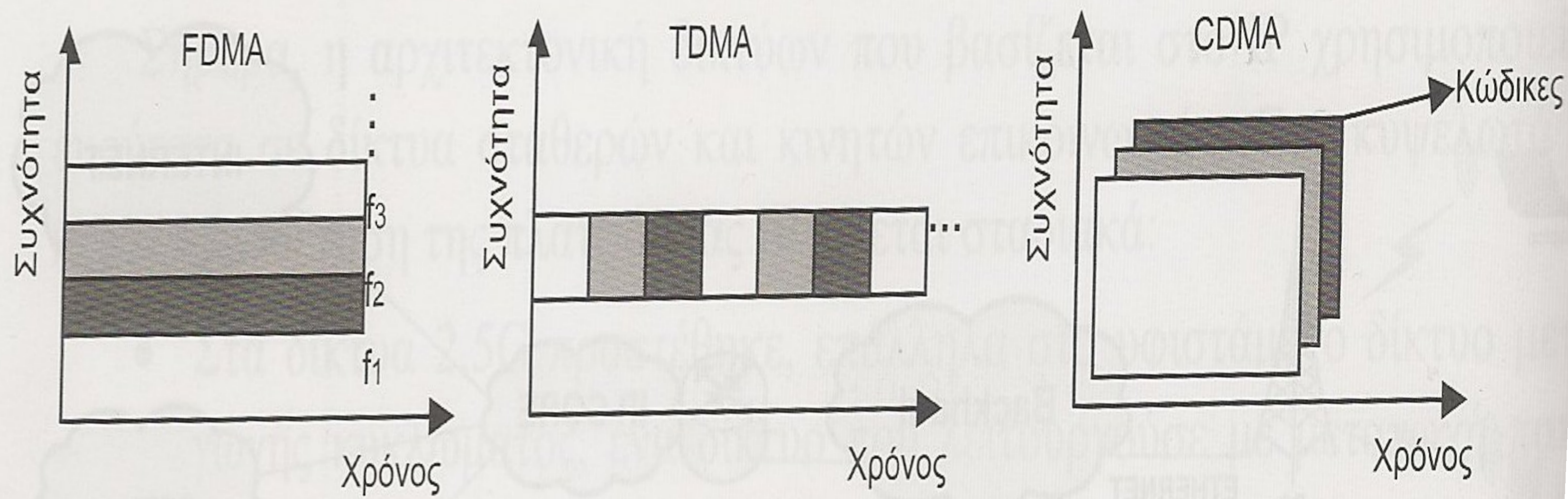
Πρόσβαση στο Ραδιοδίαυλο

Spread Spectrum

Πρόσβαση στο Ραδιοδίαυλο

- Ο συνδρομητής ενός κυψελωτού δικτύου απολαμβάνει υπηρεσίες όταν αποκτήσει πρόσβαση στον ραδιοδίαυλο, στον οποίο εκπέμπει ο σταθμός βάσης που εξυπηρετεί την συγκεκριμένη γεωγραφική περιοχή
- Οι μέθοδοι πρόσβασης στον ραδιοδίαυλο εξελίσσονται ακολουθώντας την πορεία των τεχνολογιών

FDMA



Σχήμα 2.10 Τεχνικές πρόσβασης χρηστών στο ραδιοδίαυλο.

FDMA

- Κάθε χρήστης χρησιμοποιεί διαφορετικό ραδιοδίαυλο
- Το διαθέσιμο φάσμα χωρίζεται σε διαύλους συγκεκριμμένου φασματικού εύρους
- Κάθε δίαυλος αποδίδεται σε έναν και μόνο χρήστη για το χρονικό διάστημα που διαρκει η κλήση

TDMA

- Το σήμα κάθε διαύλου χωρίζεται σε χρονοθυρίδες
- Κάθε χρονοθυρίδα αποδίδεται σε έναν χρήστη
- Ο σταθμός βάσης αλλάζει συνεχώς χρονοθυρίδες εξυπηρετώντας διαφορετικούς χρήστες
- Καποιές χρονοθυρίδες μπορεί να χρησιμοποιούνται για σηματοδοσία κλπ

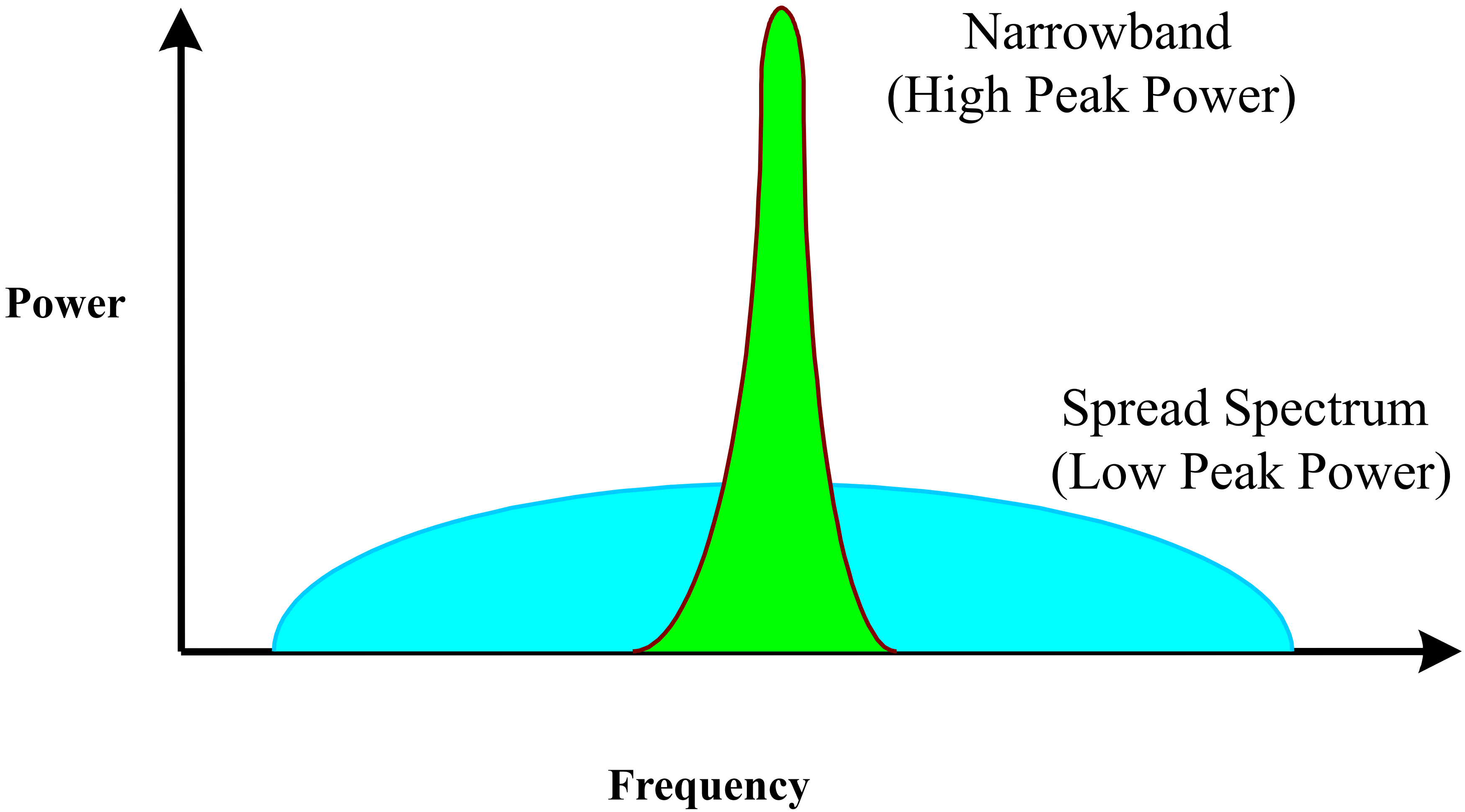
Spread Spectrum

- Analog or digital data
- Analog signal
- Spread data over wide bandwidth
- 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** is a communication technique that spreads a narrowband communication signal over a wide range of frequencies for transmission then de-spreads it into the original data bandwidth at the receiver.
- **Spread spectrum** is characterized by:
  - wide bandwidth and
  - low power
- **Jamming** and **interference** have less effect on Spread spectrum because it is:
  - Resembles noise
  - Hard to detect
  - Hard to intercept

Narrowband *vs* Spread Spectrum



Narrow Band vs Spread Spectrum

- **Narrow Band**
  - Uses only enough frequency spectrum to carry the signal
  - High peak power
  - Easily jammed
- **Spread Spectrum**
  - The bandwidth is much wider than required to send to the signal.
  - Low peak power
  - Hard to detect
  - Hard to intercept
  - Difficult to jam

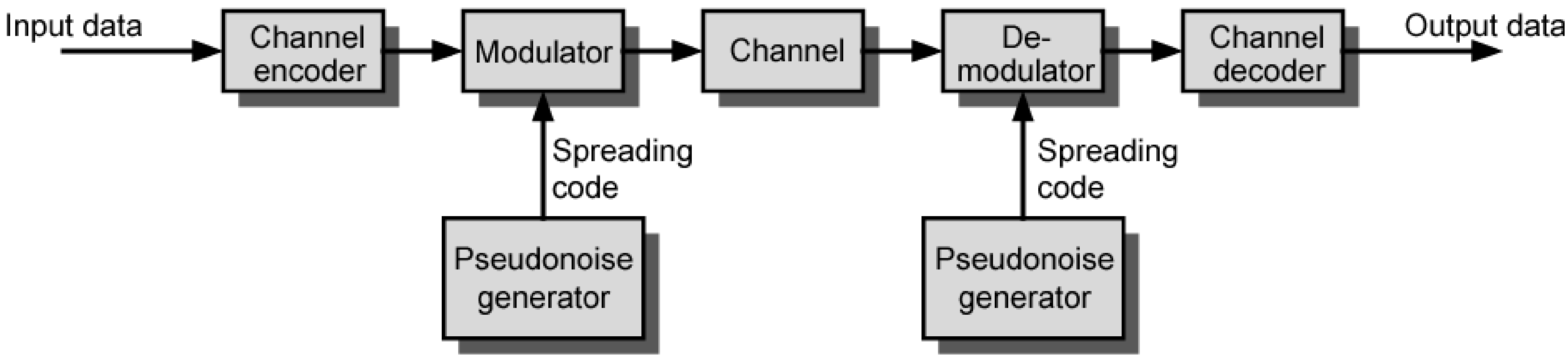
ISM Frequency Bands

UHF ISM	902 - 928 Mhz
S-Band	2 - 4 Ghz
S-Band ISM (802.11b)	**2.4 - 2.5 Ghz**
C-Band	4 - 8 Ghz
C-Band Satellite downlink	3.7 - 4.2Ghz
C-Band Radar (weather)	5.25 - 5.925 Ghz
C-Band ISM (802.11a)	**5.725 - 5.875 Ghz**
C-Band satellite uplink	5.925-6.425 Ghz
X-Band	8-12 Ghz
X-Band Radar (police/weather)	9.5-10.55 Ghz
Ku-band	12-18 Ghz
Ku-band Radar (Police)	13.5-15 Ghz
	15.7-17.7 Ghz

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

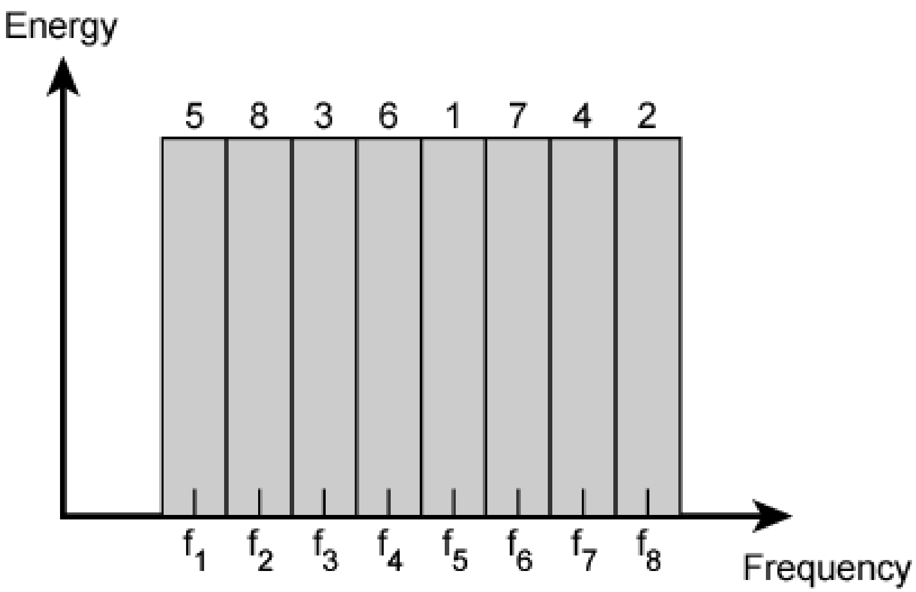
Frequency Hopping Spread Spectrum (FHSS)

- 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

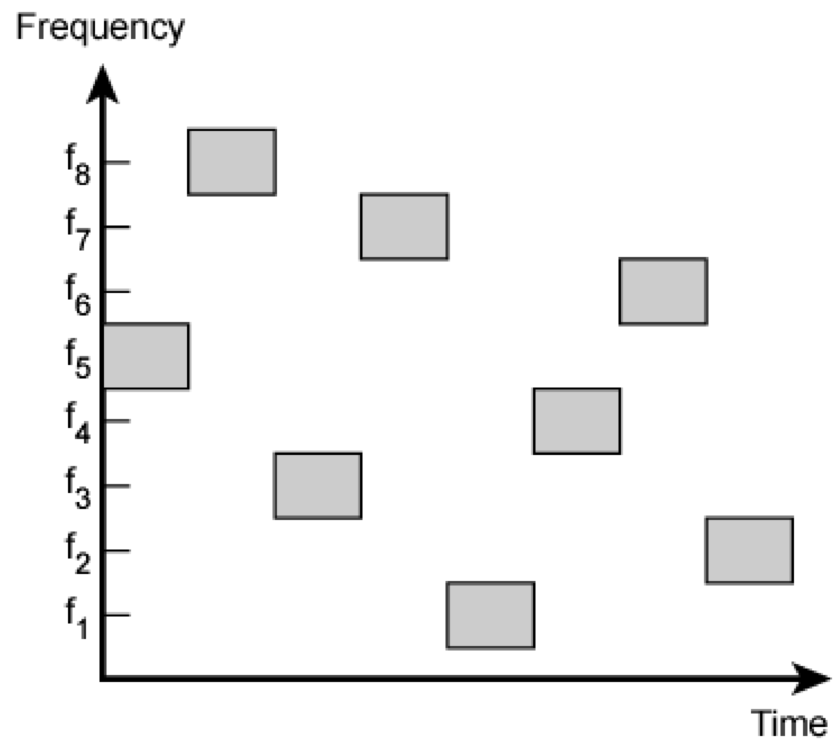
Basic Operation

- 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

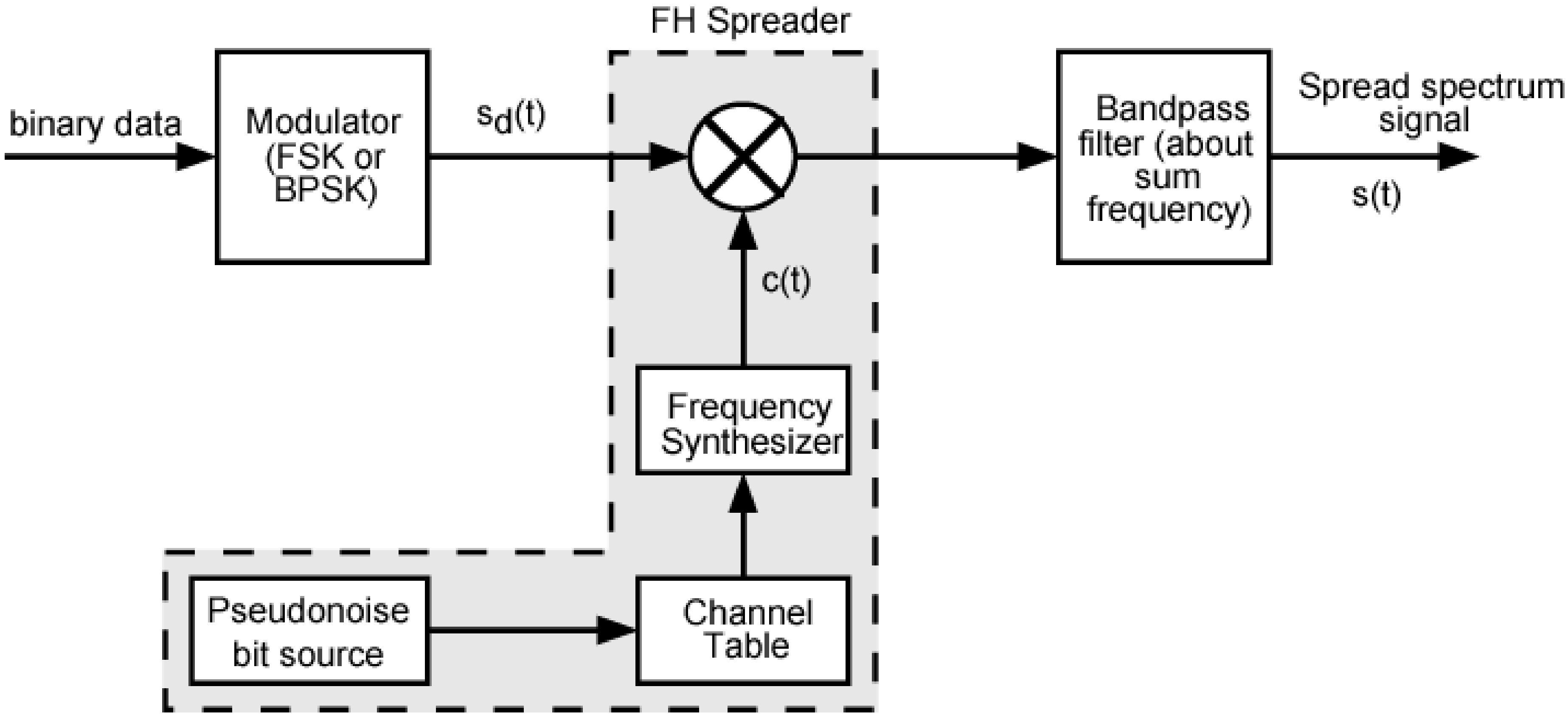


(a) Channel assignment

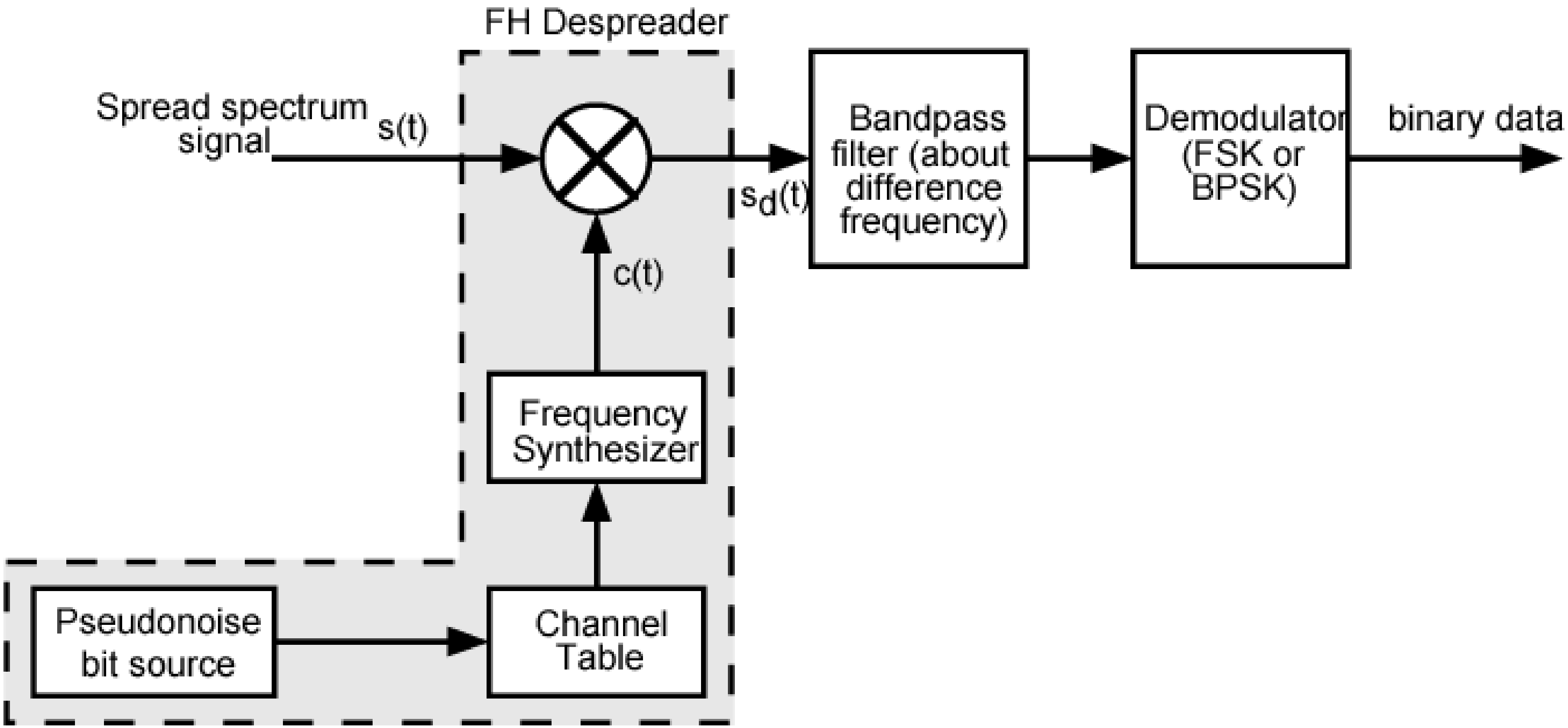


(b) Channel use

Frequency Hopping Spread Spectrum System (Transmitter)



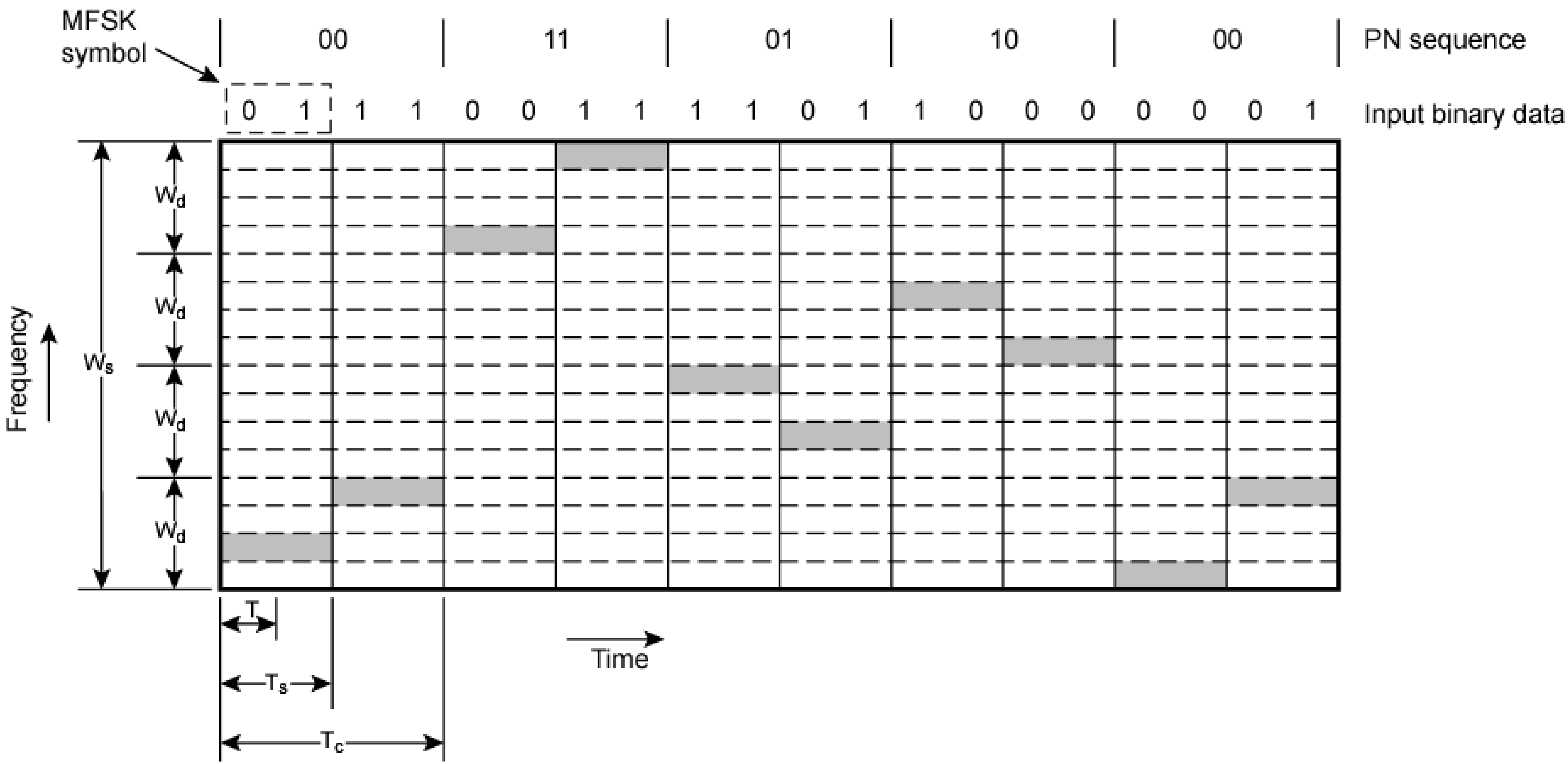
Frequency Hopping Spread Spectrum System (Receiver)



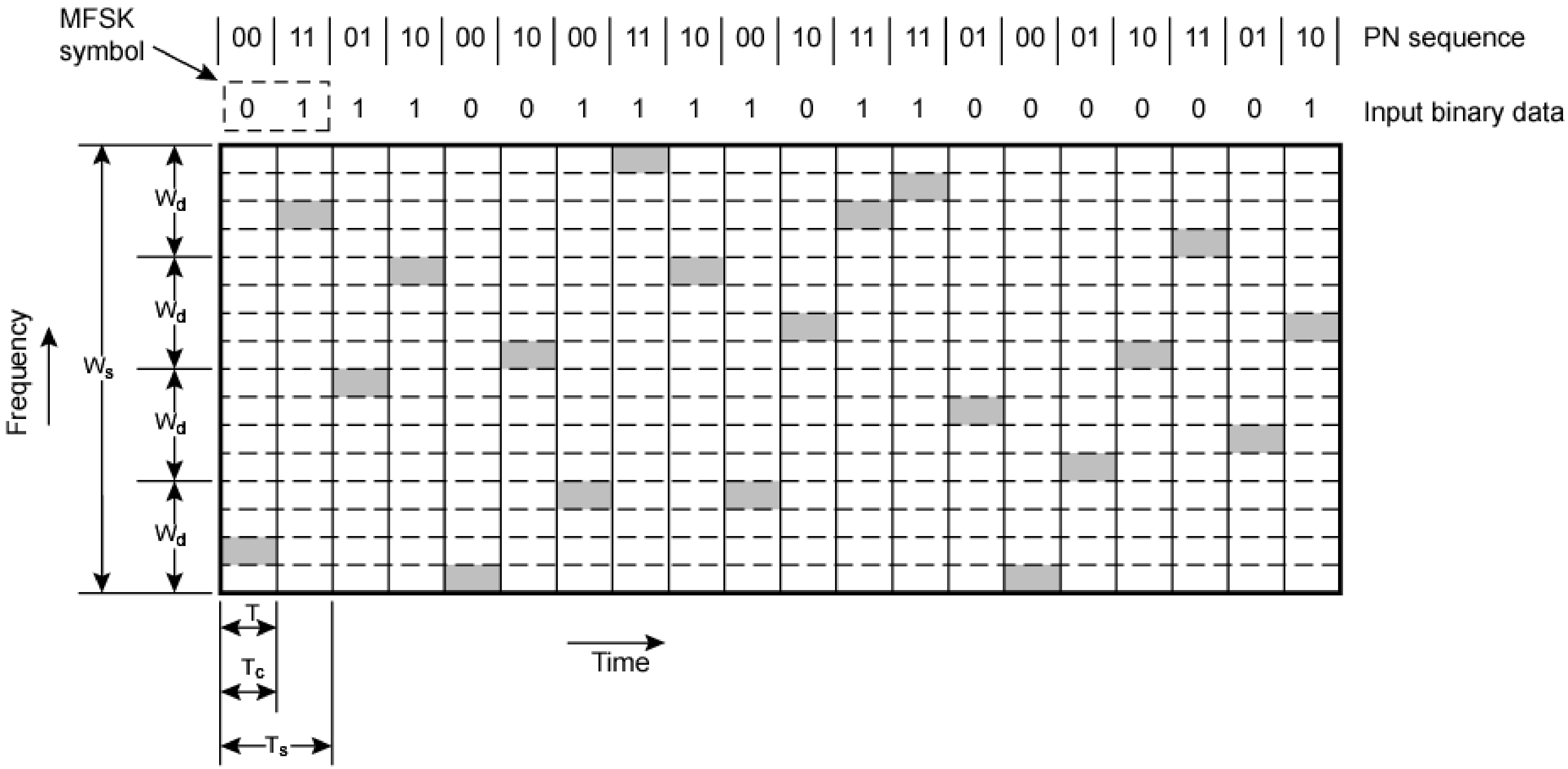
Slow and Fast FHSS

- 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)

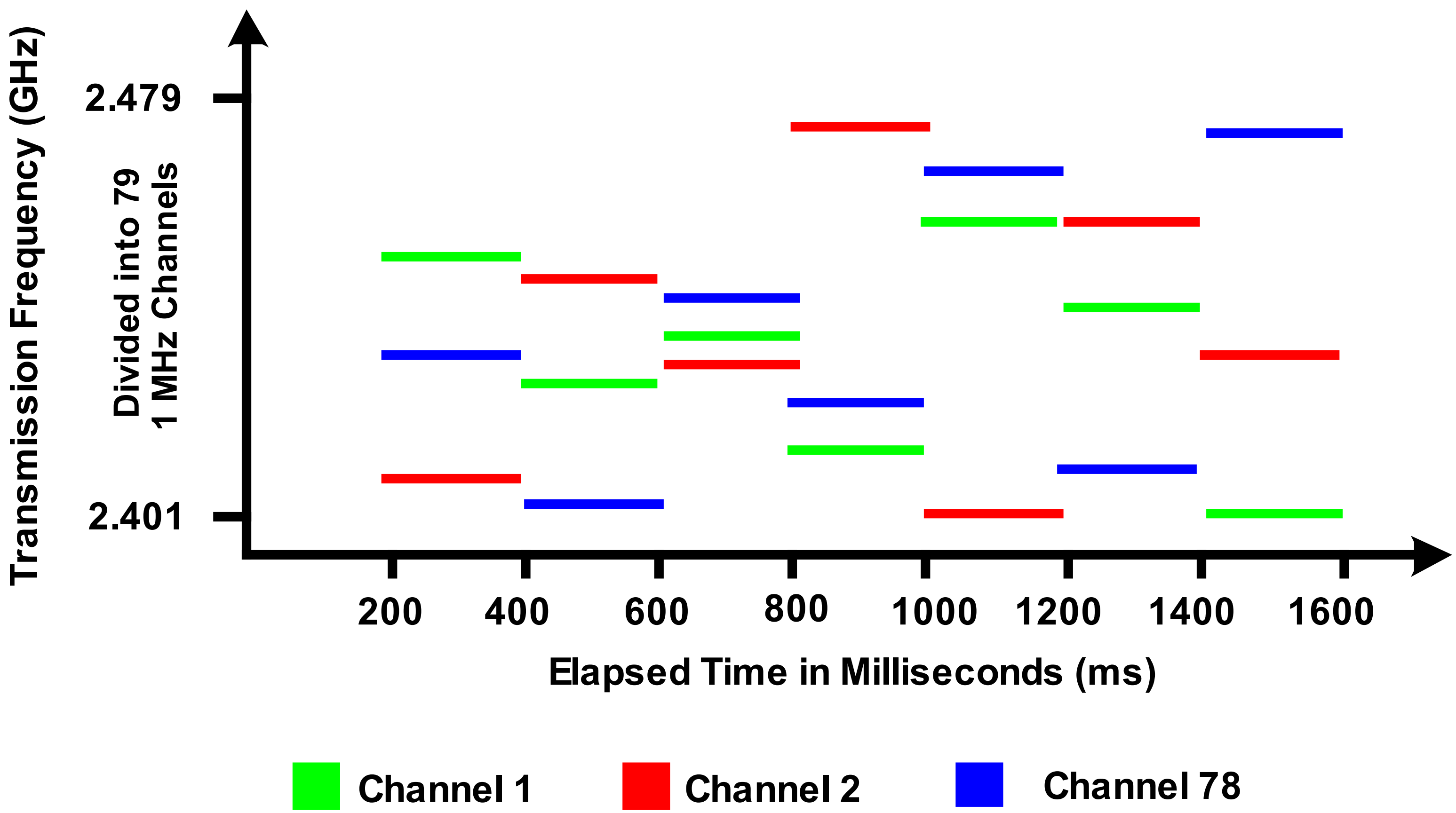


FHSS Performance Considerations

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

Frequency Hopping Spread Spectrum

An Example of a Co-located Frequency Hopping System



FHSS Contd

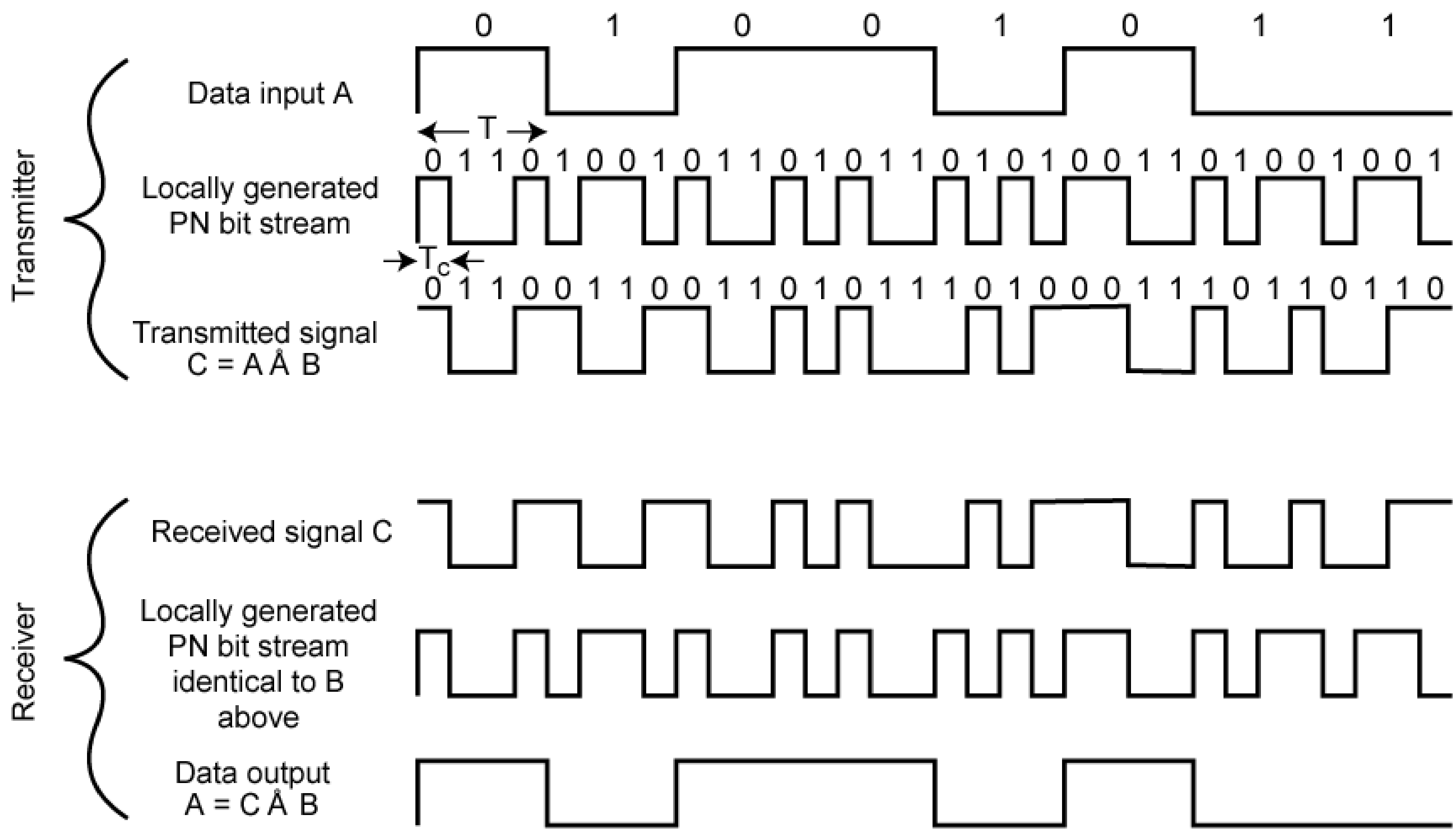
- The original 802.11 FHSS standard supports 1 and 2 Mbps data rate.
  - FHSS uses the 2.402 – 2.480 GHz frequency range in the ISM band.
  - It splits the band into *79* non-overlapping channels with each channel *1 MHz* wide.
  - FHSS hops between channels at a minimum rate of 2.5 times per second. Each hop must cover at least 6 MHz
  - The hopping channels for the US and Europe are shown below.

Set	Hopping Pattern
1	{0,3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48,51,54,57,60,63,66,69,72,75}
2	{1,4,7,10,13,16,19,22,25,28,31,34,37,40,43,46,49,52,55,58,61,64,67,70,73,76}
3	{2,5,8,11,14,17,20,23,26,29,32,35,38,41,44,47,50,53,56,59,62,65,68,71,72,77}

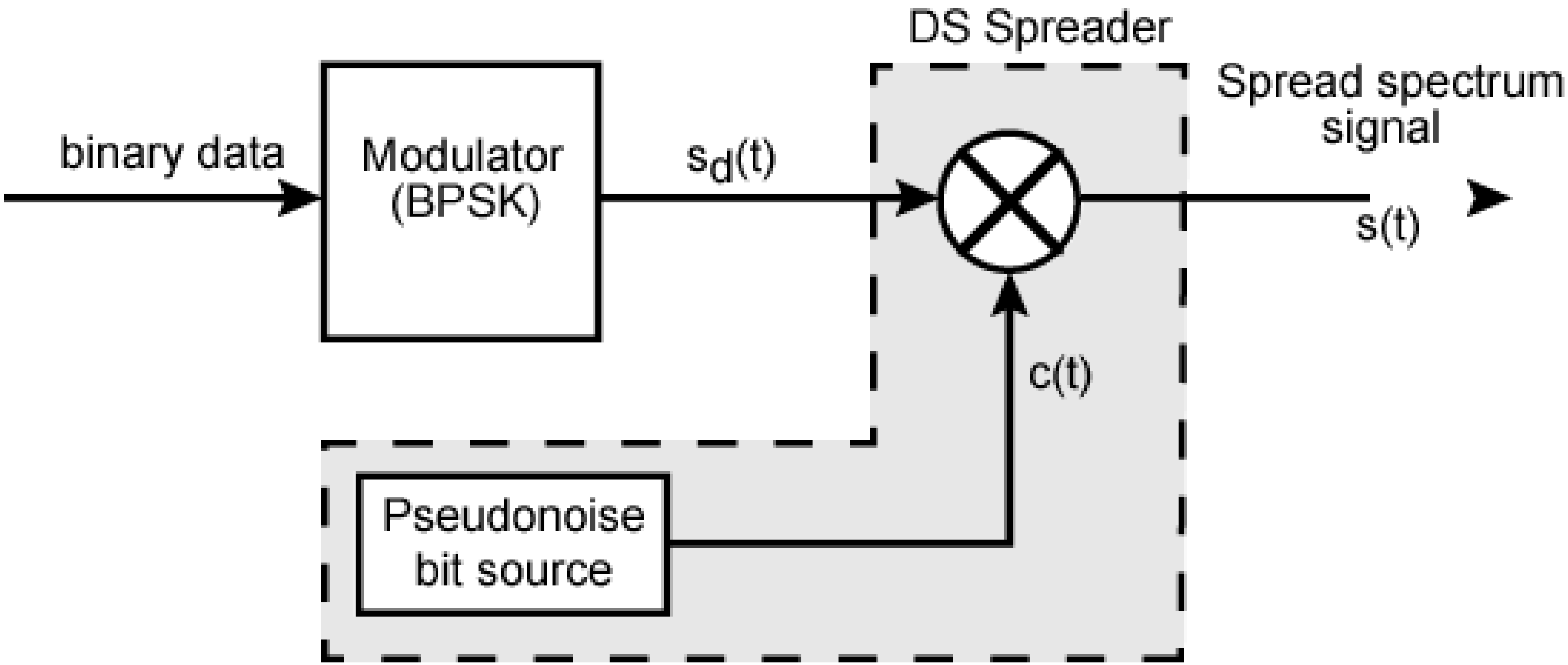
Direct Sequence Spread Spectrum (DSSS)

- 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

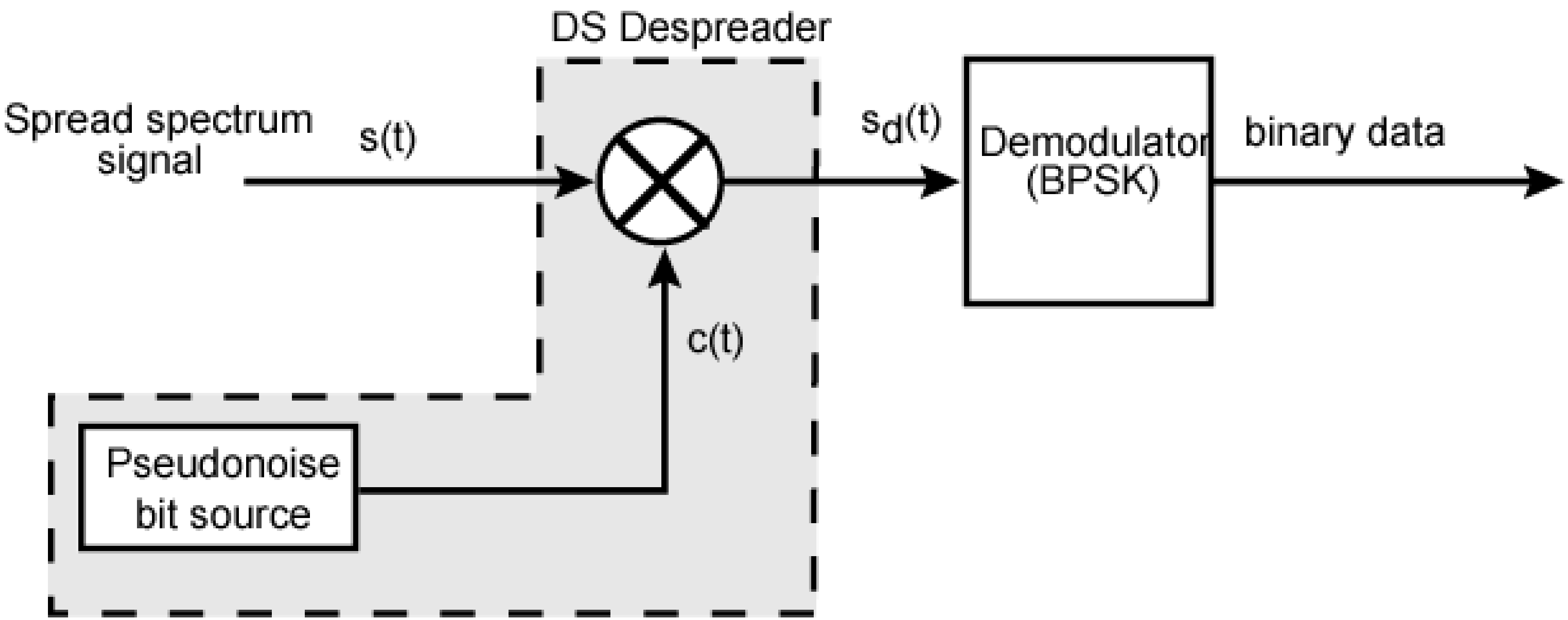
Direct Sequence Spread Spectrum Example



Direct Sequence Spread Spectrum Transmitter

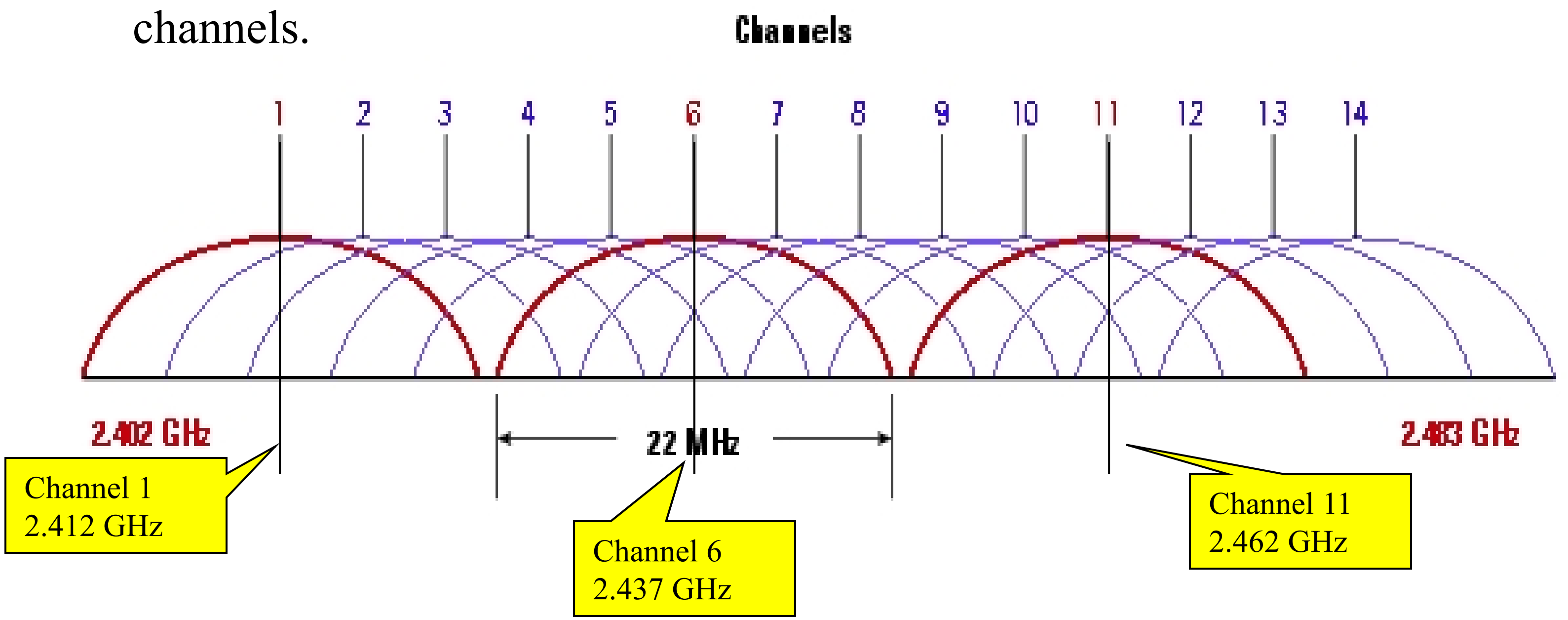


Direct Sequence Spread Spectrum Transmitter



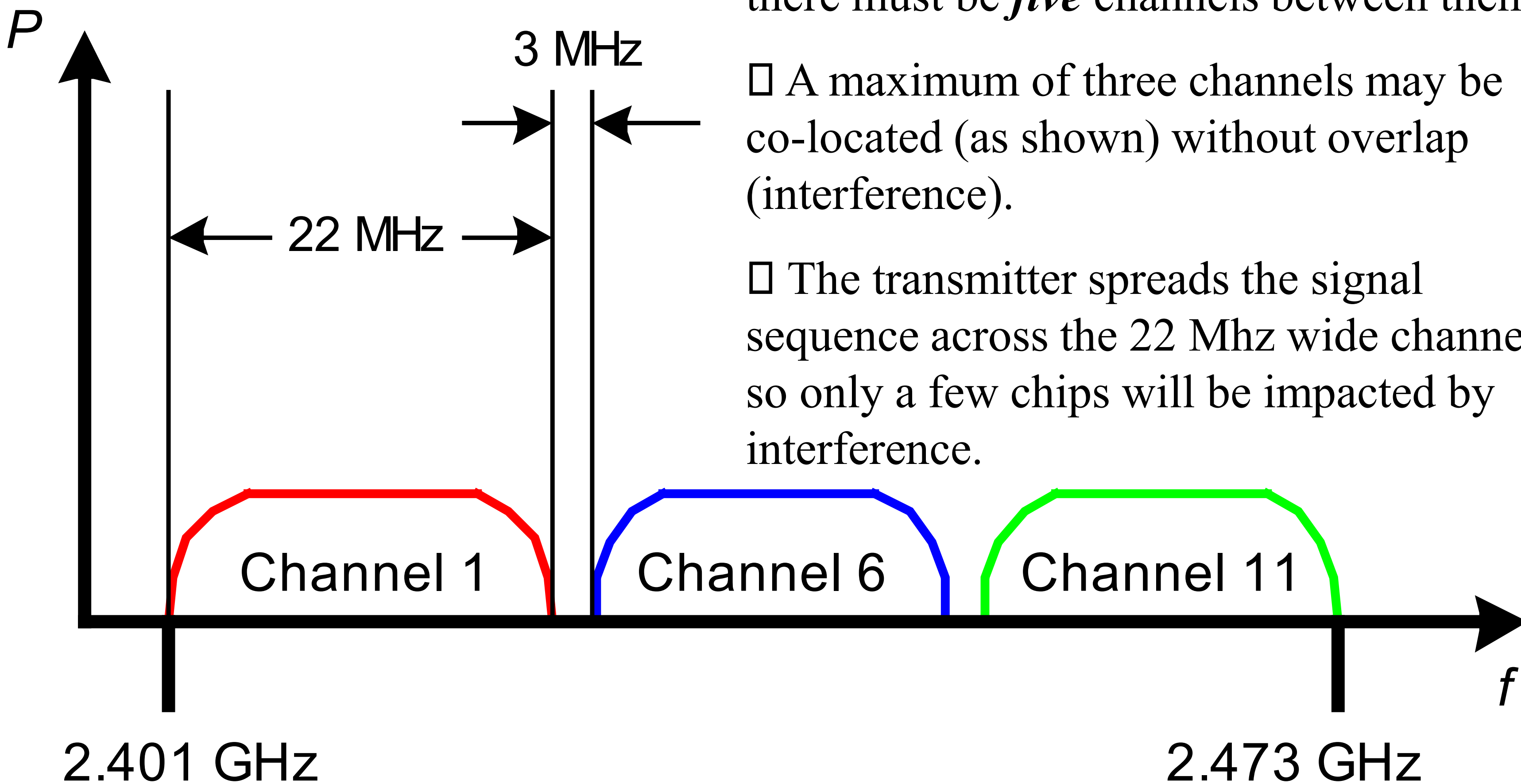
Direct Sequence Spread Spectrum

- The Center DSSS frequencies of each channel are only **5 Mhz apart** but each channel is **22 Mhz wide** therefore adjacent channels will overlap.
- DSSS systems with overlapping channels in the same physical space would cause interference between systems.
  - Co-located DSSS systems should have frequencies which are at least **5 channels apart**, e.g., Channels 1 and 6, Channels 2 and 7, etc.
  - Channels 1, 6 and 11 are the only theoretically non-overlapping channels.

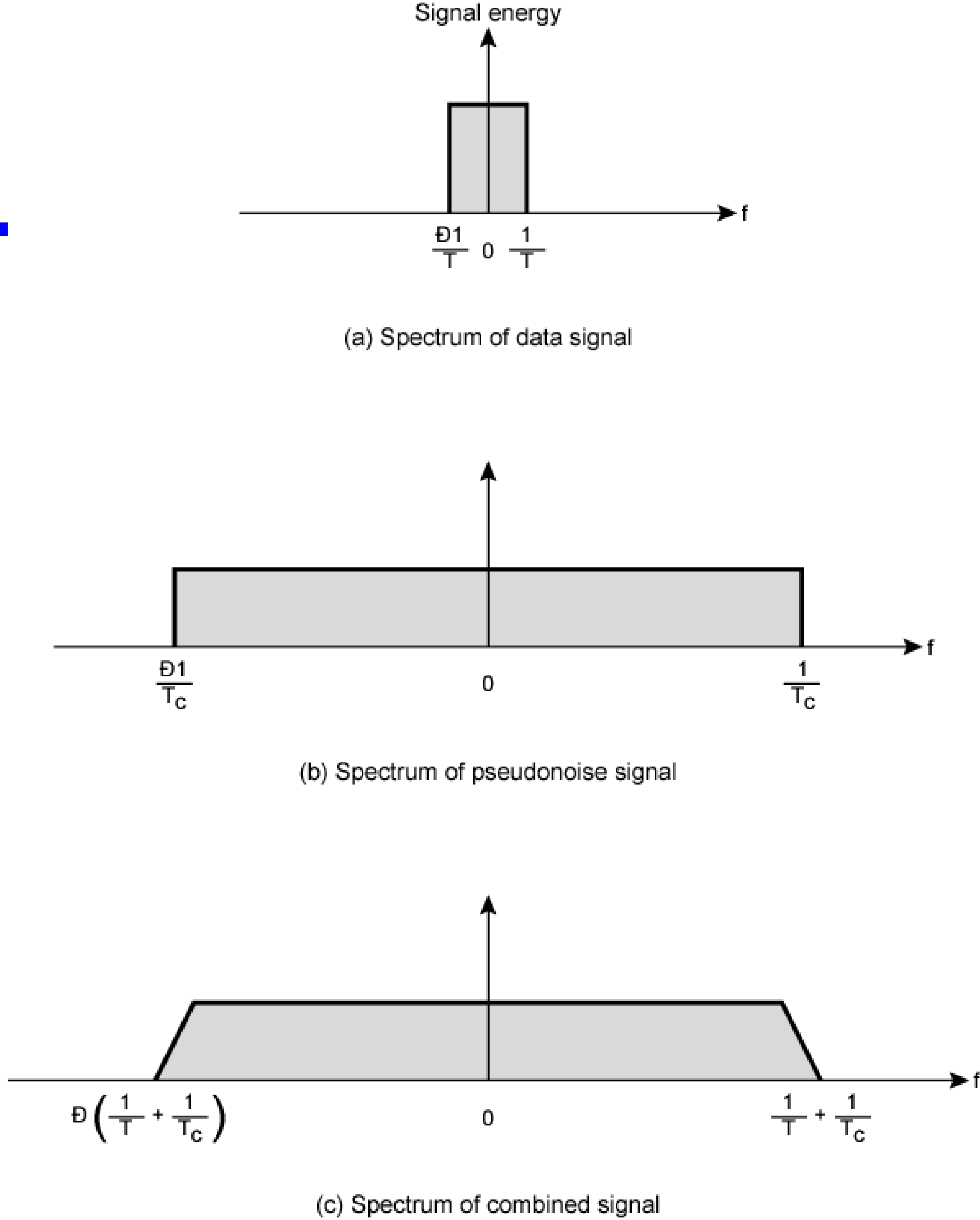


DSSS Non-overlapping Channels

- Each channel is ***22 MHz wide***. In order for two bands not to overlap (interfere), there must be ***five*** channels between them.
- A maximum of three channels may be co-located (as shown) without overlap (interference).
- The transmitter spreads the signal sequence across the 22 Mhz wide channel so only a few chips will be impacted by interference.



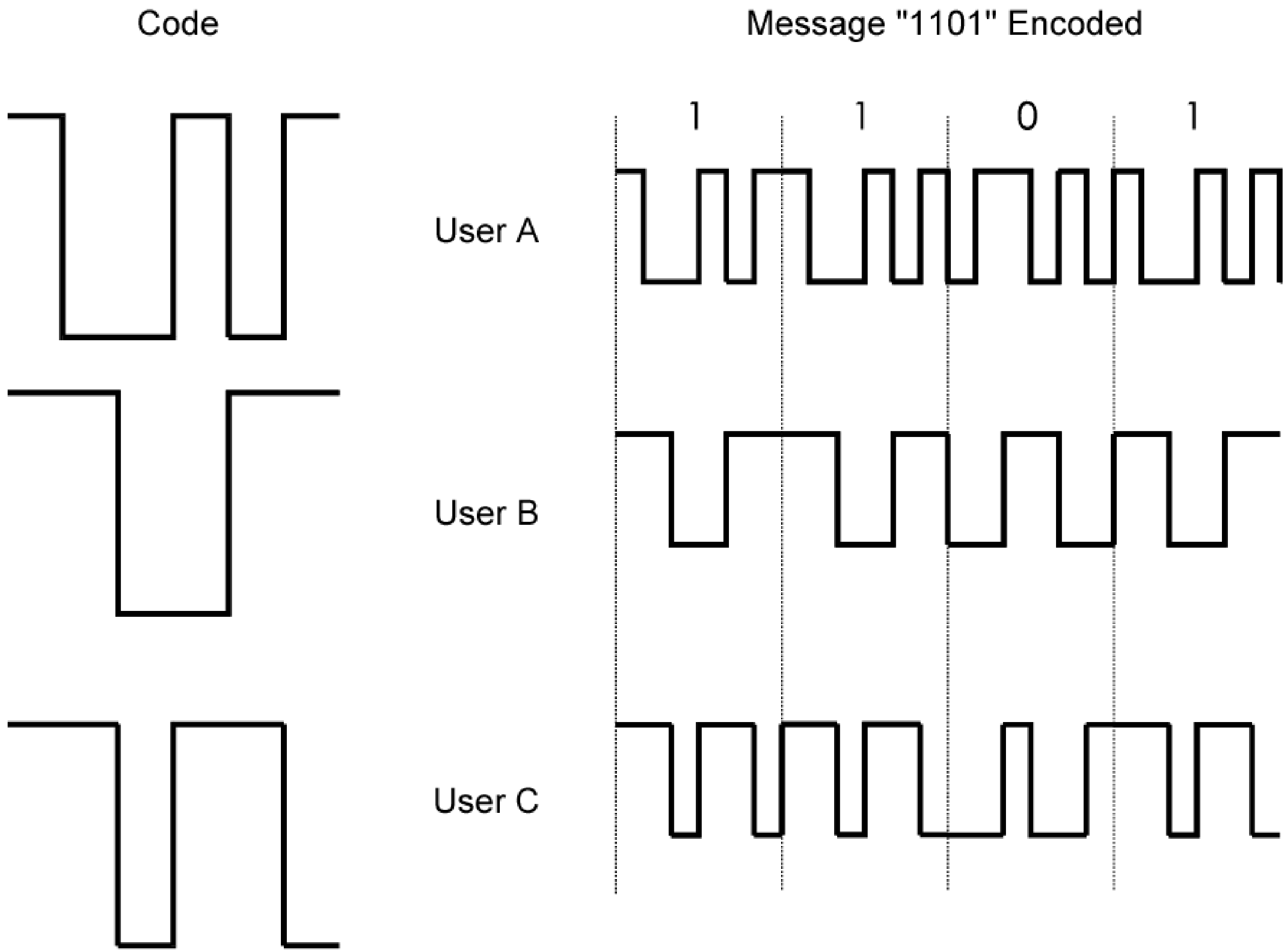
Approximate Spectrum of DSSS Signal



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>

CDMA Example



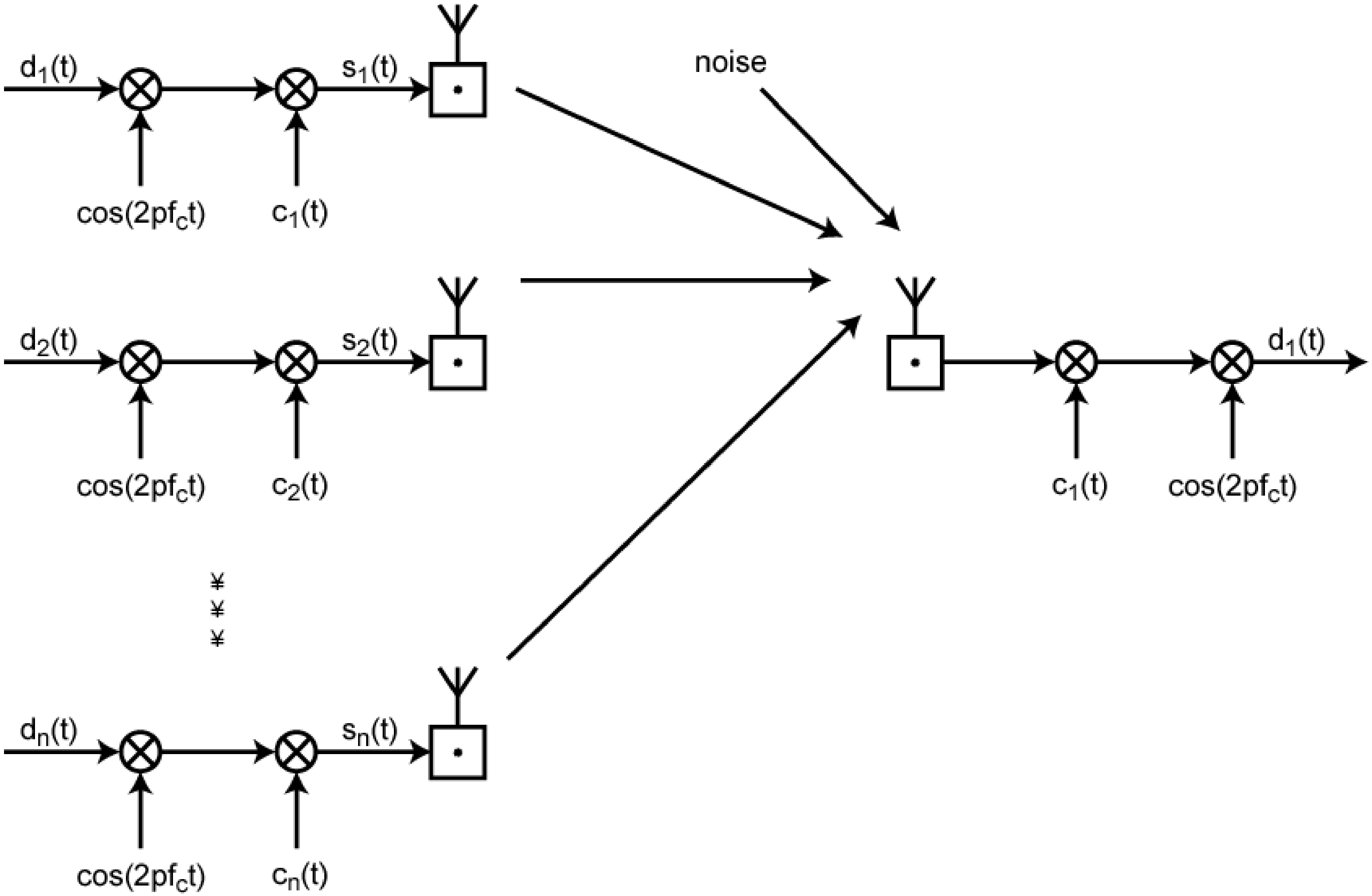
CDMA Explanation

- 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

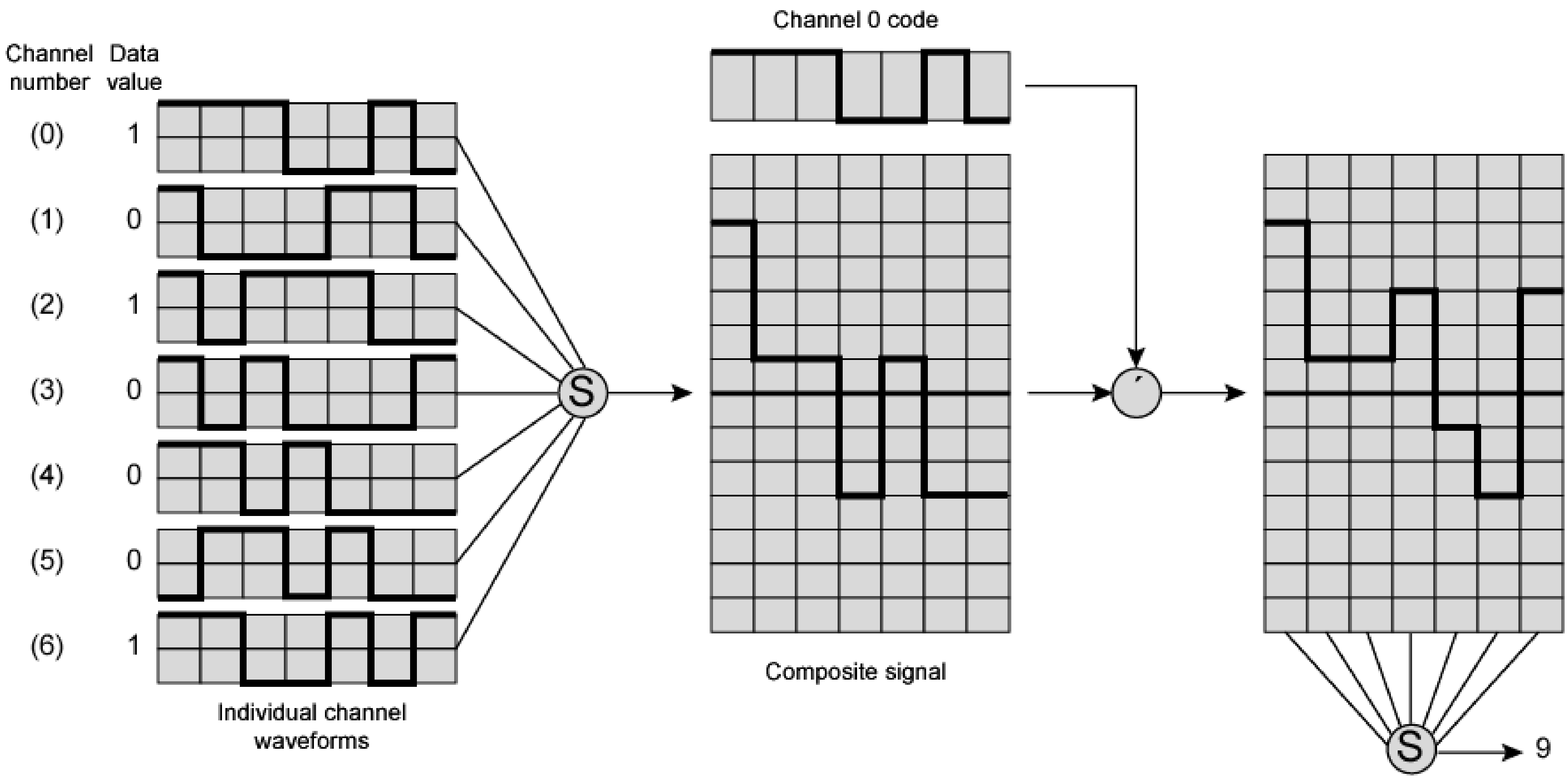
CDMA for DSSS

- n users each using different orthogonal PN sequence
- Modulate each users data stream
  - Using BPSK
- Multiply by spreading code of user

CDMA in a DSSS Environment



Seven Channel CDMA Encoding and Decoding



CDMA

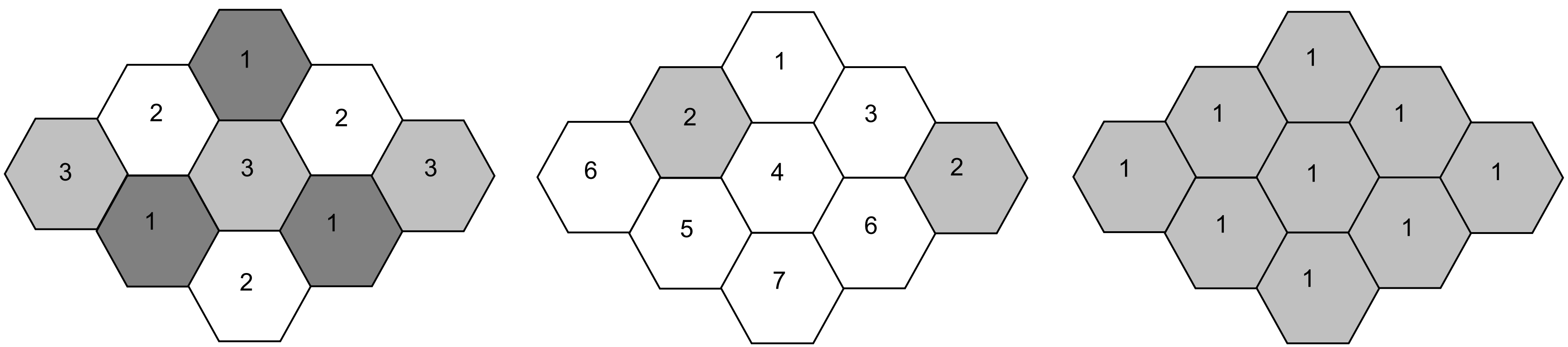
- Η τεχνική CDMA επιτρέπει σε πολλούςχρήστες να χρησιμοποιούν τον ραδιοδίαυλο ταυτόχρονα (και όχι διαδοχικά όπως στη TDMA)
- Οσο μεγαλώνει ο αριθμός των χργστών στον ραδιοδίαυλο, πληθαίνουν τα λάθη στην μετάδοση και περιορίζεται ο μεγιστος αριθμός χρήστών
- Εφαρμόζονται τεχνικές μείωσης θορύβου με έλεγχο ισχύος

CDMA

- Ενδεικτικά, το σύστημα cdmaOne, χρησιμοποιώντας την CDMA απαιτεί εύρος φάσματος 1,25MHz ενώ θα μπορούσε (με άλλες τεχνικές) να χρησιμοποιήσει ραδιοδίαυλο με εύρος 50 φορές μικρότερο
- Μπορεί όμως να εξυπηρετήσει 800 χρήστες ταυτόχρονα

CDMA

- Στην CDMA επιτρέπεται γειτονικές κυψέλες να επαναχρησιμοποιούν το ίδιο φάσμα



Σχήμα 2.12 Επαναχρησιμοποίηση συχνοτήτων σε κυψέλες με κεραίες omni. (α) επαναχρησιμοποίηση 3 συχνοτήτων, (β) επαναχρησιμοποίηση 7 συχνοτήτων, (γ) επαναχρησιμοποίηση 1 συχνότητας.

OFDMA

- Η βασική αρχή της OFDMA είναι ότι, αντί για το ενιαίο σήμα, μεταδίδονται οι συνιστώσες του, μετά από μετασχηματισμό Fourier στον χώρο των συχνοτήτων.
- Το προς μετάδοση σήμα χωρίζεται σε χρονοθυρίδες συγκεκριμμένης διάρκειας.
- Κάθε χρονοθυρίδα υπόκειται σε FFT και αναλύεται σε συνιστώσες που εκπέμπονται παράλληλα σε διαφορετικά υποφέροντα
- Η OFDMA επιτρέπει την χρήση ίδιων συχνοτήτων σε γειτονικές κυψέλες