter, which involves *frequency modulation* followed by *mixing*

- In the receiver depicted in fig (b), the frequency hopping is first removed by *mixing* the received signal with the output of a local frequency synthesizer

- An individual FH/MFSK tone of shortest duration is referred to as a *chip*
- The *chip rate*, R_c, for an FH/MFSK system is given by: $\boldsymbol{R_c = max(R_h, R_s)}$
- Here, $\boldsymbol{R_h}$ **is the *hop rate*** and $\boldsymbol{R_s}$ **is the *symbol rate***

Slow-Frequency Hopping

- In a slow FH/MFSK system, the bit rate R_b, the symbol rate R_s, the chip rate R_c, and the hop rate R_h are related by:

$$R_c = R_s = \frac{R_b}{K} \geq R_b \qquad where, K = \log_2 M$$

- The spread-spectrum system is characterized by *the symbol energy-to-noise spectral density ratio* given by:

$$\frac{E}{N_0} = \frac{P/J}{W_c/R_s}$$

- Here, W_c is the FH bandwidth
- The ratio P/J is the reciprocal of jamming margin

Slow-Frequency Hopping

- Also, the processing gain (PG) of the slow FH/MFSK system is given by:

$$PG = \frac{W_c}{R_s} = 2^k$$

- The processing gain (expressed in dB) is equal to $10 \log_{10} 2^k \cong 3k$

- Here, k is the length of the PN segment employed to select a fequency hop

Numerical

- Illustrate the variation of the frequency of a slow FH/MFSK signal with time for one complete period of the PN sequence. The FH/MFSK signal has the following parameters.

- Number of bits per MFSK symbol K=2
- Length of PN segment per hop k= 3
- Number of flip-slops in Shift register m= 4
- Number of MFSK tones M=?
- Total number of frequency hops = ?
- Period of PN sequence = ?
- Transmit two symbols in one hop

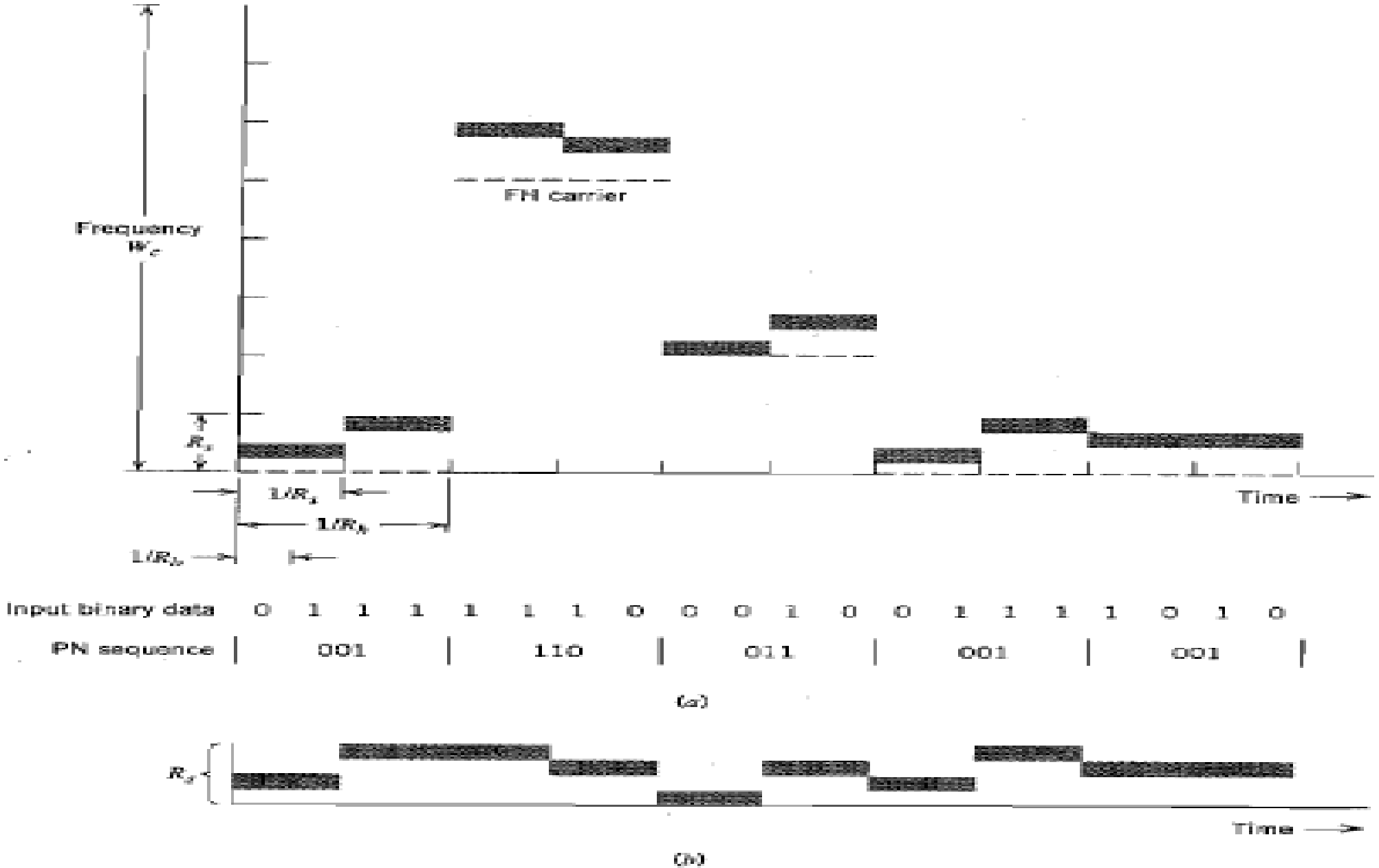
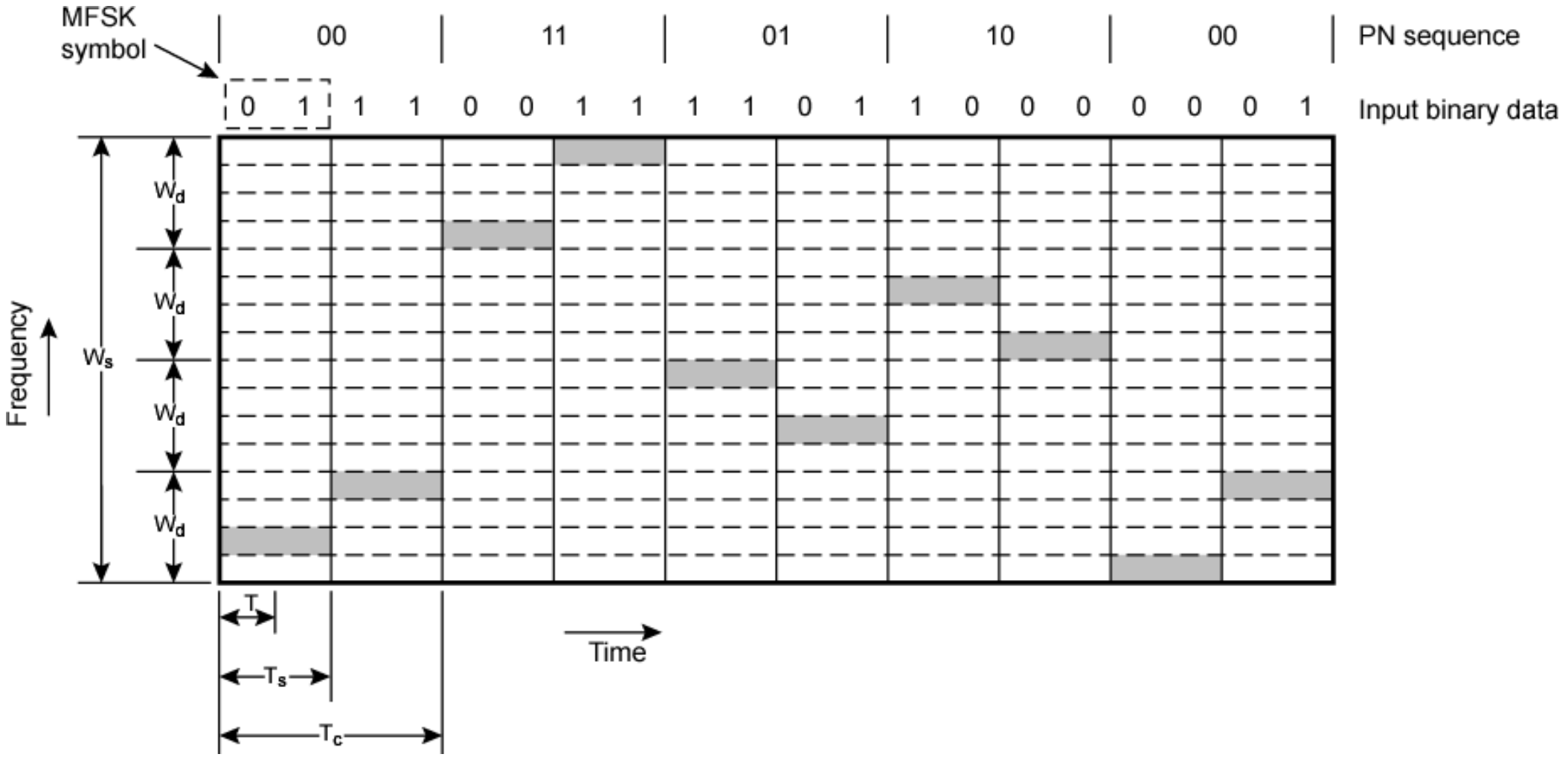


FIGURE 7.11 Illustrating slow-frequency hopping. (*a*) Frequency variation for one complete period of the PN sequence. (*b*) Variation of the dehopped frequency with time.

Slow Frequency Hop Spread Spectrum Using MFSK (M=4, k=2)

Slow Frequency Hop Spread Spectrum Using MFSK (M=4, k=2)



Fast-Frequency Hopping

- In general, a fast-frequency hopping is used to defeat a smart jammer's tactic that involves two functions:

i. Measurement of the spectral content of the transmitted signal

ii. Returning of the interfering signal to that portion of the frequency band

- To overcome the jammer, the transmitted signal must be hopped to a new carrier frequency before the jammer is able to process the two functions
- The data recovery at the receiver is noncoherent detection

Fast-Frequency Hopping

- The detection procedure of a fast-frequency hopping are:

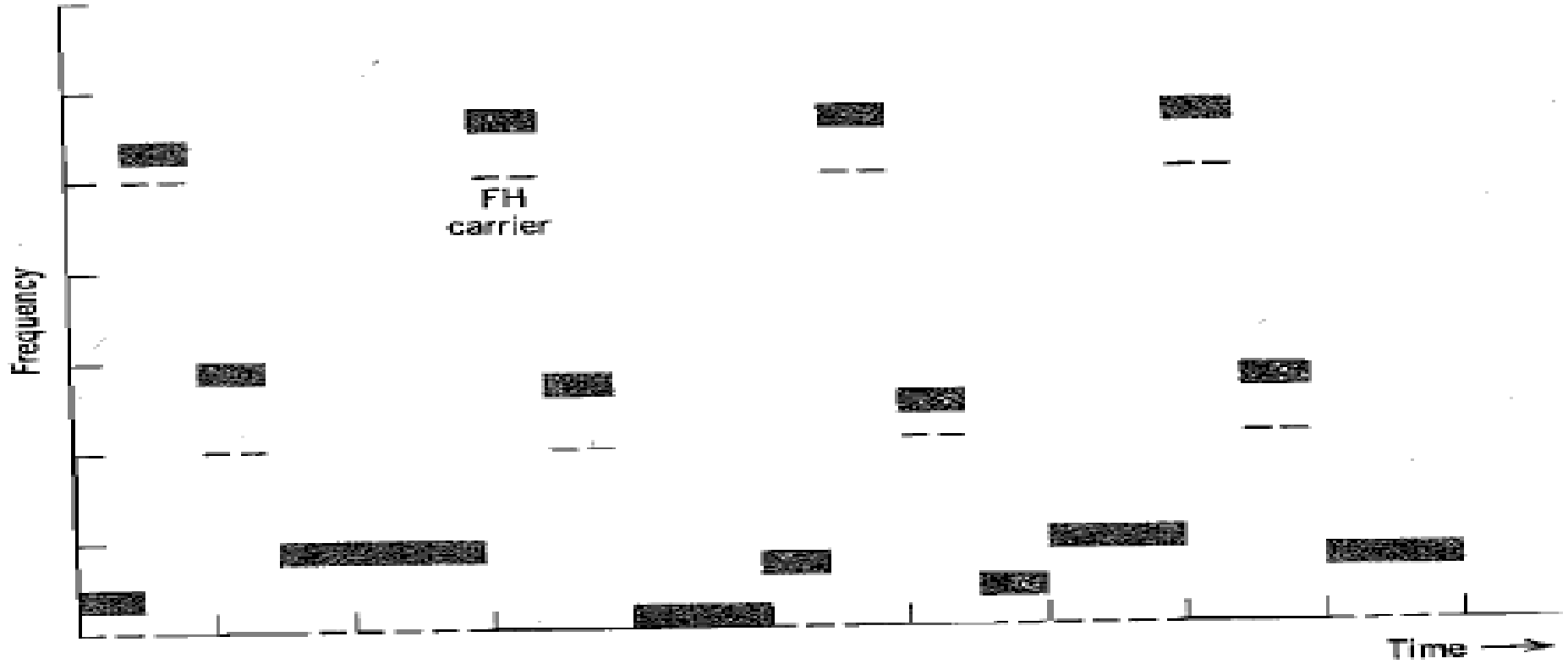
i. For each FH/MFSK symbol, separate decisions are made on the K frequency-hop chips received

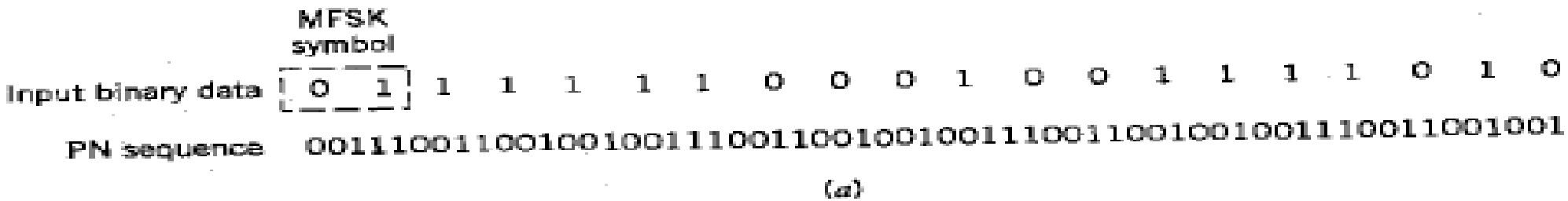
ii. For each FH/MFSK symbol, likelihood functions are computed as functions of the total signal received over K chips, and the largest one is selected

Numerical

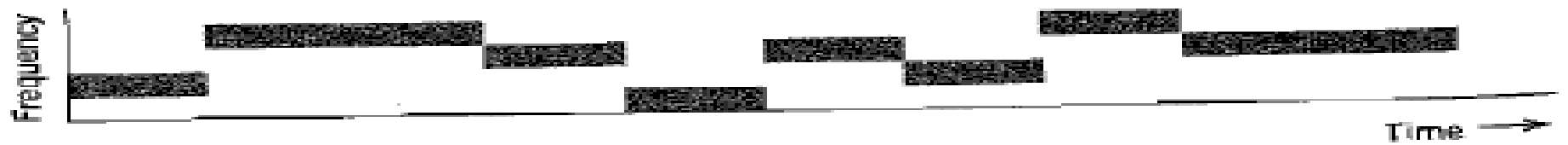
- Illustrate the variation of the frequency of a slow FH/MFSK signal with time. The FH/MFSK signal has the following parameters.

- Number of bits per MFSK symbol K=2
- Length of PN segment per hop k= 3
- Number of MFSK tones M=?
- Total number of frequency hops = ?
- Transmit one symbol in two hop


Frequency
FH
carrier
Time

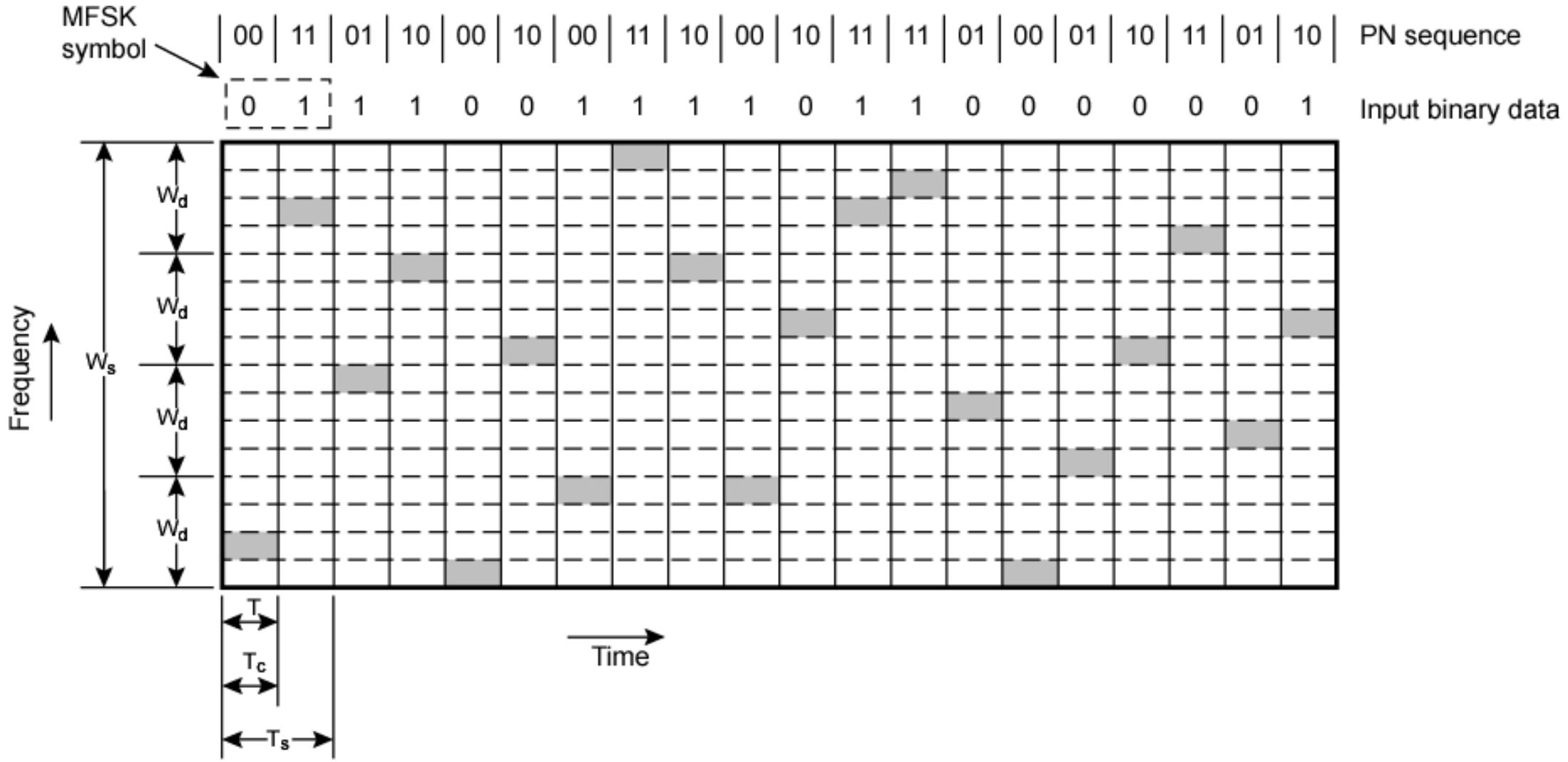

MFSK
symbol
Input binary data
0 1 1 1 1 1 0 0 0 1 0 0 1 1 1 1 0 1 0
PN sequence
001110011001001001110011001001001110011001001

(*a*)

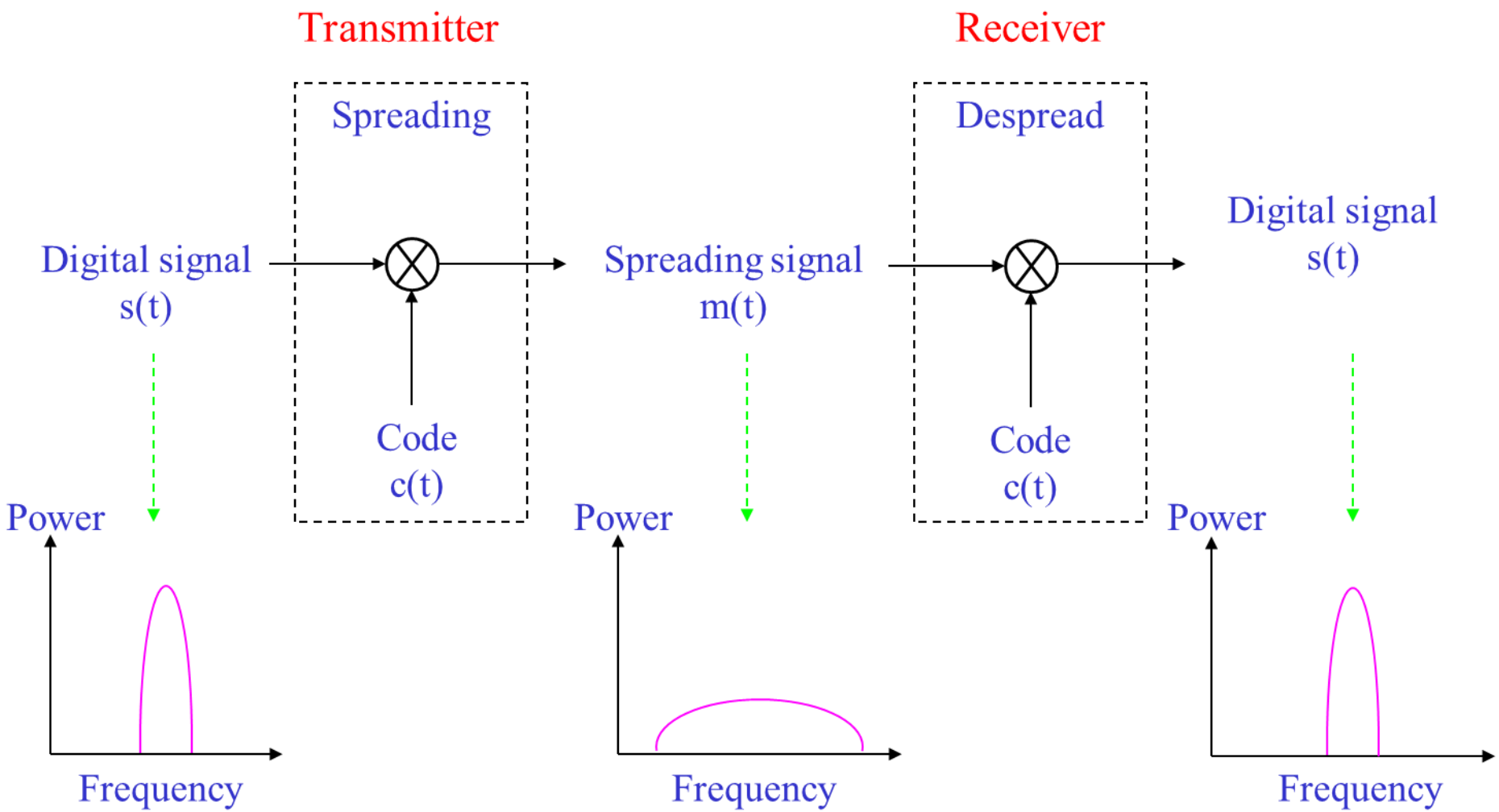

Frequency
Time

Fast Frequency Hop Spread Spectrum Using MFSK (M=4, k=2)

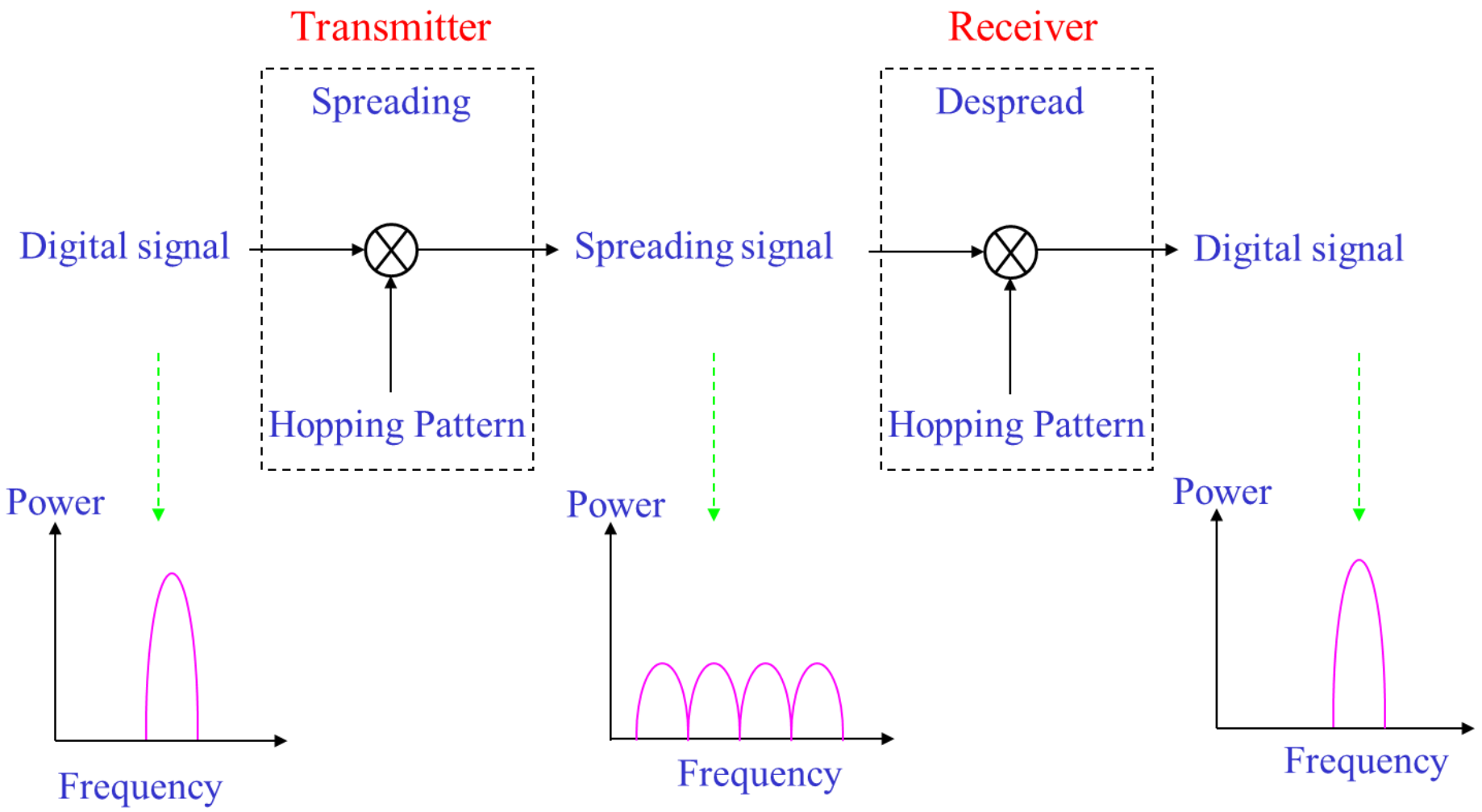
Fast Frequency Hop Spread Spectrum Using MFSK (M=4, k=2)



Concept of Direct Sequence Spread Spectrum



Concept of Frequency Hopping Spread Spectrum



Benefits of Spread Spectrum