실시간 통신과 IoT

(CC533)

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Spread Spectrum

CONTENTS

- Spread Spectrum
- Frequency Hopping Spread Spectrum
- Direct Sequence Spread Spectrum
- Code Division Multiple Access

SPREAD SPECTRUM

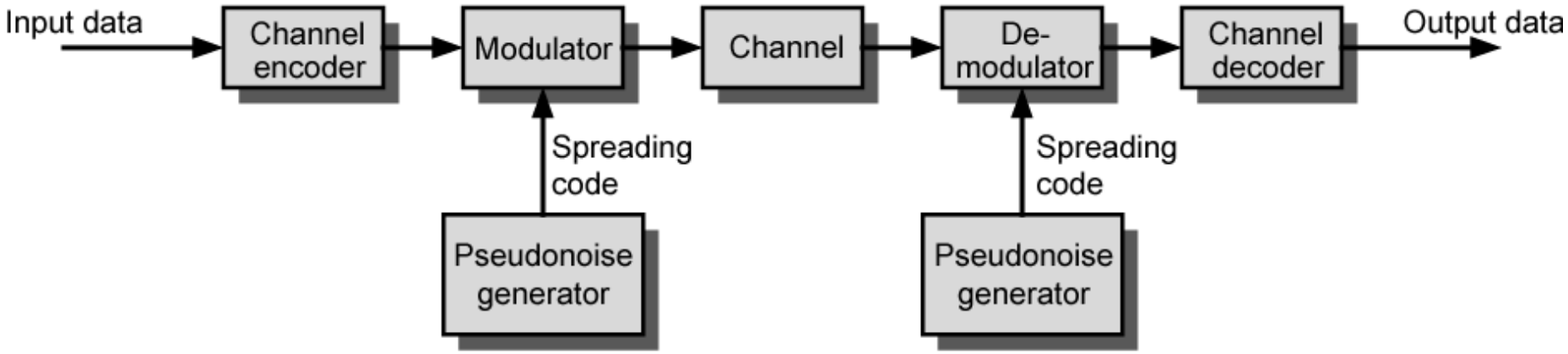
- **Spread spectrum overview**
  - Spread data over wide bandwidth
  - Makes jamming and interception harder
  - 2 methods
    - Frequency hoping
      - Signal broadcast over seemingly random series of frequencies
    - Direct Sequence
      - Each bit is represented by multiple bits in transmitted signal
      - Chipping code

SPREAD SPECTRUM

- **Spread spectrum concept**
  - Input fed into channel encoder
    - Produces narrow bandwidth analog signal around central frequency
  - Signal modulated using sequence of digits
    - Spreading code/sequence
    - Typically generated by pseudonoise/pseudorandom number generator
  - Increases bandwidth significantly
    - Spreads spectrum
  - Receiver uses same sequence to demodulate signal
  - Demodulated signal fed into channel decoder

SPREAD SPECTRUM

General Model of Spread Spectrum System



SPREAD SPECTRUM

- **Gains**
  - Immunity from various noise and multipath distortion
    - Including jamming
  - Can hide/encrypt signals
    - Only receiver who knows spreading code can retrieve signal
  - Several users can share same higher bandwidth with little interference
    - Cellular telephones
    - Code division multiplexing (CDM)
    - Code division multiple access (CDMA)

SPREAD SPECTRUM

- **Pseudorandom Numbers**
  - Generated by algorithm using initial seed
  - Deterministic algorithm
    - Not actually random
    - If algorithm good, results pass reasonable tests of randomness
  - Need to know algorithm and seed to predict sequence

FREQUENCY HOPPING SPREAD SPECTRUM

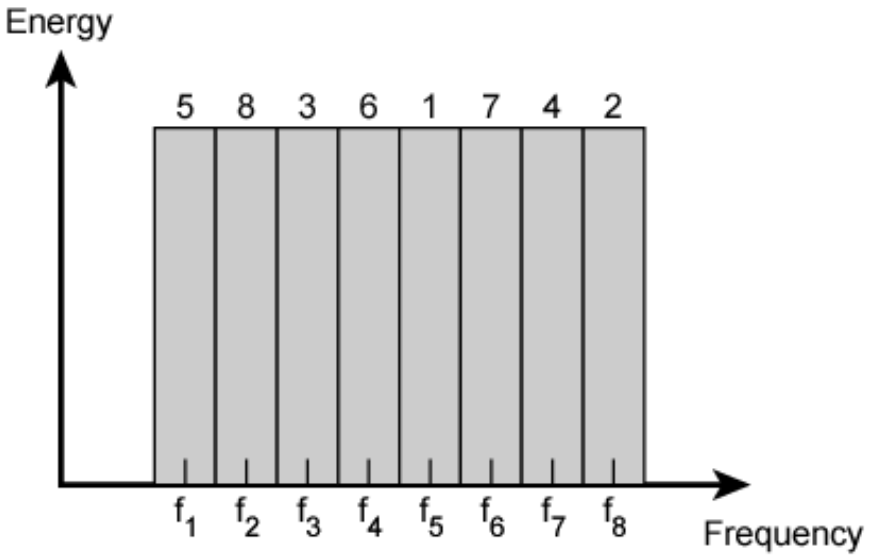
- **Frequency Hopping Spread Spectrum (FHSS) Overview**
  - Signal broadcast over seemingly random series of frequencies
  - Receiver hops between frequencies in sync with transmitter
  - Eavesdroppers hear unintelligible blips
  - Jamming on one frequency affects only a few bits

FREQUENCY HOPPING SPREAD SPECTRUM

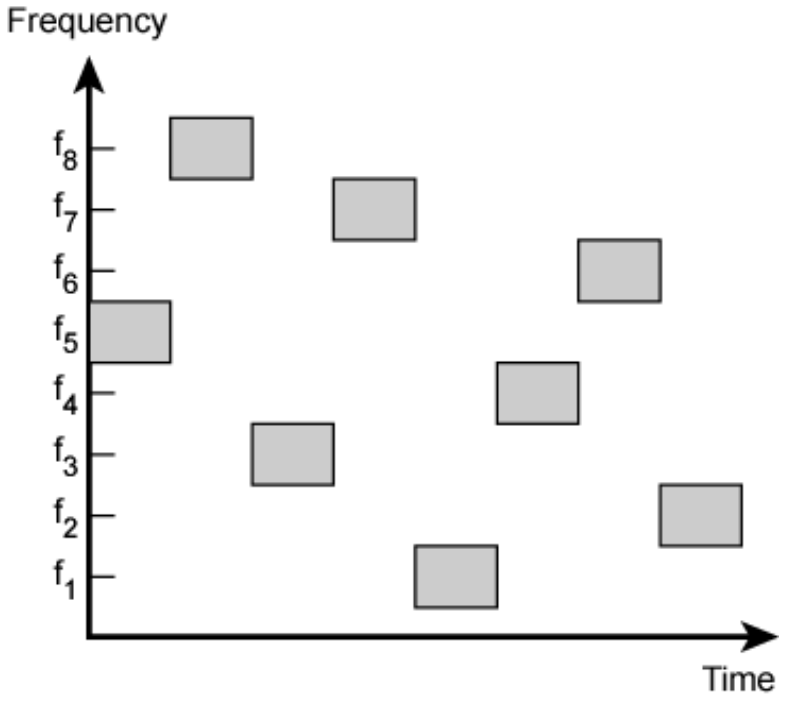
- **Basic Operation**
  - Typically 2^k carriers frequencies forming 2^k channels
  - Channel spacing corresponds with bandwidth of input
  - Each channel used for fixed interval
    - 300 ms in IEEE 802.11
    - Some number of bits transmitted using some encoding scheme
    - May be fractions of bit (see later)
    - Sequence dictated by spreading code

FREQUENCY HOPPING SPREAD SPECTRUM

- **Frequency Hopping Example**



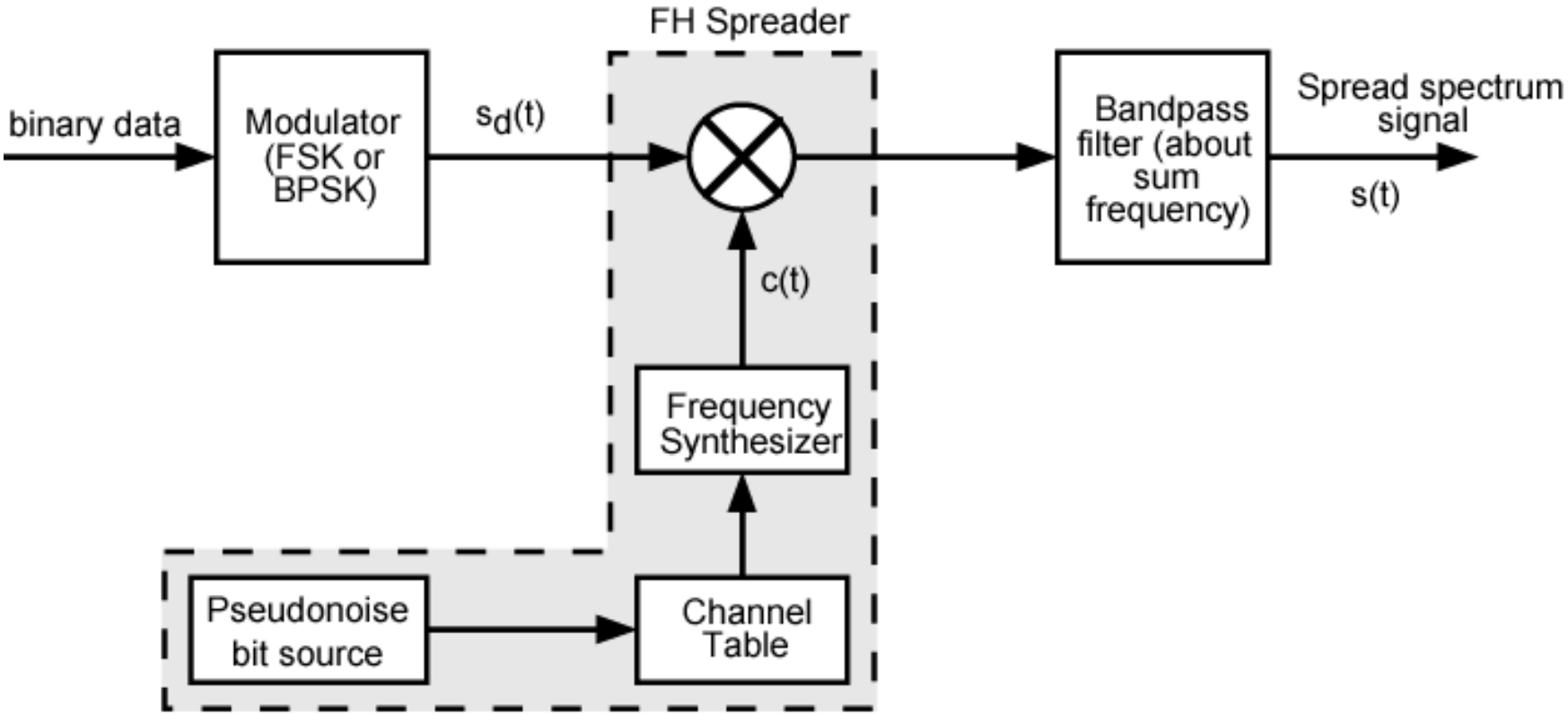
(a) Channel assignment



(b) Channel use

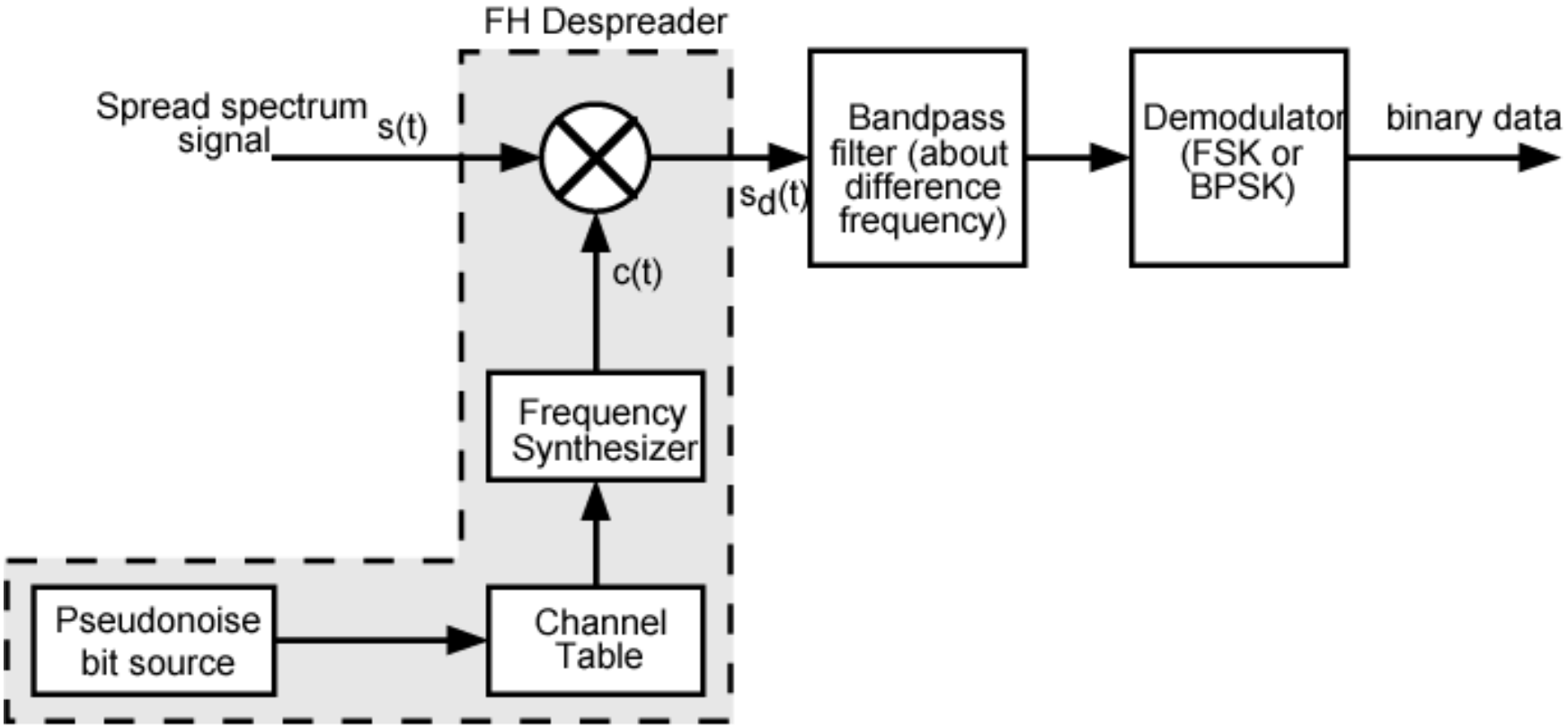
FREQUENCY HOPPING SPREAD SPECTRUM

- **FHSS System (Transmitter)**



FREQUENCY HOPPING SPREAD SPECTRUM

- **FHSS System (Receiver)**

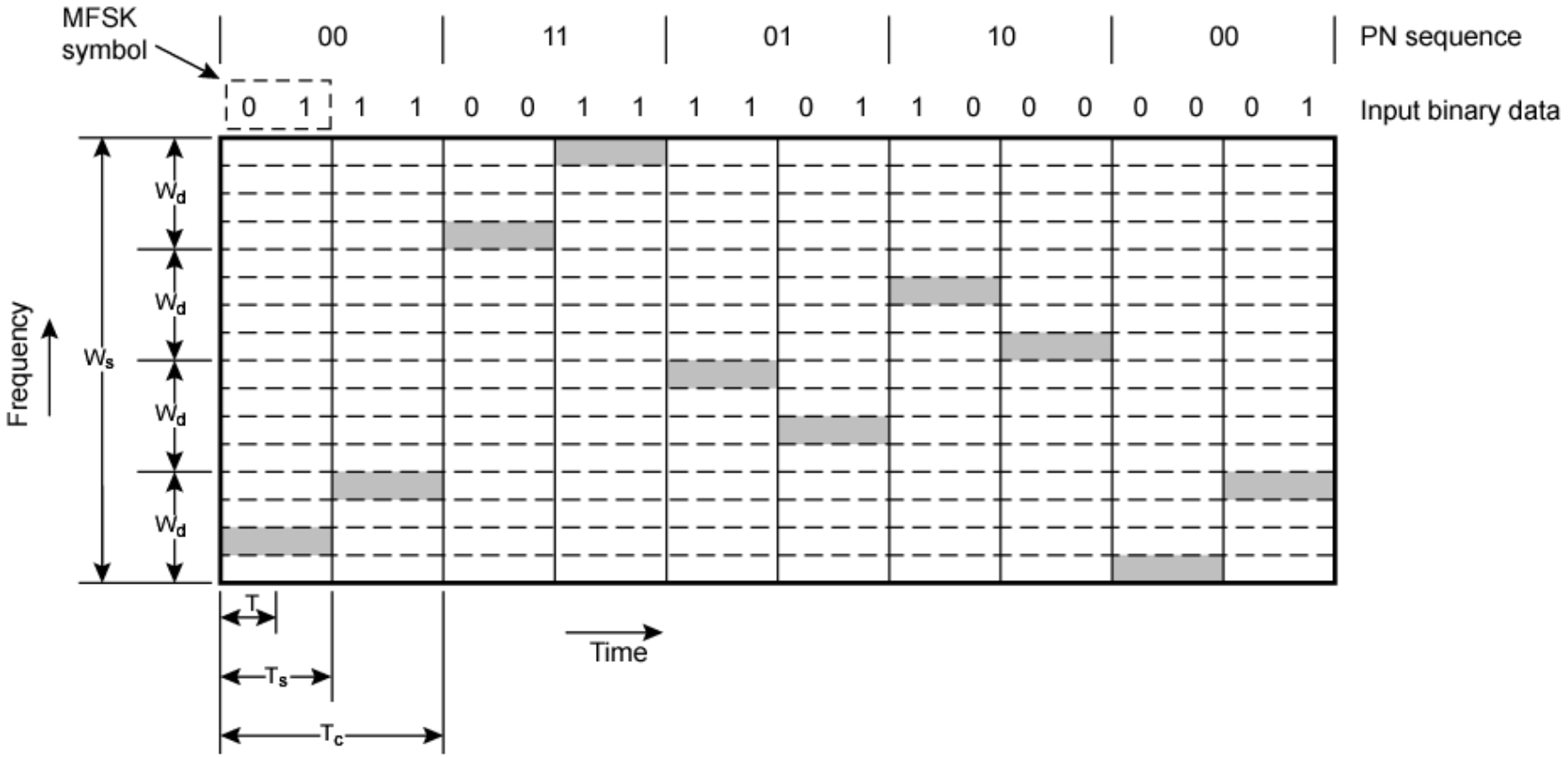


FREQUENCY HOPPING SPREAD SPECTRUM

- **Slow and Fast FHSS**
  - Frequency shifted every T_c seconds
  - Duration of signal element is T_s seconds
  - Slow FHSS has $T_c >= T_s$
  - Fast FHSS has $T_c < T_s$
  - Generally fast FHSS gives improved performance in noise (or jamming)

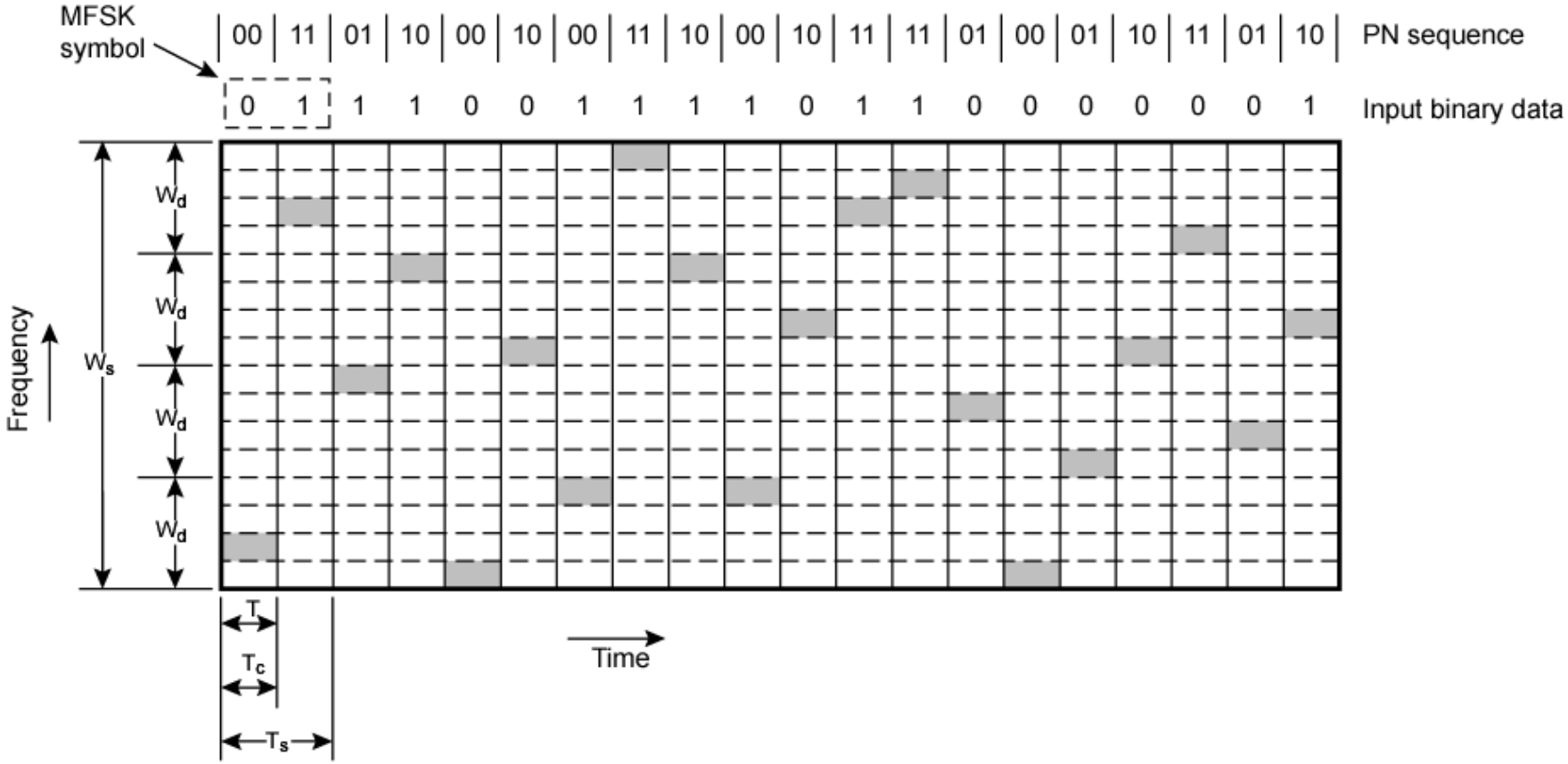
FREQUENCY HOPPING SPREAD SPECTRUM

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



FREQUENCY HOPPING SPREAD SPECTRUM

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



FREQUENCY HOPPING SPREAD SPECTRUM

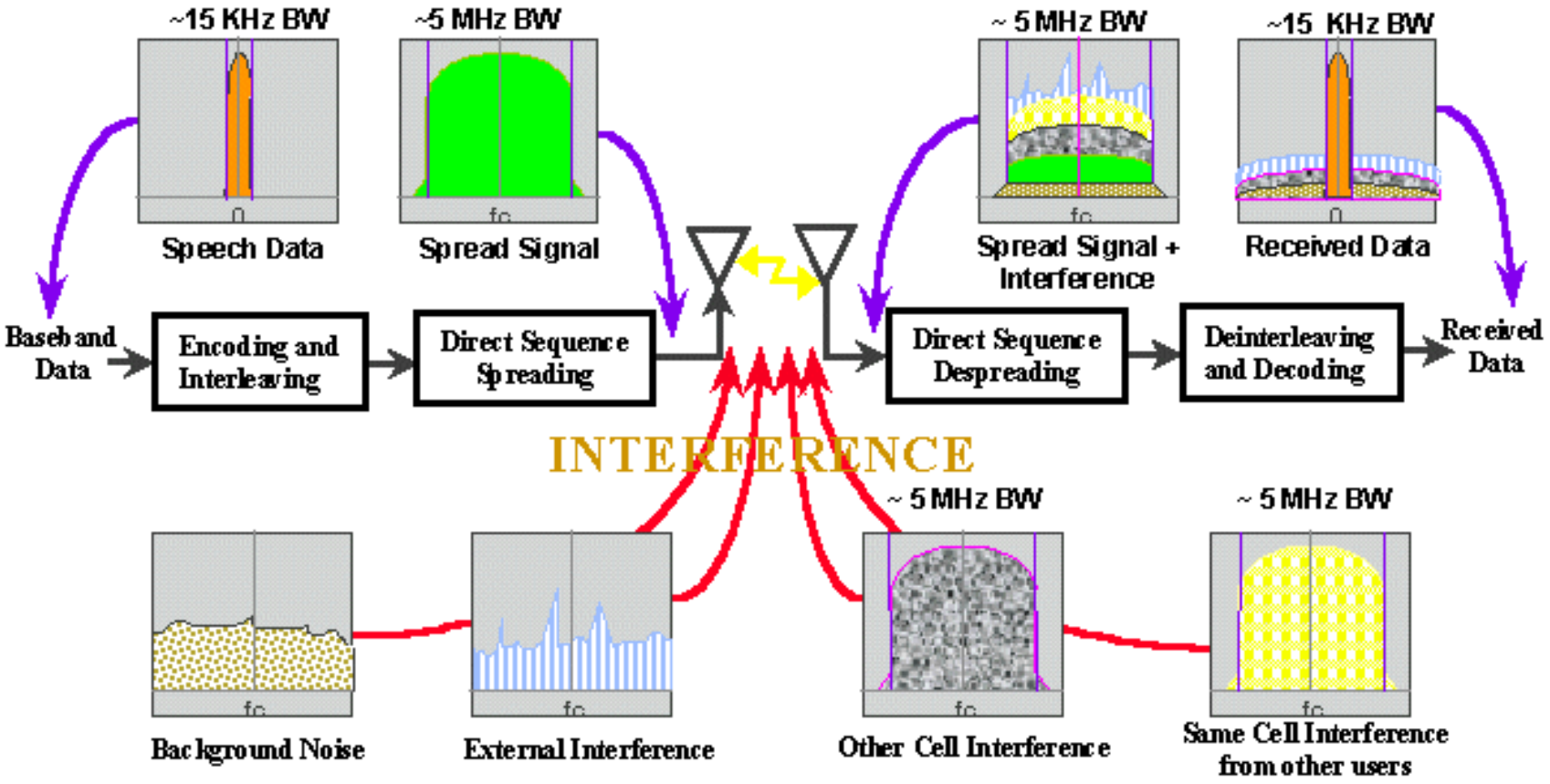
- **FHSS Performance Considerations**
  - Typically large number of frequencies used
    - Improved resistance to jamming

DIRECT SEQUENCE SPREAD SPECTRUM

- **Direct Sequence Spread Spectrum (DSSS) Overview**
  - Each bit represented by multiple bits using spreading code
  - Spreading code spreads signal across wider frequency band
    - In proportion to number of bits used
    - 10 bit spreading code spreads signal across 10 times bandwidth of 1 bit code
  - One method:
    - Combine input with spreading code using XOR
    - Input bit 1 inverts spreading code bit
    - Input zero bit doesn't alter spreading code bit
    - Data rate equal to original spreading code
  - Performance similar to FHSS

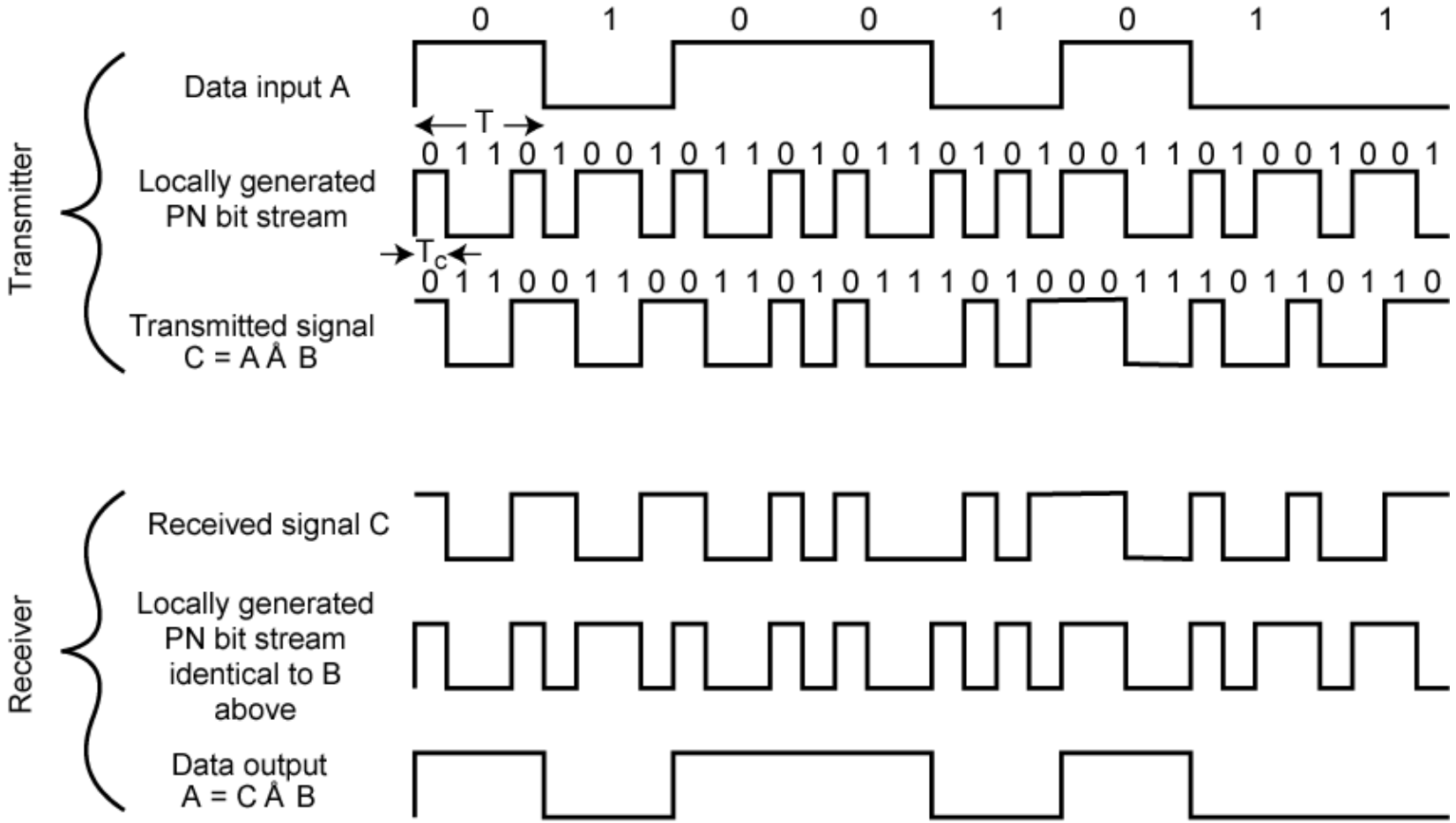
DIRECT SEQUENCE SPREAD SPECTRUM

- DSSS Interference



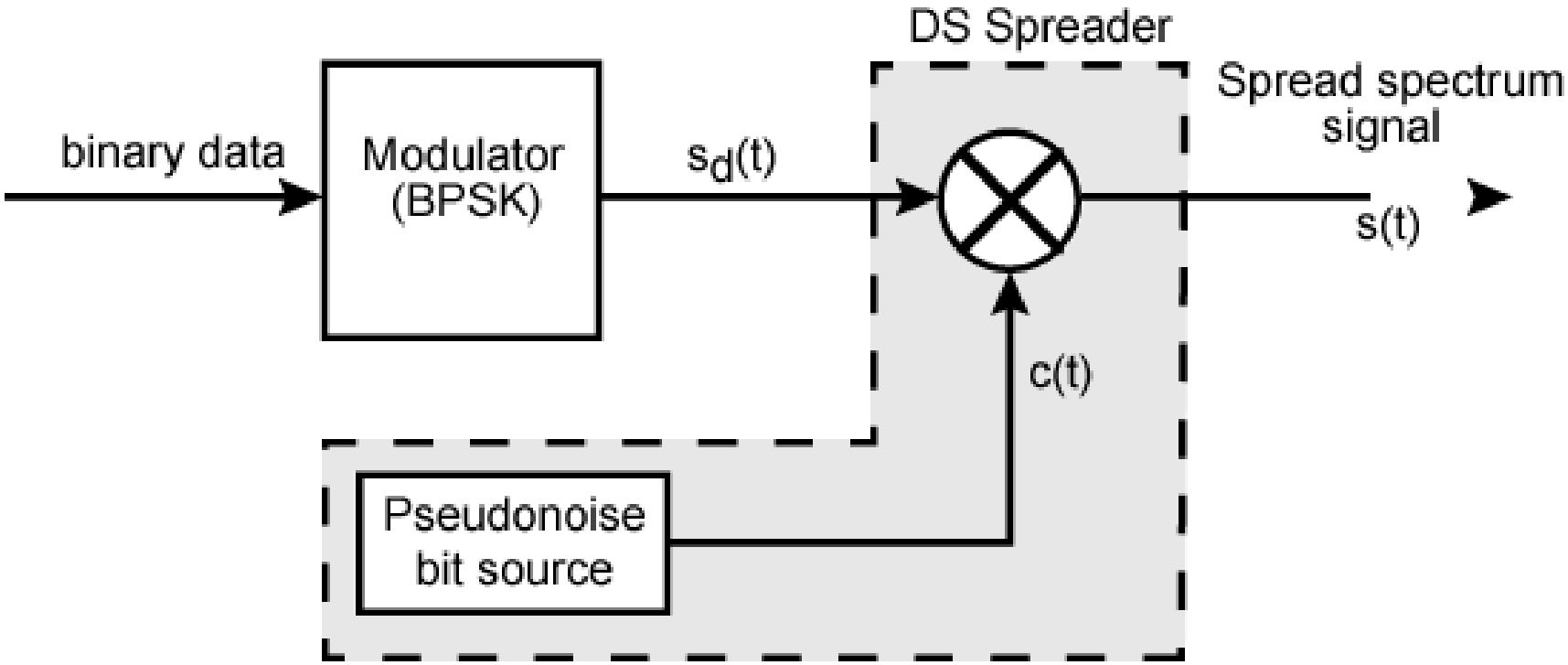
DIRECT SEQUENCE SPREAD SPECTRUM

- **DSSS Example**



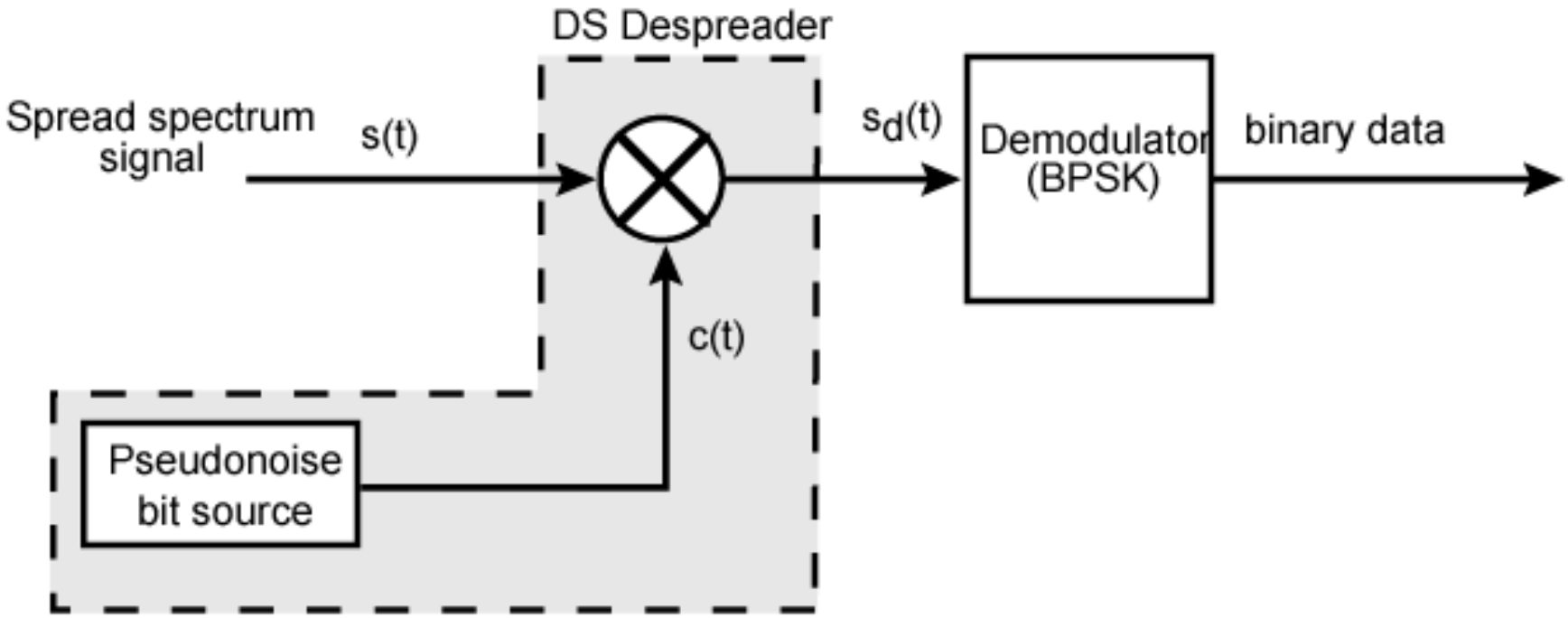
DIRECT SEQUENCE SPREAD SPECTRUM

- **DSSS Transmitter**



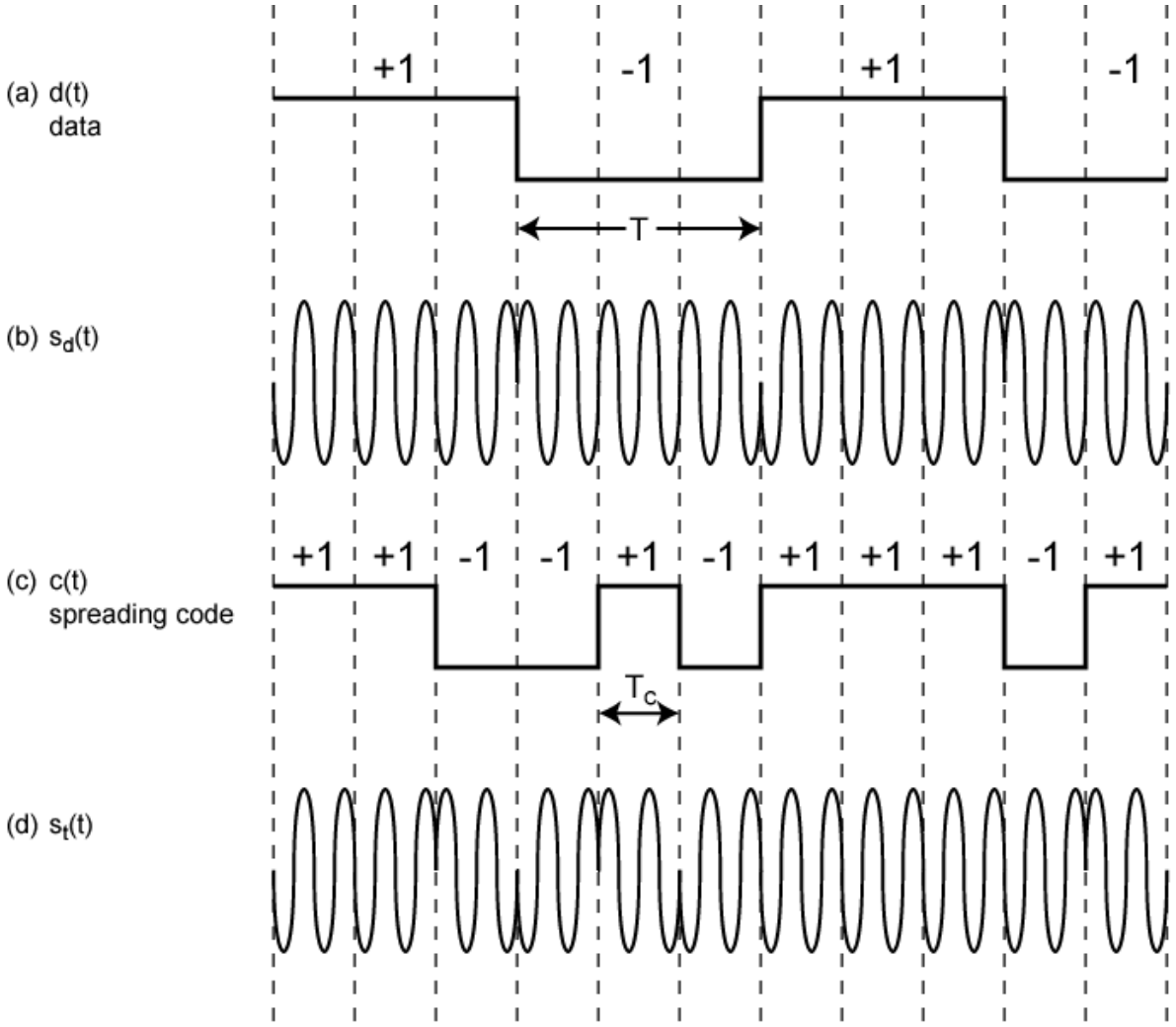
DIRECT SEQUENCE SPREAD SPECTRUM

- **DSSS Receiver**

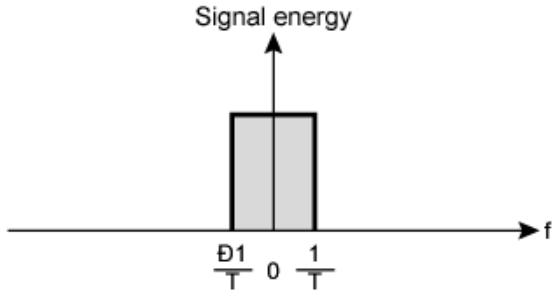


DIRECT SEQUENCE SPREAD SPECTRUM

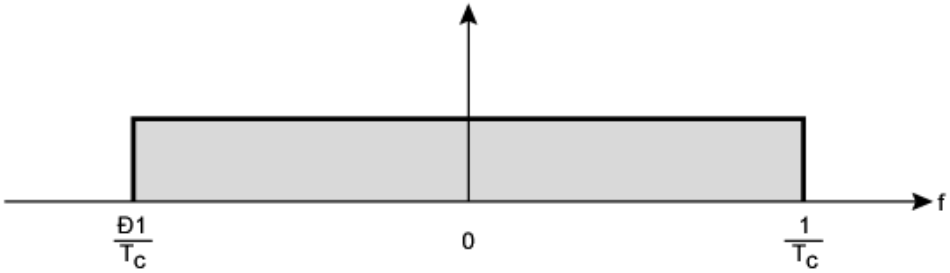
- **DSSS Using BPSK Example**



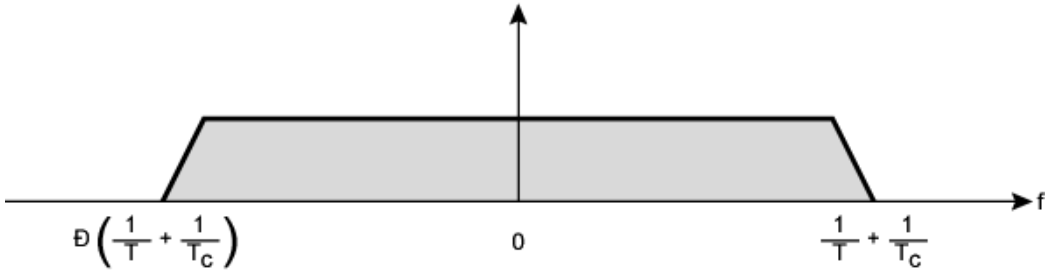
Approximate Spectrum of DSSS Signal



(a) Spectrum of data signal



(b) Spectrum of pseudonoise signal



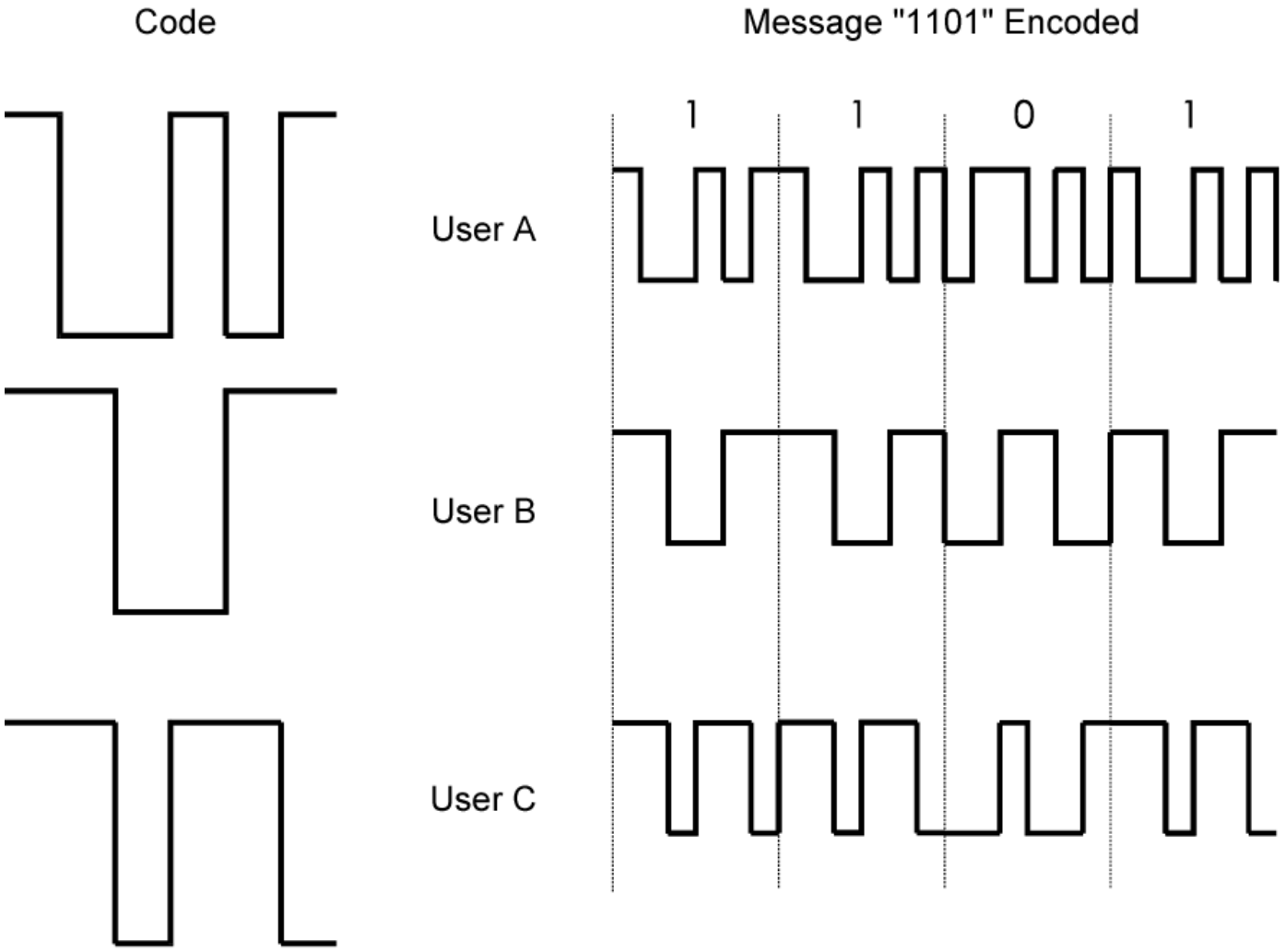
(c) Spectrum of combined signal

CODE DIVISION MULTIPLE ACCESS

- **Code Division Multiple Access (CDMA)**
  - Multiplexing Technique used with spread spectrum
  - Start with data signal rate *D*
    - Called bit data rate
  - Break each bit into *k* chips according to fixed pattern specific to each user
    - User's code
  - New channel has chip data rate *kD* chips per second
  - E.g. *k*=6, three users (A,B,C) communicating with base receiver R
  - Code for A = <1,-1,-1,1,-1,1>
  - Code for B = <1,1,-1,-1,1,1>
  - Code for C = <1,1,-1,1,1,-1>

CODE DIVISION MULTIPLE ACCESS

- **CDMA Example**



CODE DIVISION MULTIPLE ACCESS

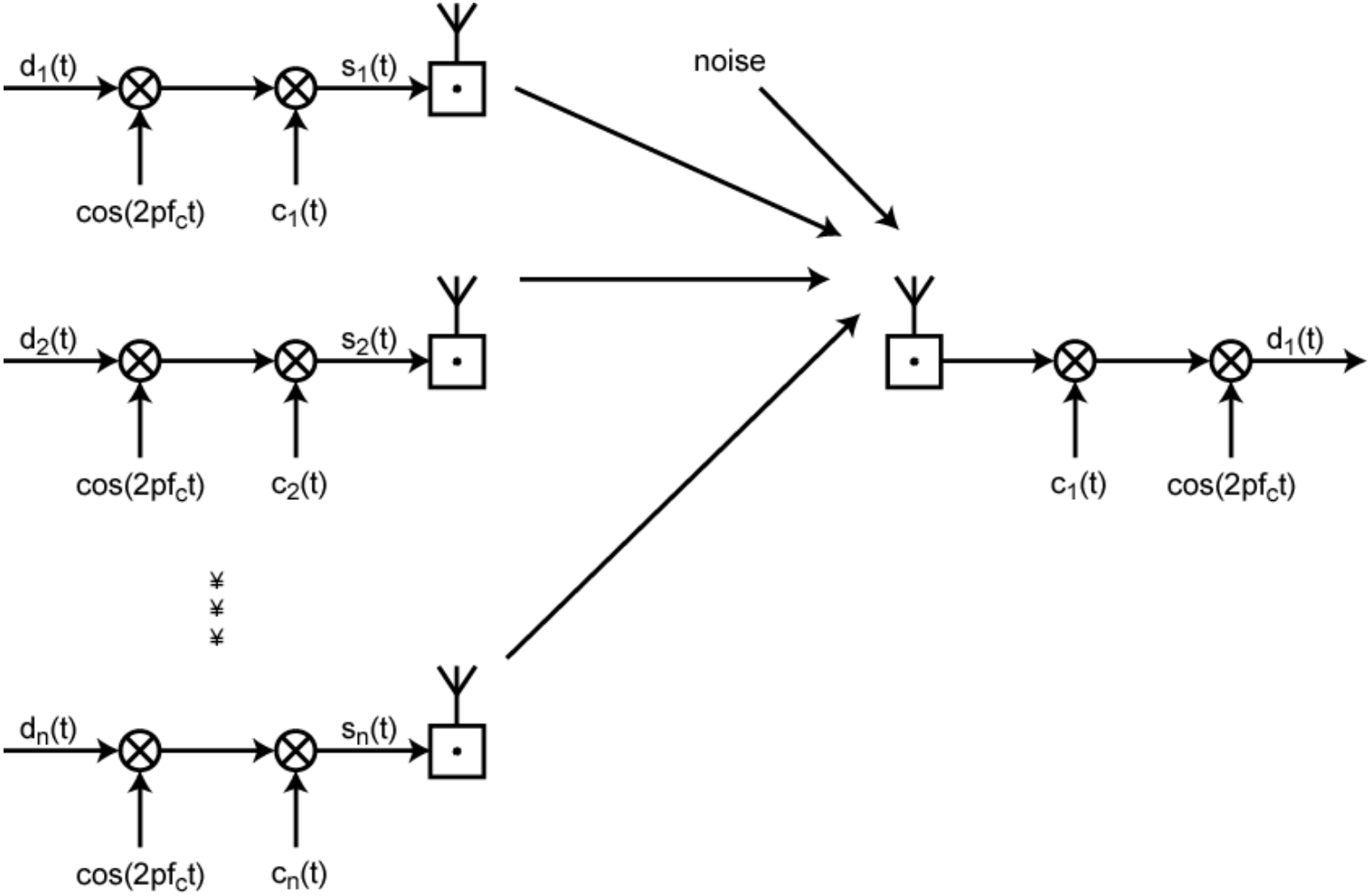
- **CDMA Explanation**
  - Consider A communicating with base
  - Base knows A's code
  - Assume communication already synchronized
  - A wants to send a 1
    - Send chip pattern <1,-1,-1,1,-1,1>
      - A's code
  - A wants to send 0
    - Send chip[pattern <-1,1,1,-1,1,-1>
      - Complement of A's code
  - Decoder ignores other sources when using A's code to decode
    - Orthogonal codes

CODE DIVISION MULTIPLE ACCESS

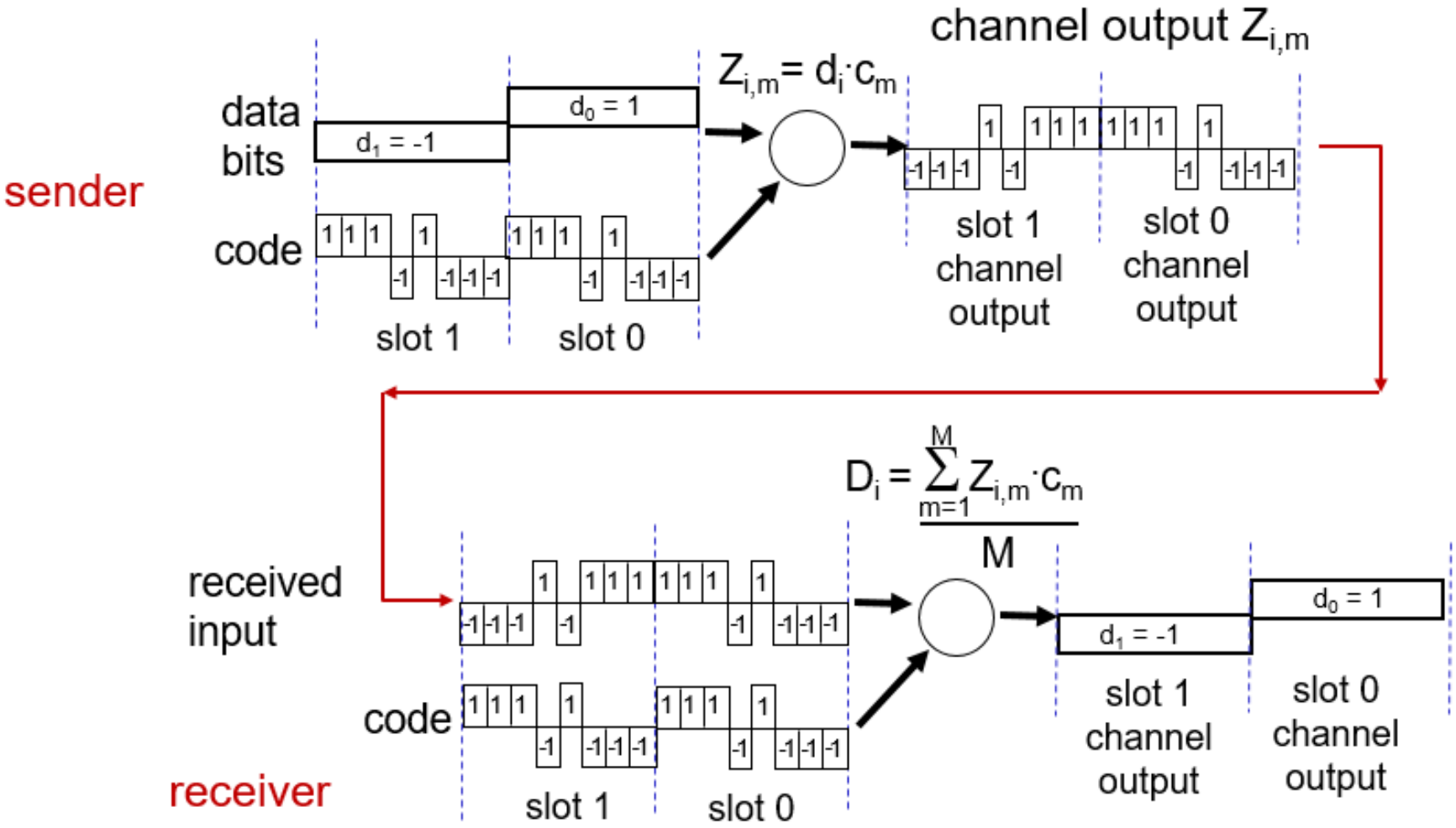
- **CDMA for DSSS**
  - *n* users each using different orthogonal PN sequence
  - Modulate each user's data stream
    - Using BPSK
  - Multiply by spreading code of user

CODE DIVISION MULTIPLE ACCESS

- **CDMA in a DSSS Environment**



CODE DIVISION MULTIPLE ACCESS



CODE DIVISION MULTIPLE ACCESS

4 Channel CDMA Encoding and Decoding