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Data and Computer Communications
7th Edition

Chapter 9 Add Text
Spread Spectrum

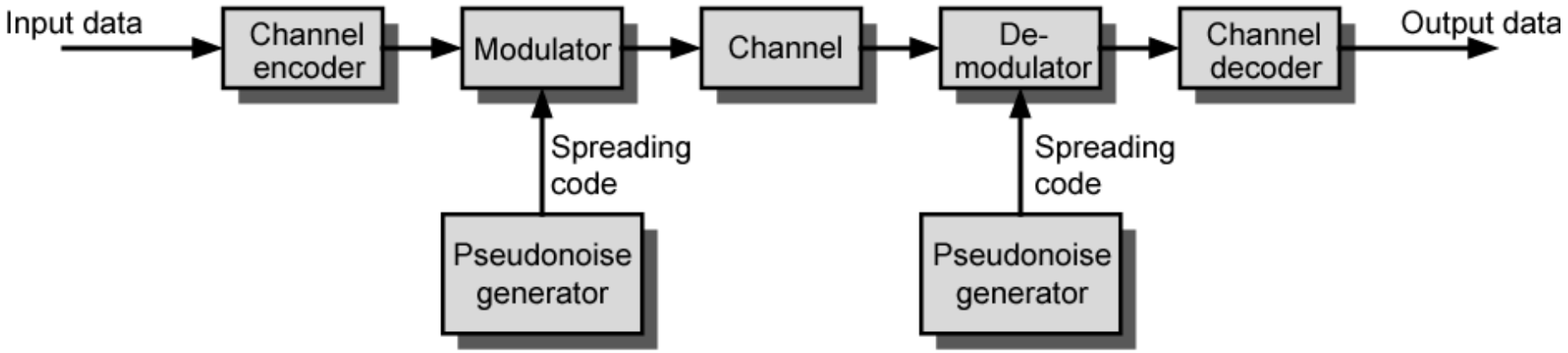
Spread Spectrum

- Analog or digital data
- Analog signal
- Spread data over wide bandwidth
- Makes jamming and interception harder
- 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 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

General Model of Spread Spectrum System



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)

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

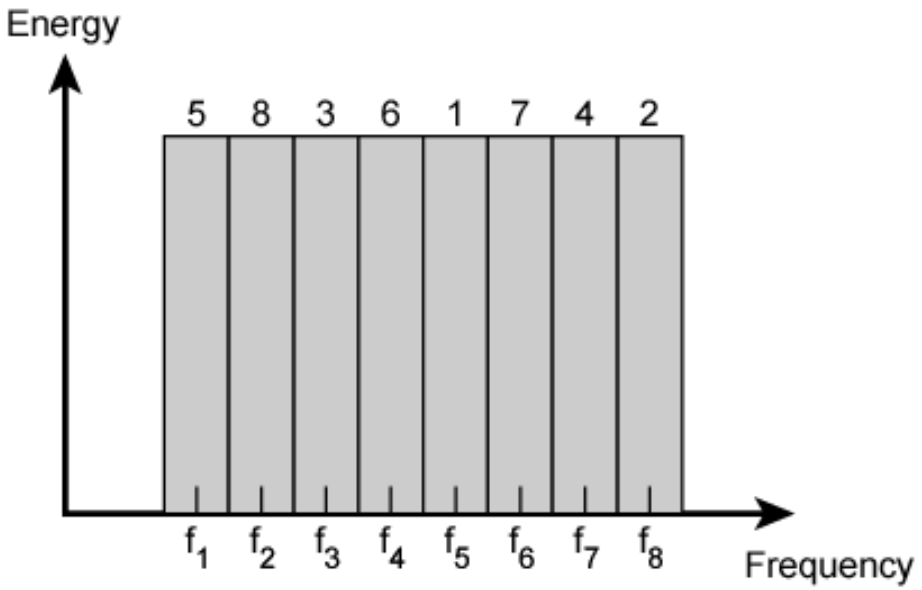
Frequency Hopping Spread Spectrum (FHSS)

- 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

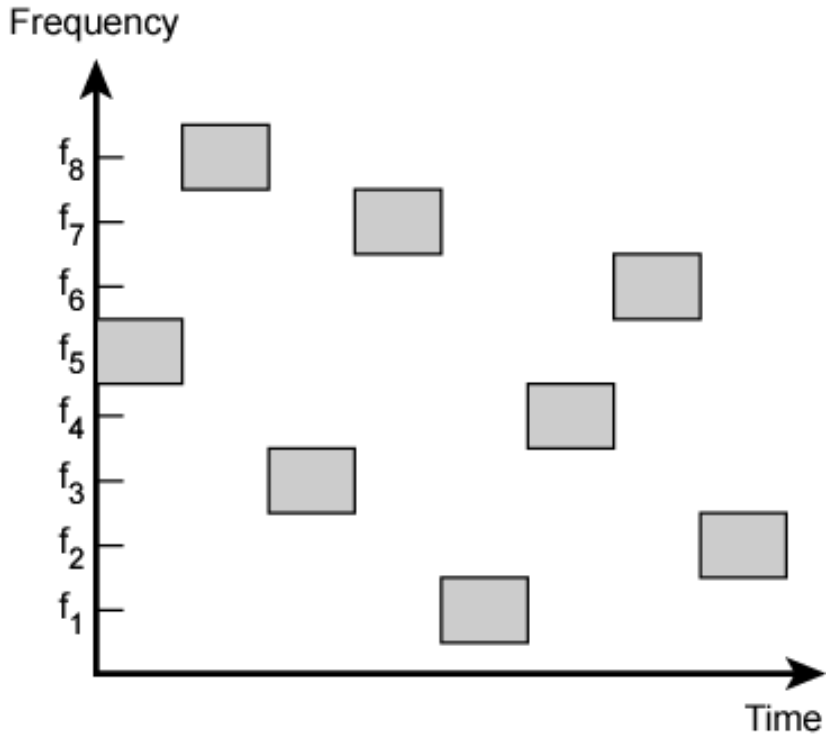
Basic Operation

- 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 Example

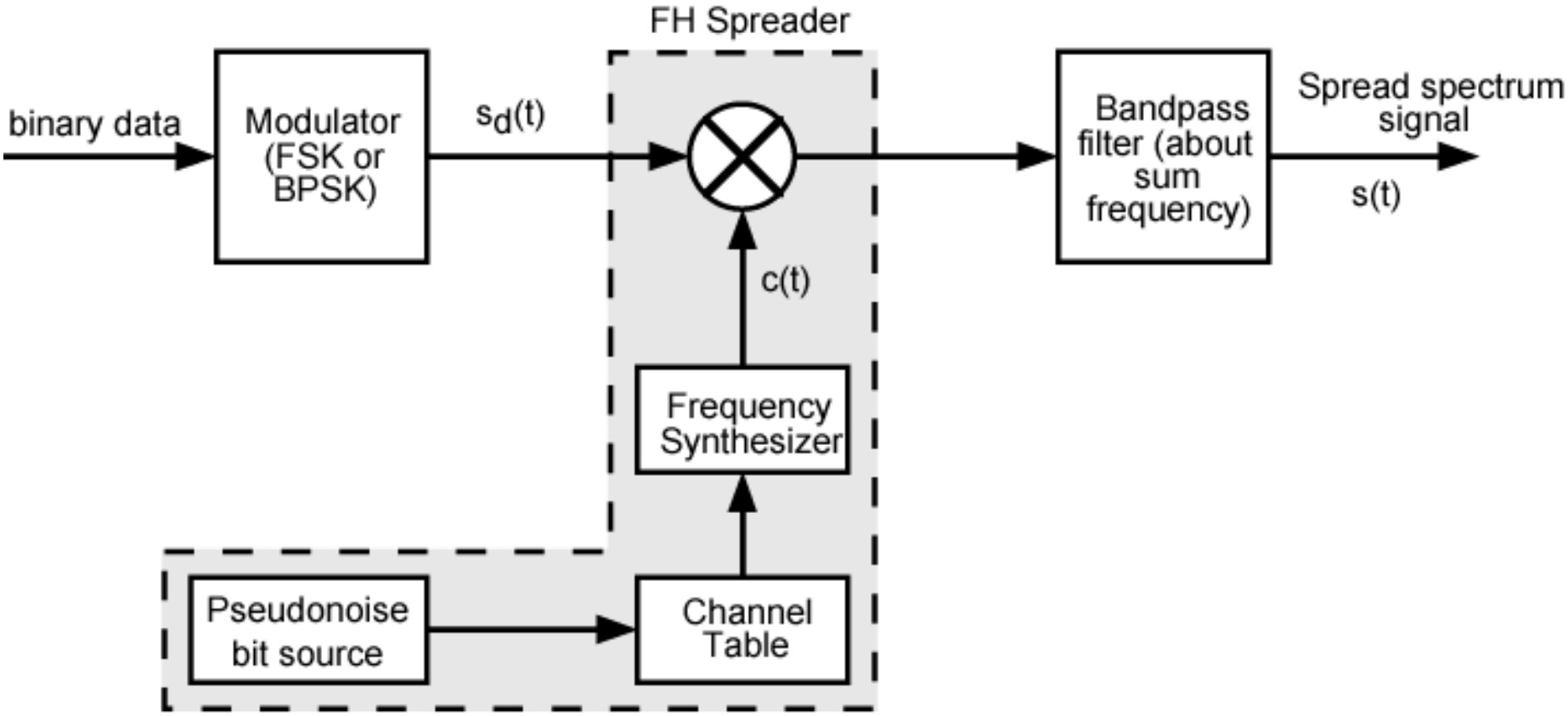


(a) Channel assignment

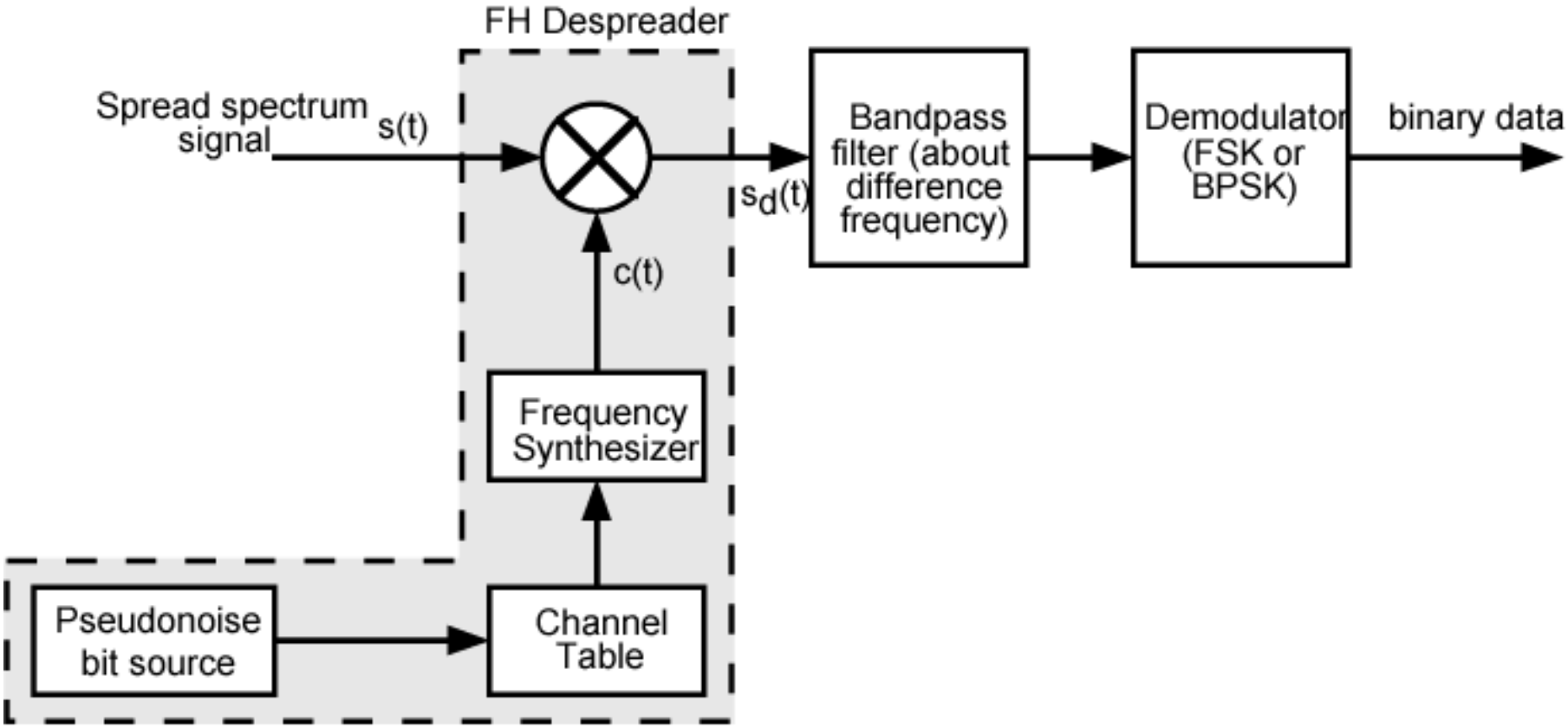


(b) Channel use

Frequency Hopping Spread Spectrum System (Transmitter)



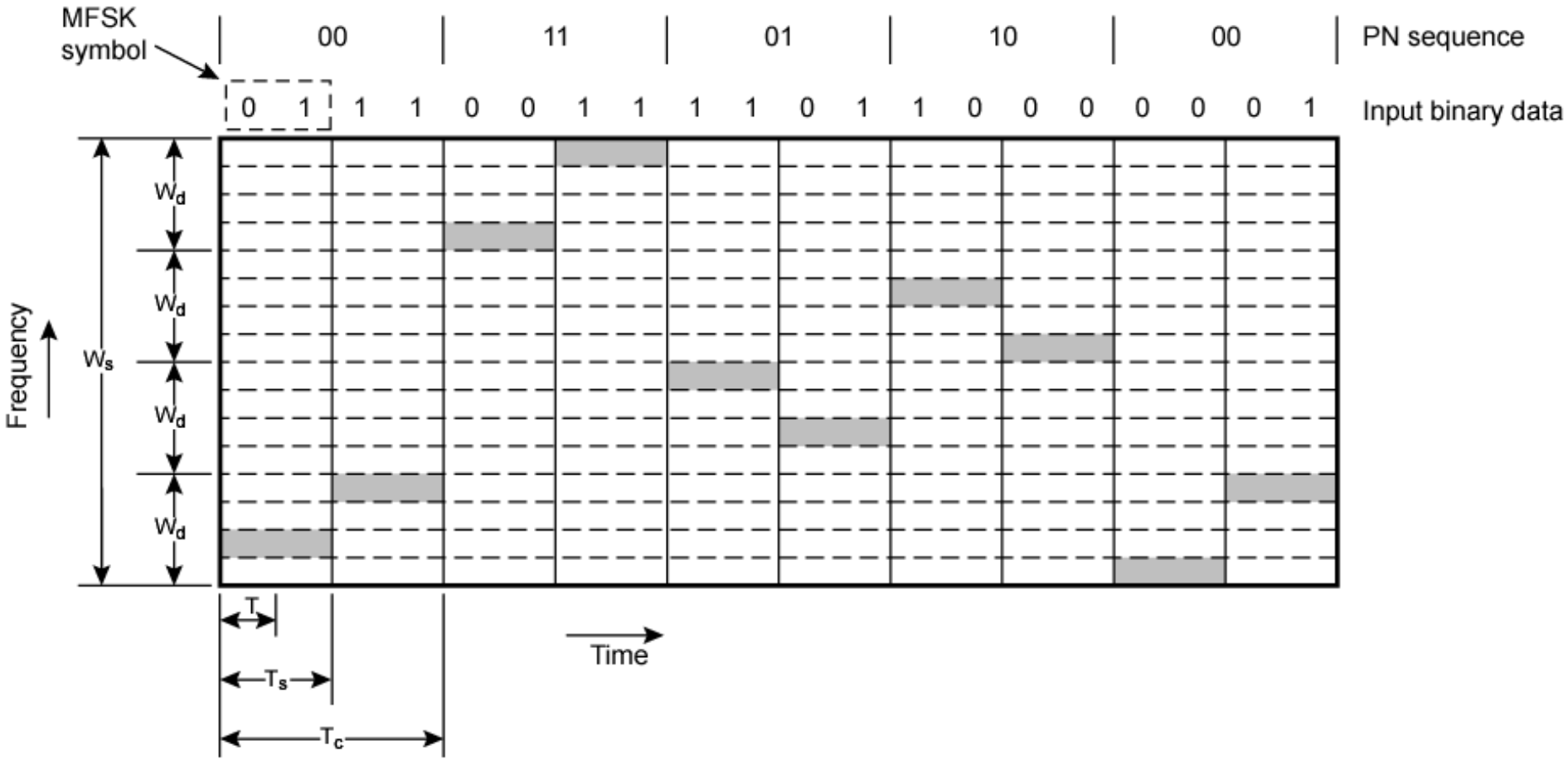
Frequency Hopping Spread Spectrum System (Receiver)



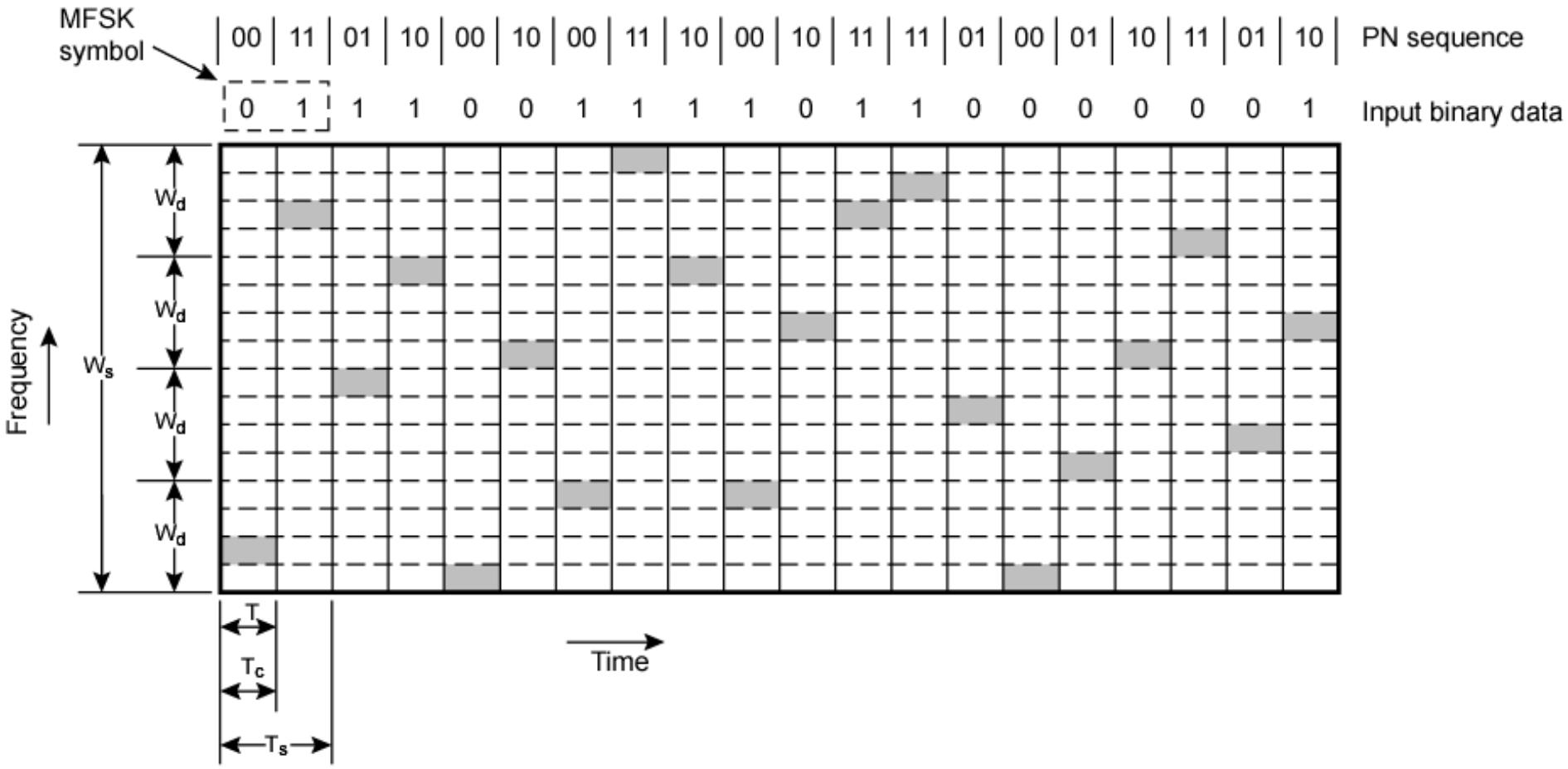
Slow and Fast FHSS

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

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



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



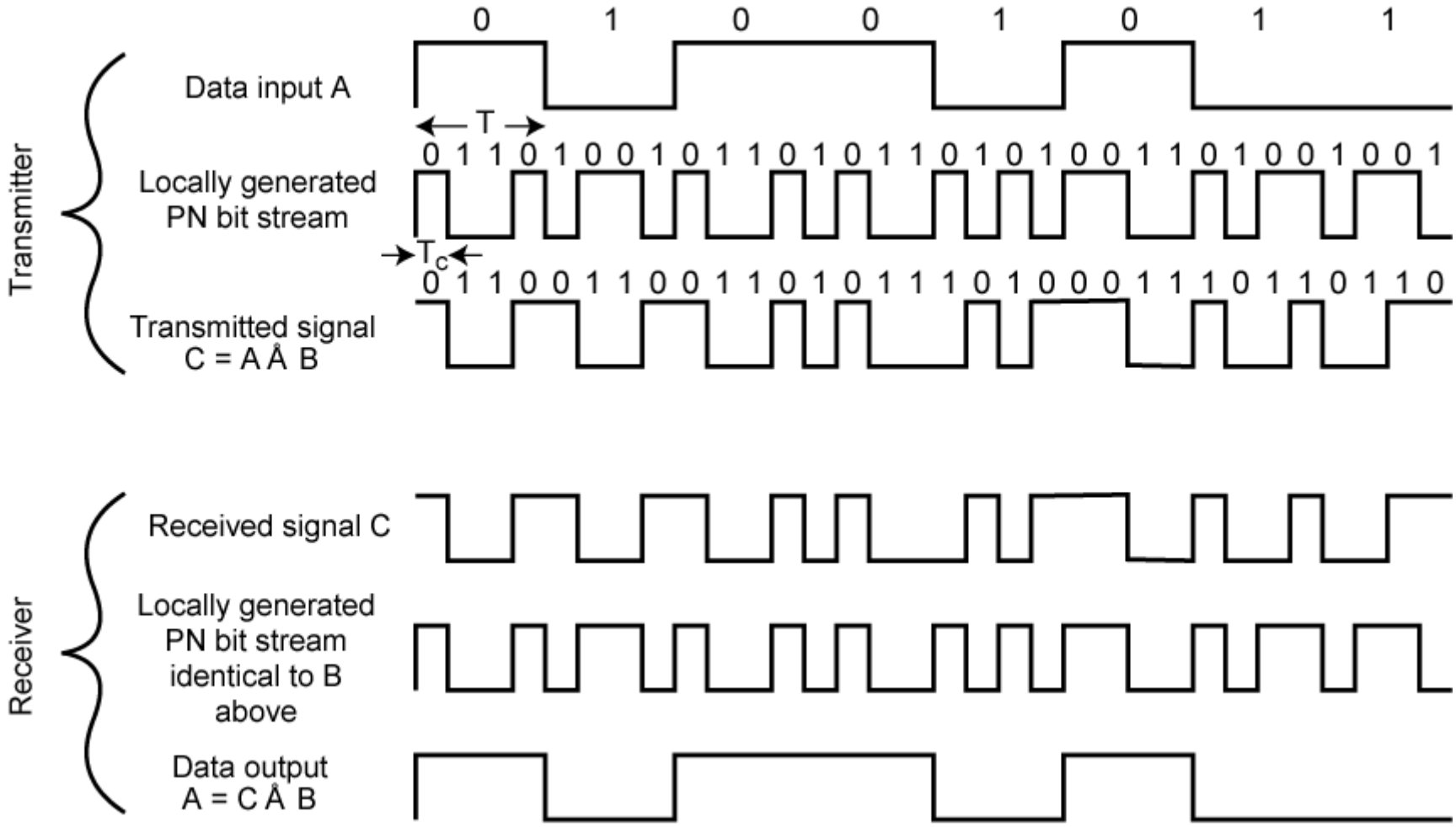
FHSS Performance Considerations

- Typically large number of frequencies used
  - —Improved resistance to jamming

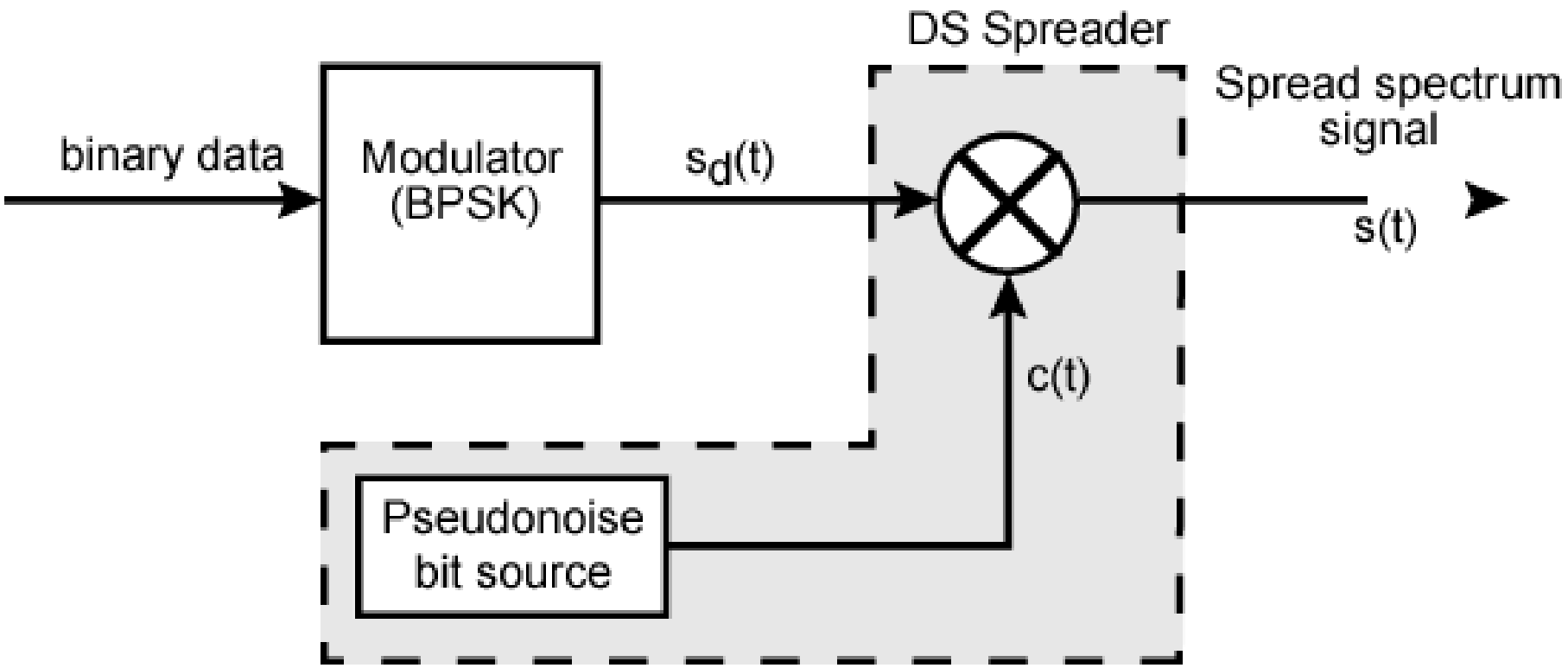
Direct Sequence Spread Spectrum (DSSS)

- 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

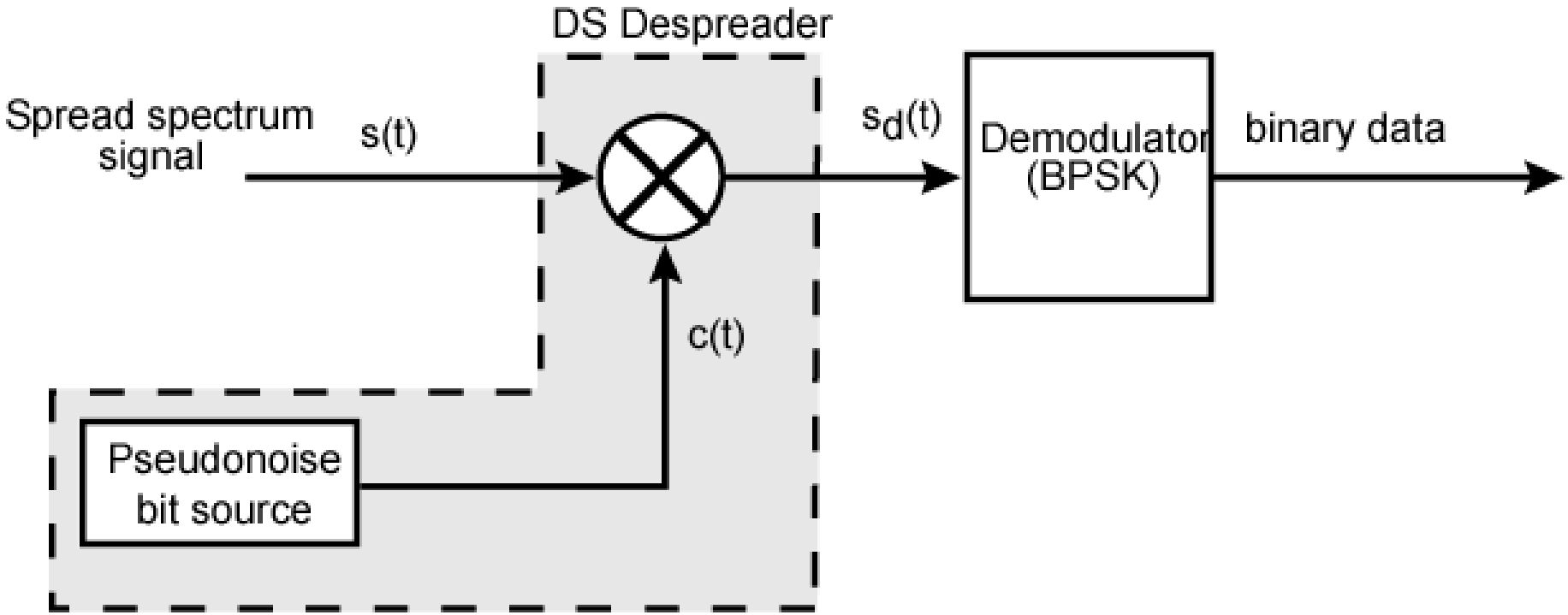
Direct Sequence Spread Spectrum Example



Direct Sequence Spread Spectrum Transmitter



Direct Sequence Spread Spectrum Transmitter



Direct Sequence Spread Spectrum Using BPSK Example