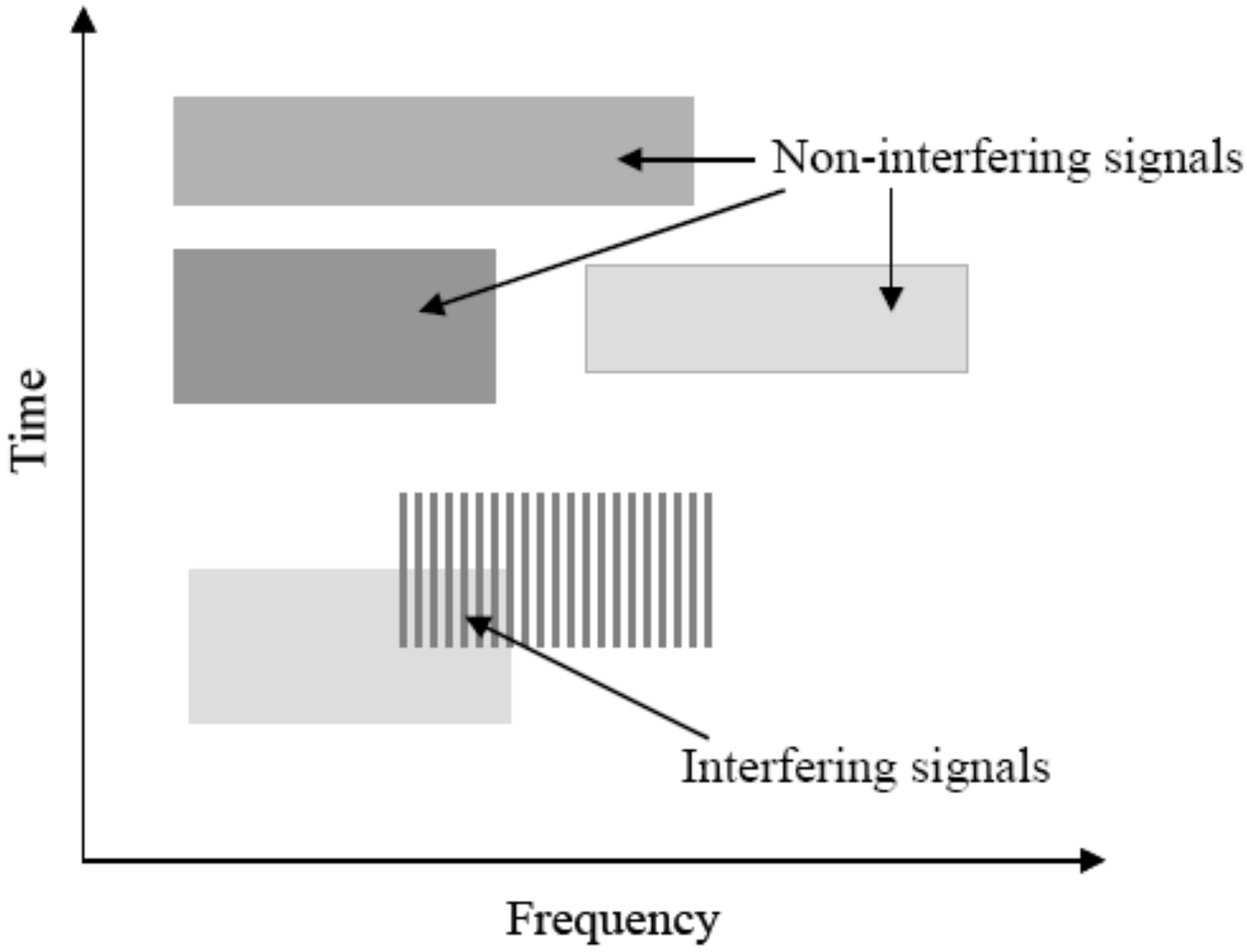
Multiple Access Techniques for Wireless Communications

Contents

- Multiple Access Techniques
  - ✓ Frequency Division Multiple Access (FDMA)
  - ✓ Time Division Multiple Access (TDMA)
  - ✓ Code Division Multiple Access (CDMA)
- Spread Spectrum Multiple Access
  - ✓ Direct Sequence Spread Spectrum (DSSS)
  - ✓ Frequency Hopping Spread Spectrum (FHSS)

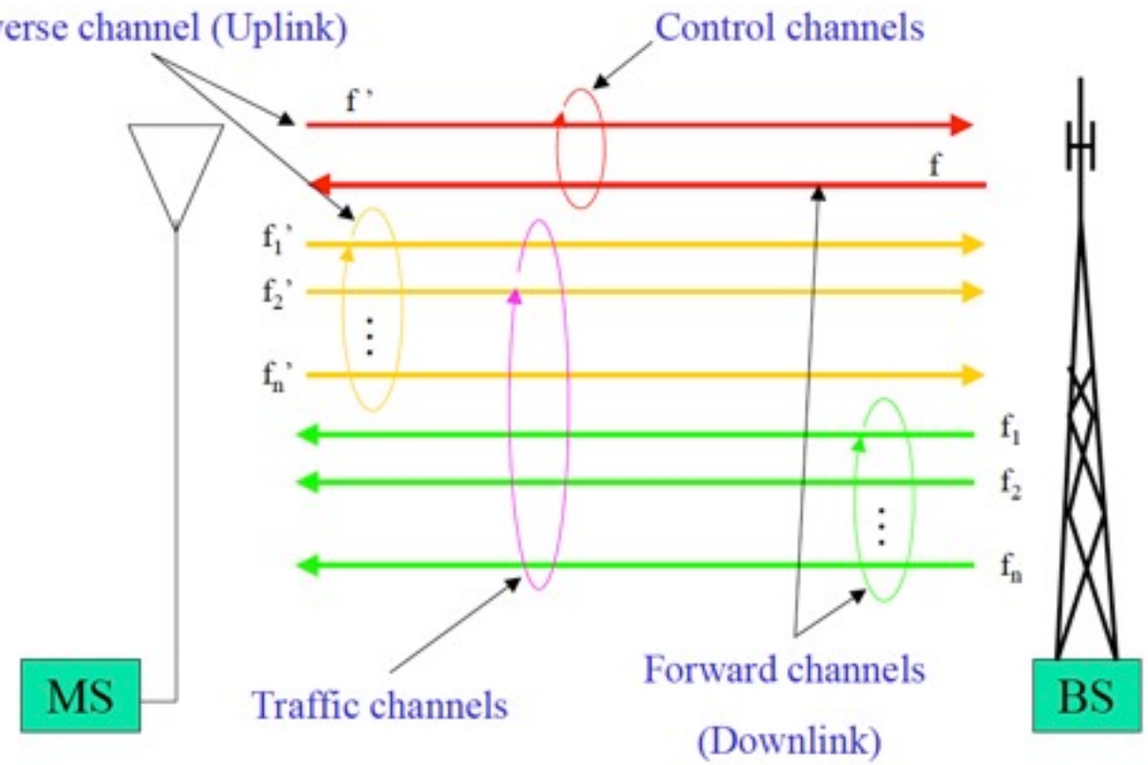
Multiple Access

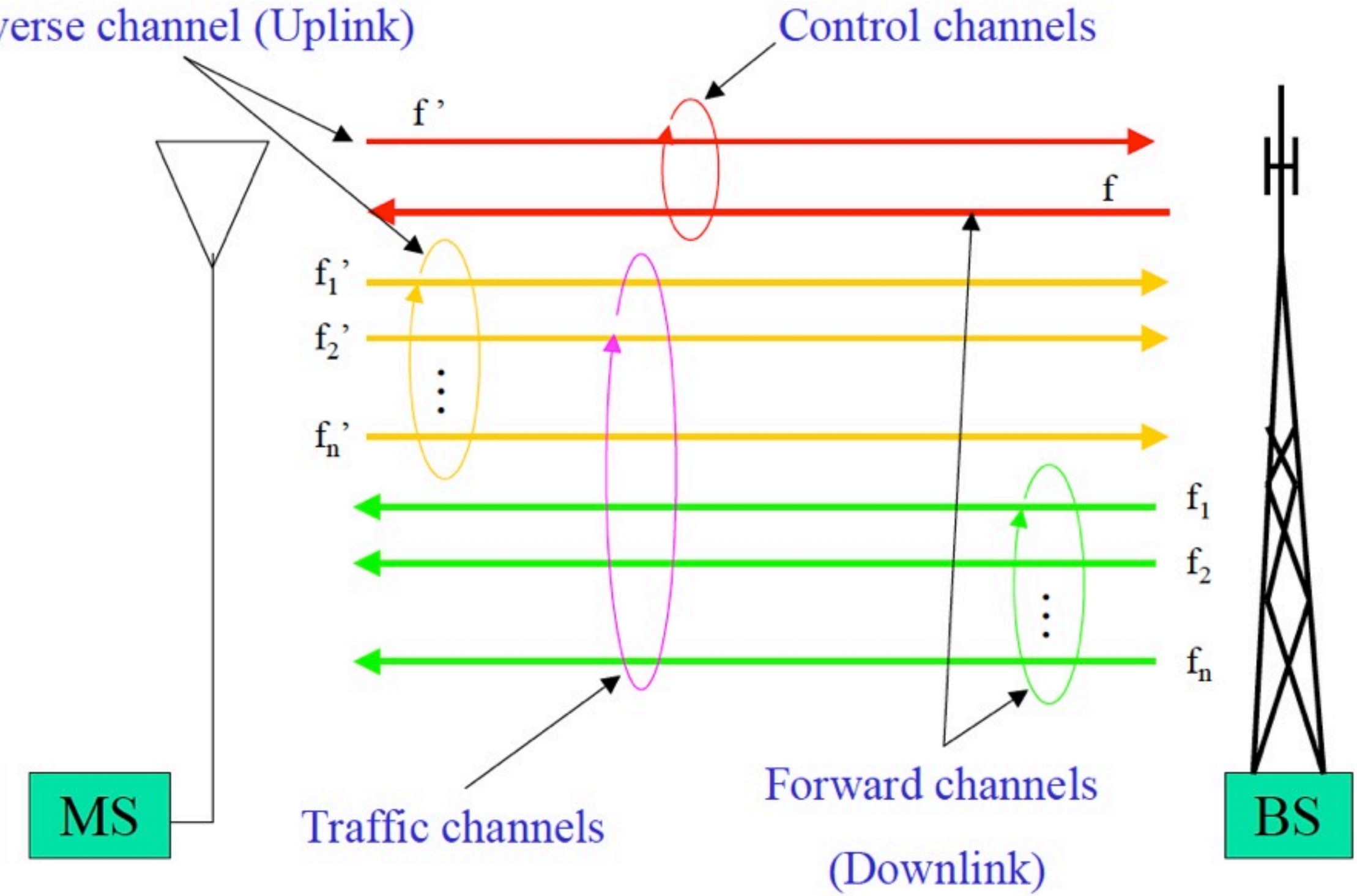
- Enable many mobile users to share simultaneously radio spectrum
- Provide for the sharing of channel capacity between a number of transmitters at different locations
- Aim to share a channel between two or more signals in such way that each signal can be received without interference from another


Non-interfering signals
Time
Interfering signals
Frequency

Types of Channels

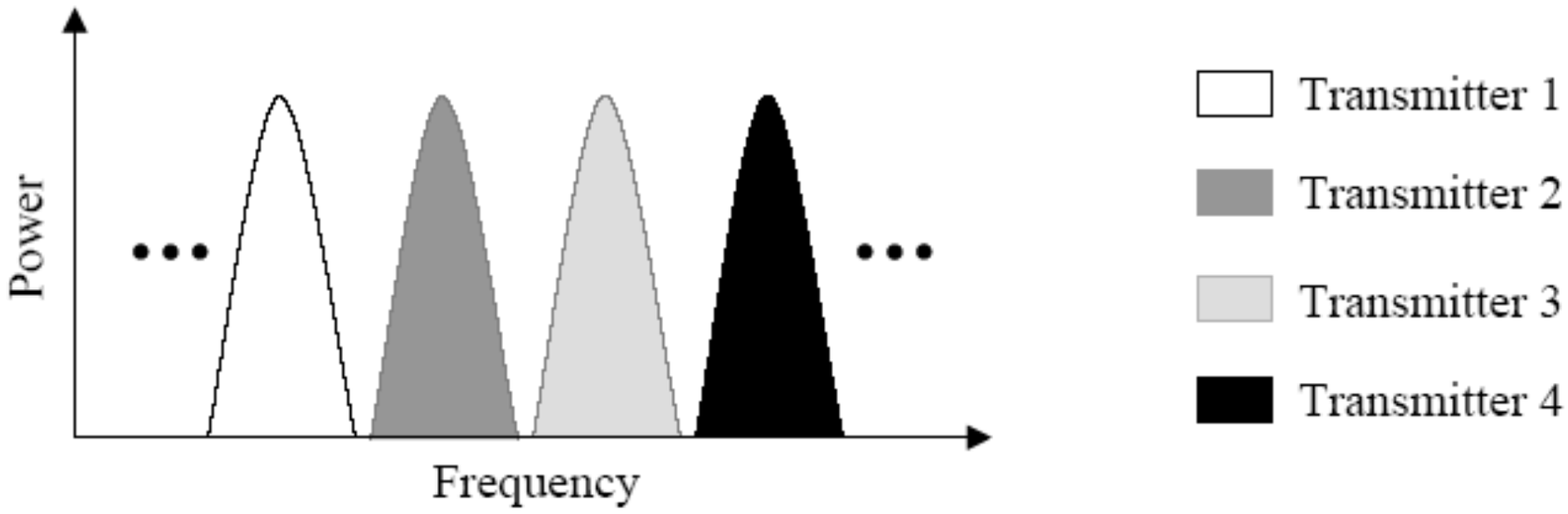
- Control channel
  - ✓ Forward (Downlink) control channel
  - ✓ Reverse (Uplink) control channel
- Traffic channel
  - ✓ Forward traffic (information) channel
  - ✓ Reverse traffic (information) channel

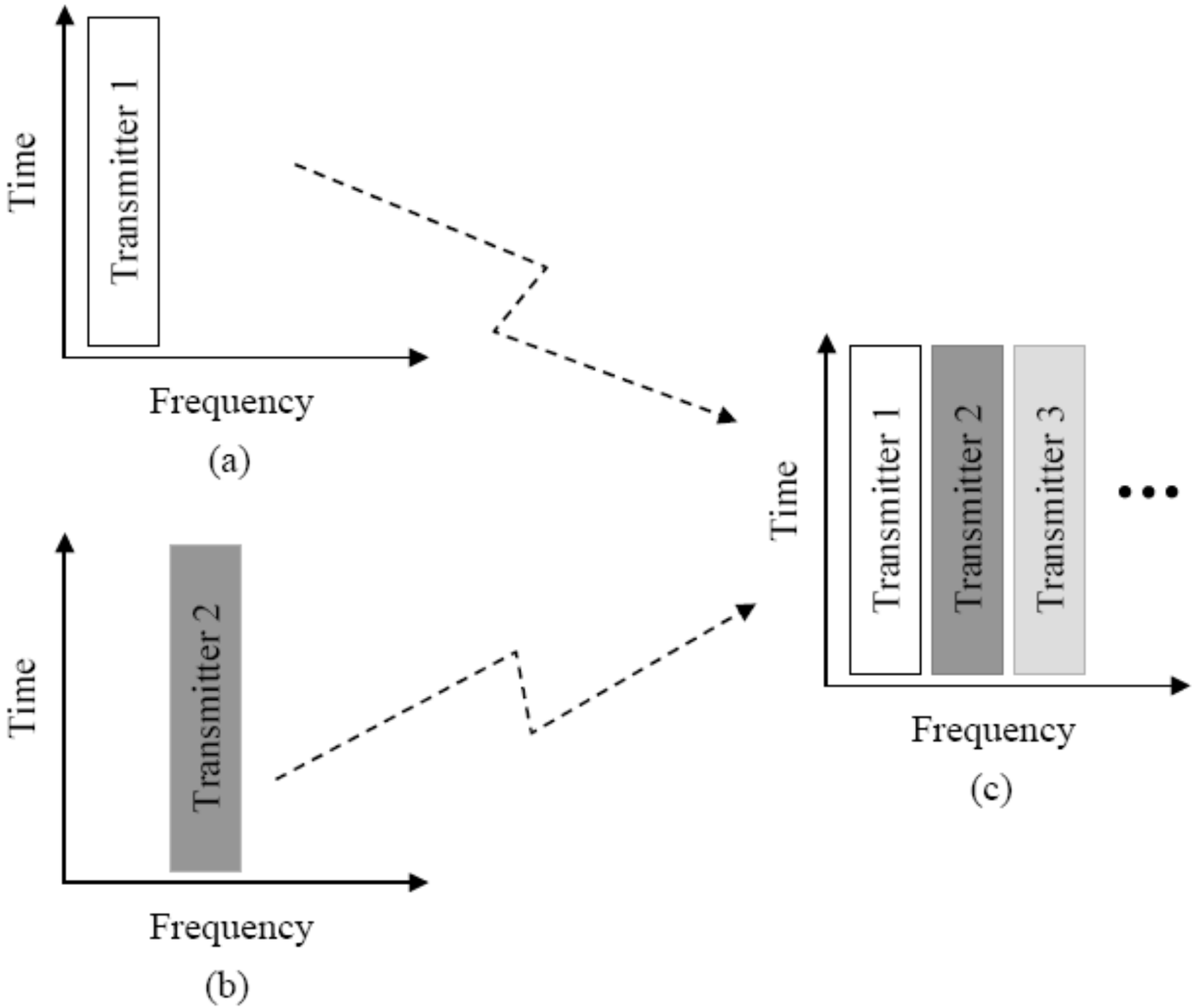



Reverse channel (Uplink)
Control channels
f '
f
f1'
f2'
fn'
f1
f2
fn
MS
Traffic channels
Forward channels
(Downlink)
BS

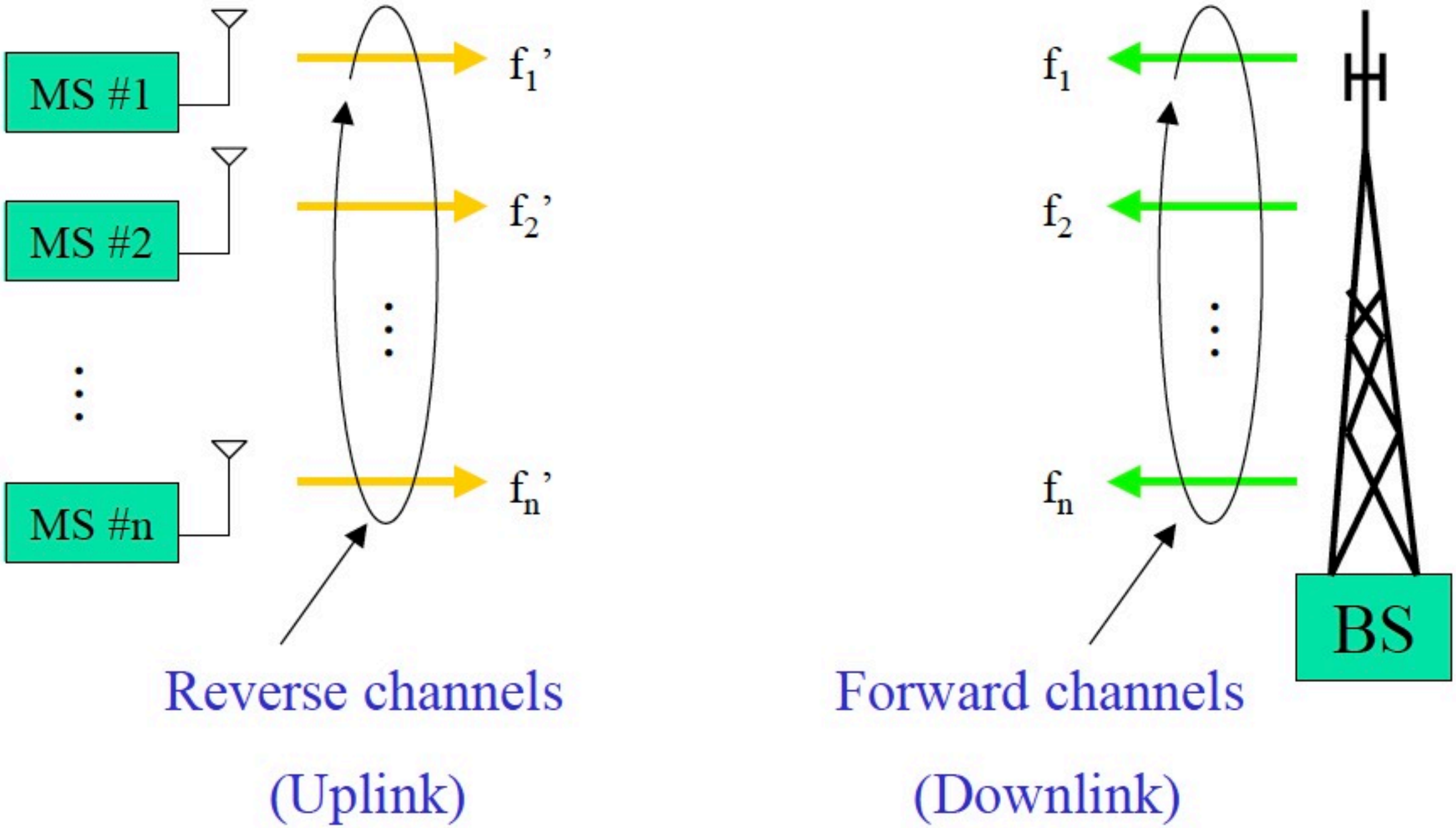
Frequency Division Multiple Access (FDMA)

- Allocation of separate channels to FDMA signals (single channel per carrier)
- All 1G systems use FDMA

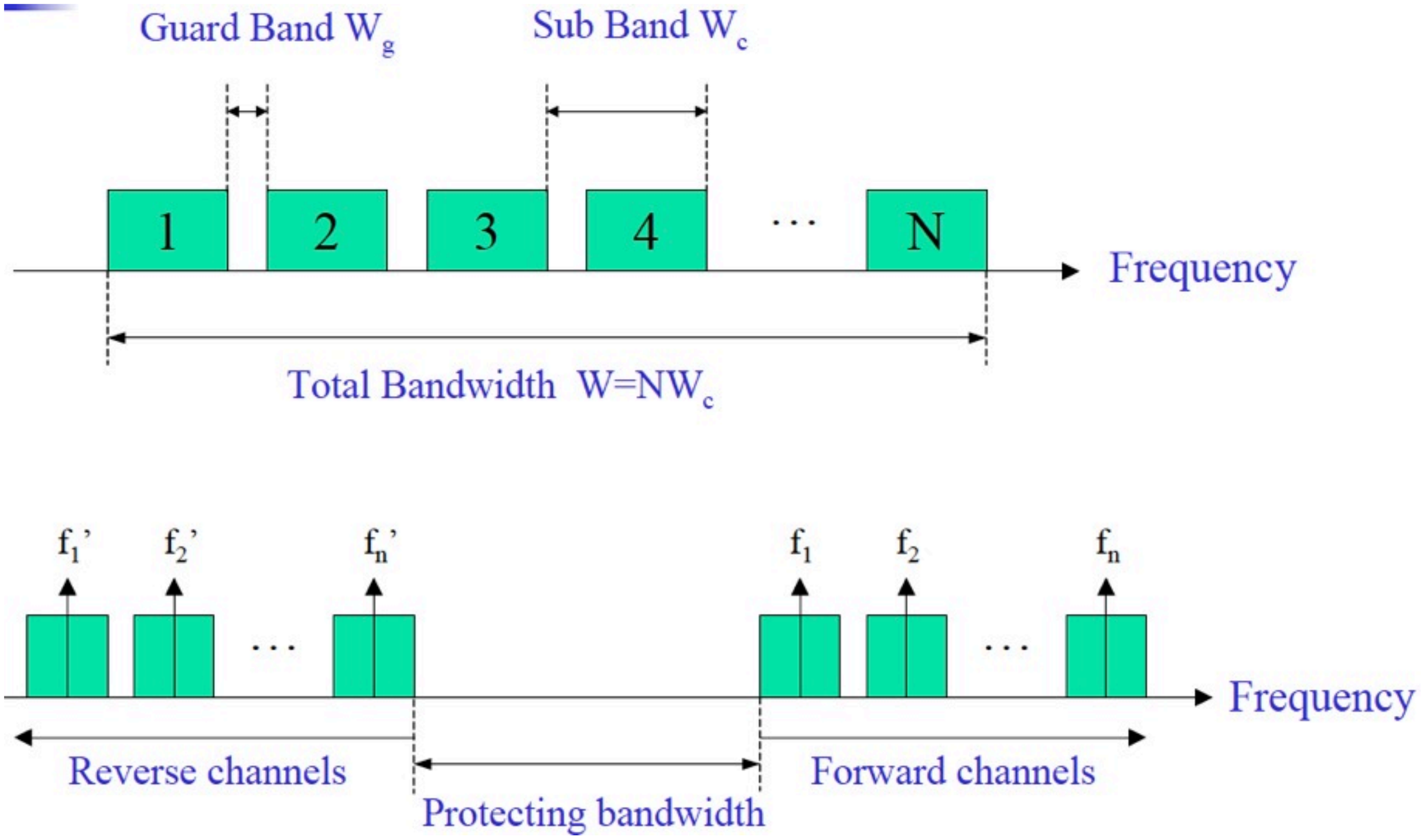



Time
Transmitter 1
Frequency
(a)
Time
Transmitter 2
Frequency
(b)
Time
Transmitter 1
Transmitter 2
Transmitter 3
Frequency
(c)

FDMA

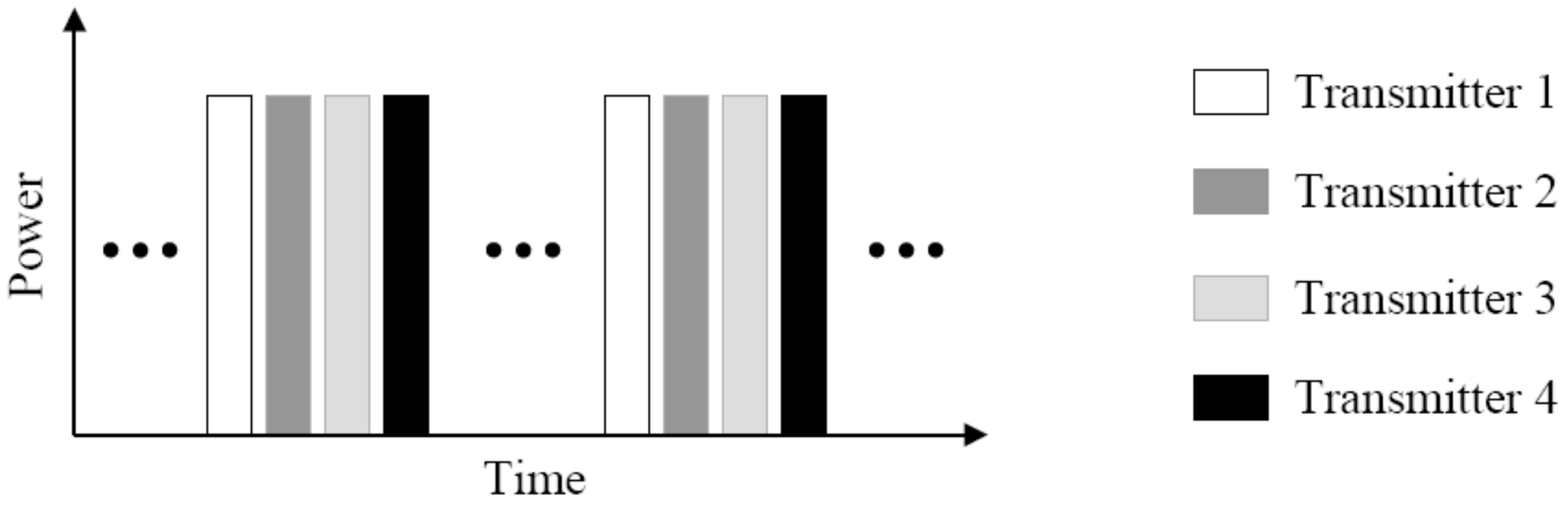

MS #1
MS #2
MS #n
f_1'
f_2'
f_n'
f_1
f_2
f_n
BS
Reverse channels
(Uplink)
Forward channels
(Downlink)

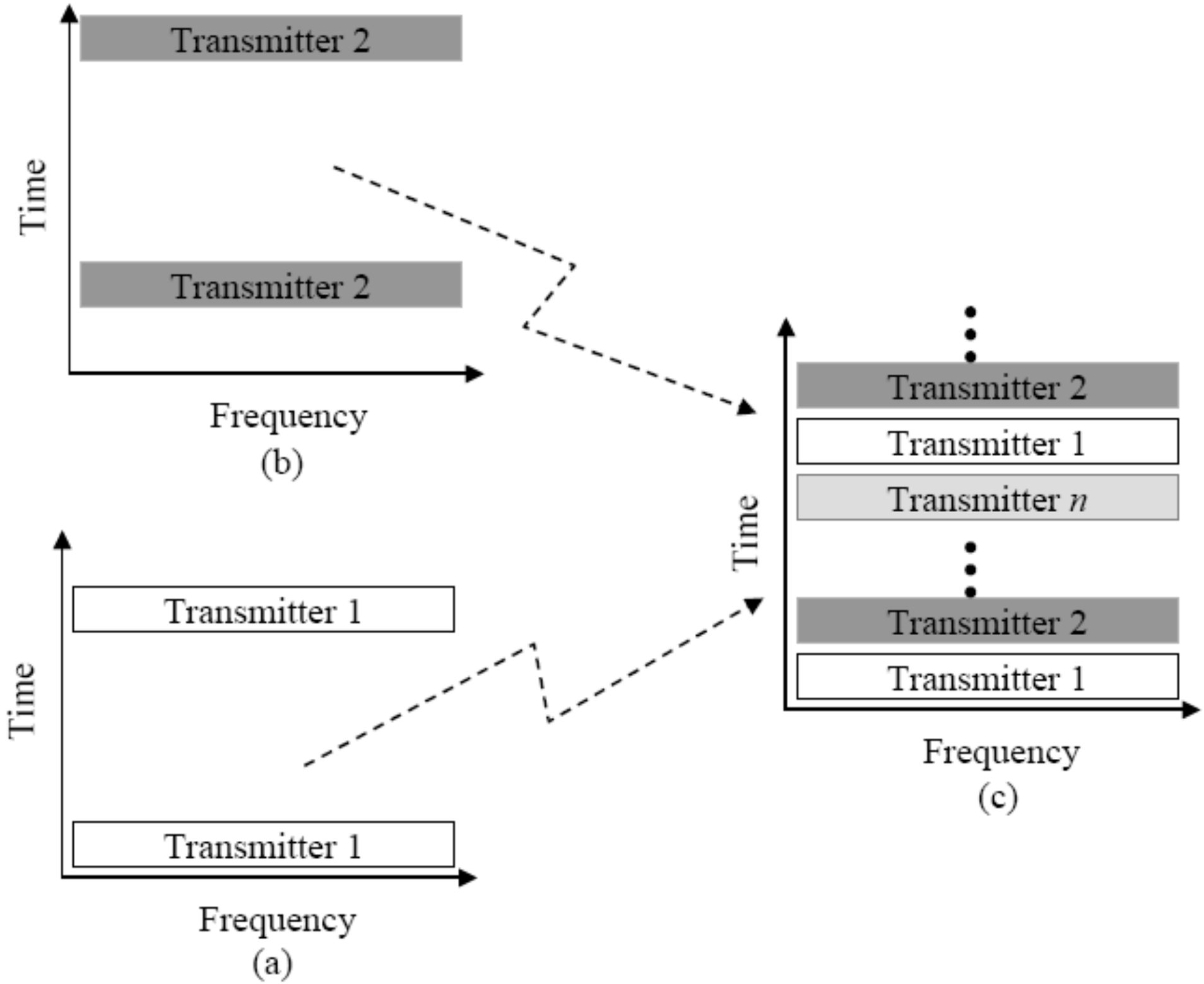
FDMA Channel Structure



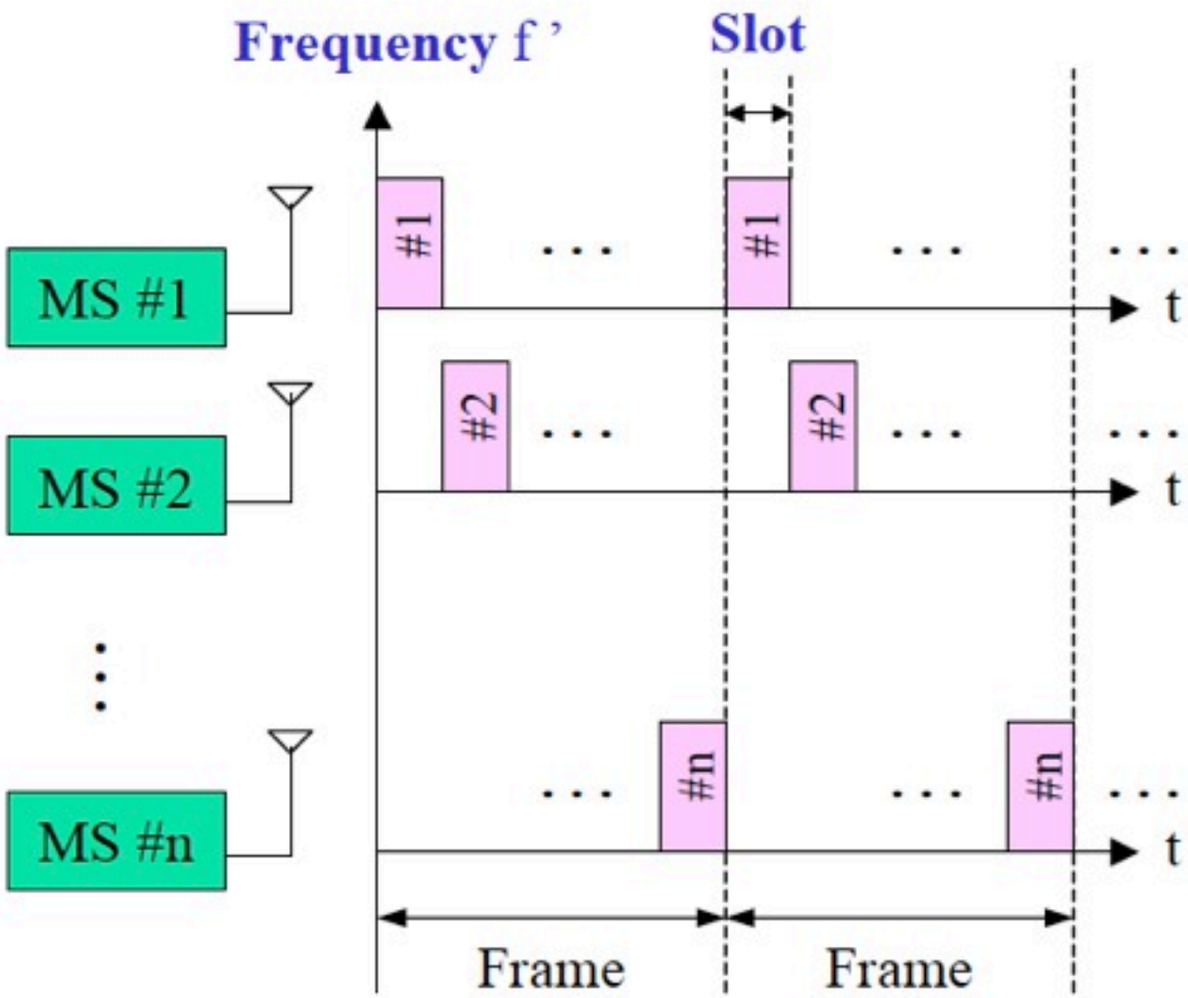
Time Division Multiple Access (TDMA)

- Multiple channels per carrier
- Most of 2G systems use TDMA



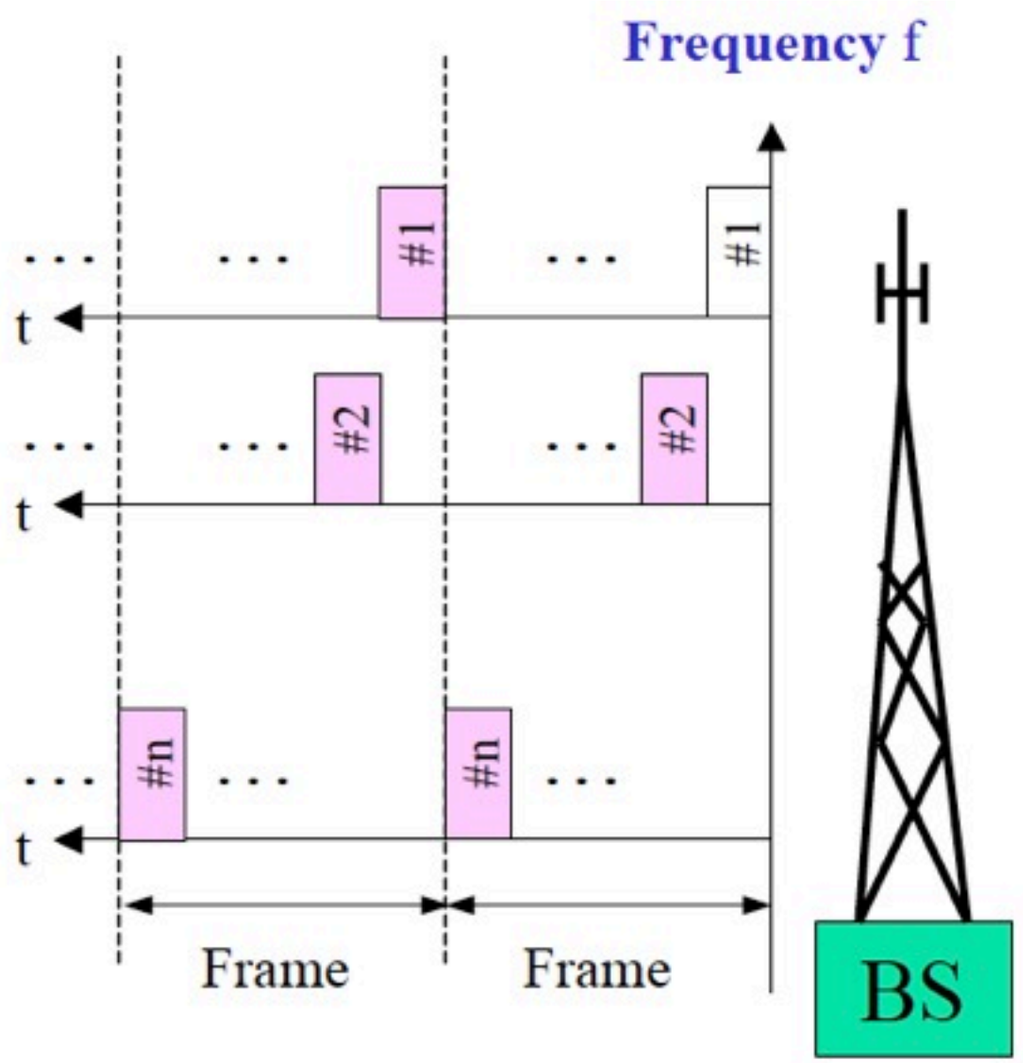

Transmitter 2
Time
Transmitter 2
Frequency
(b)
Transmitter 1
Time
Transmitter 1
Frequency
(a)
Transmitter 2
Transmitter 1
Transmitter n
Transmitter 2
Transmitter 1
Frequency
(c)

TDMA



Reverse channels

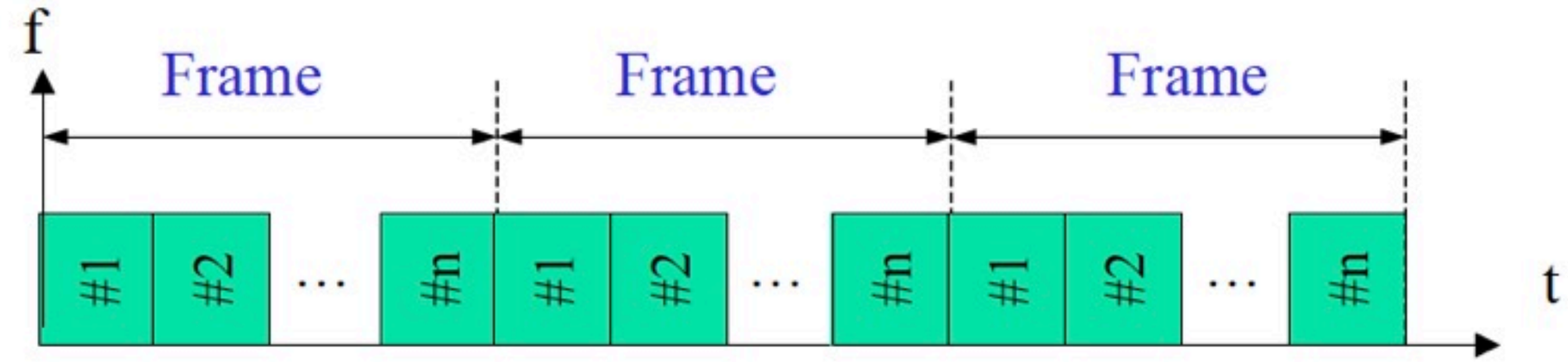
(Uplink)



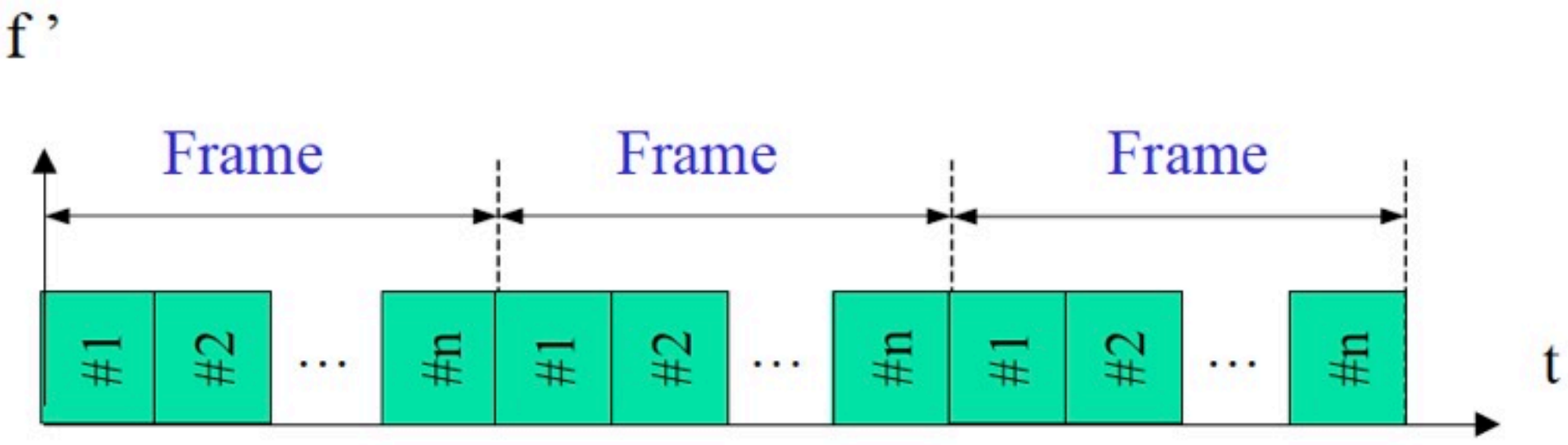
Forward channels

(Downlink)

TDMA Channel Structure

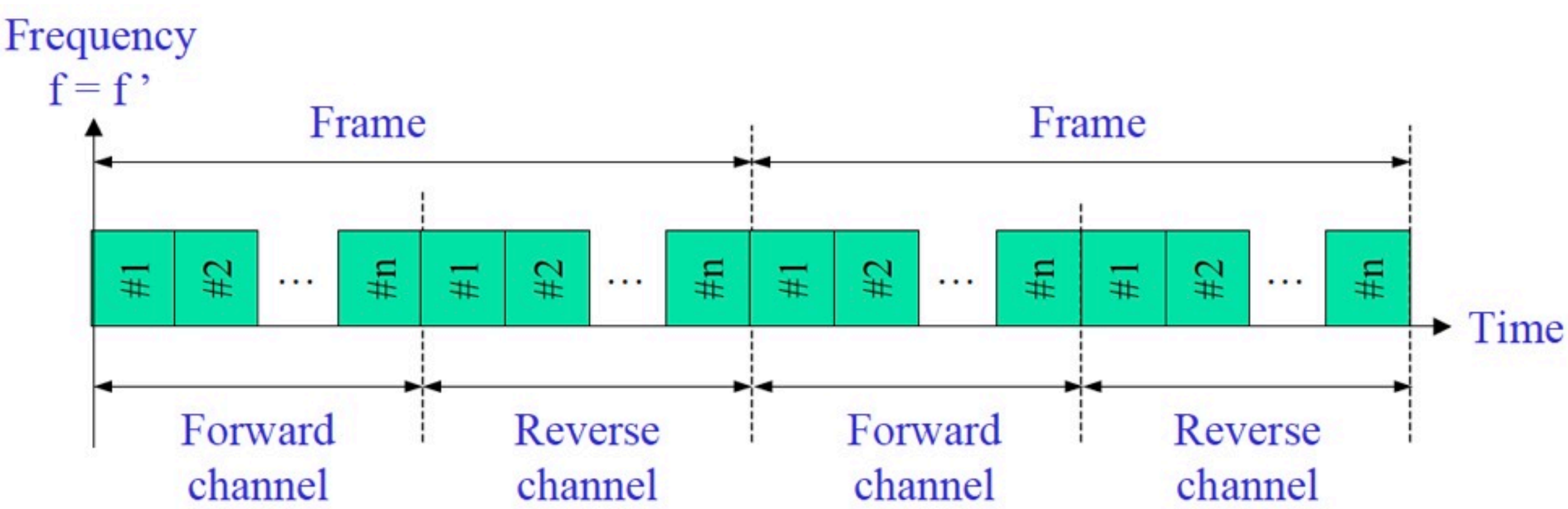


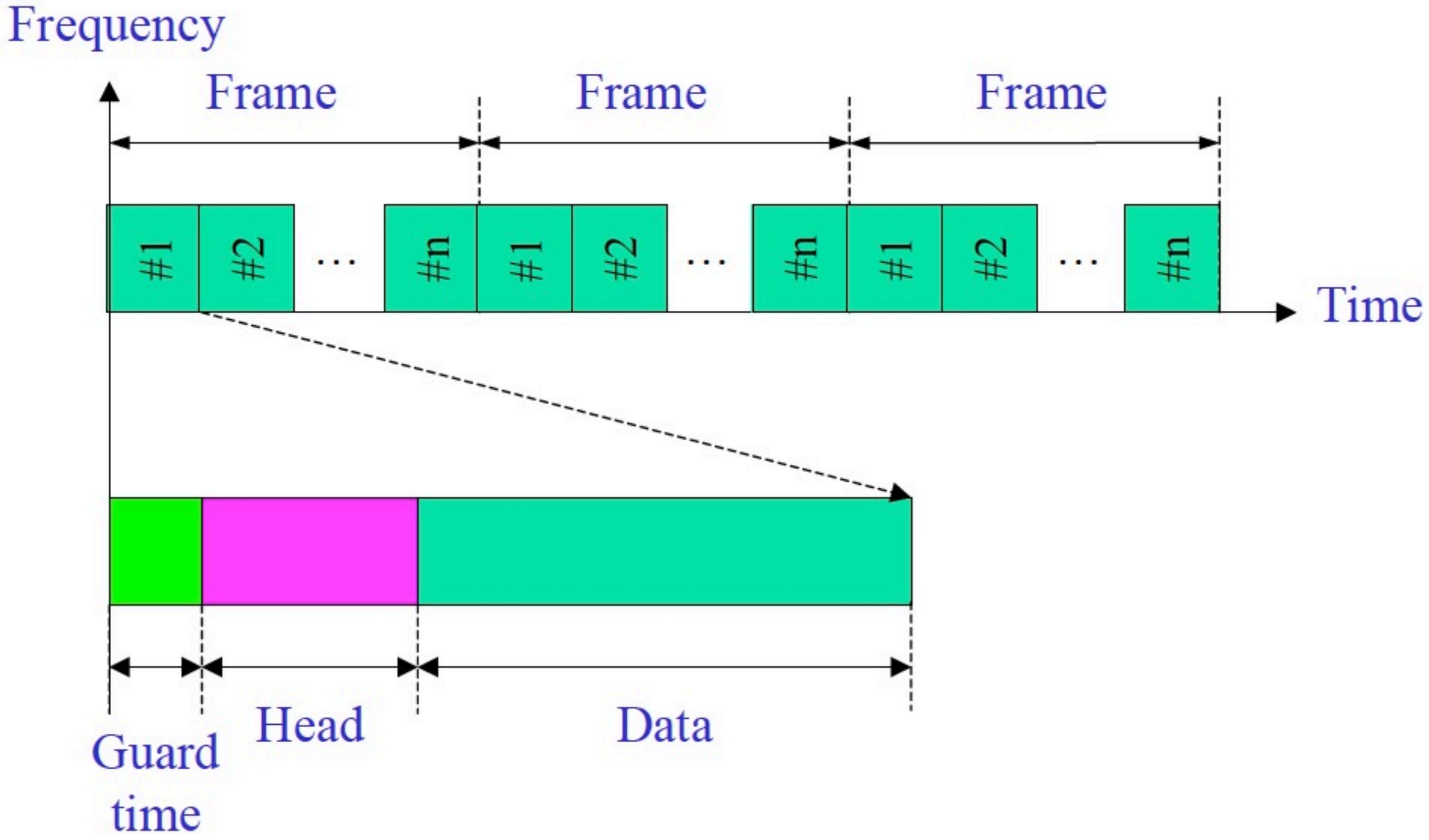
(a). Forward channel



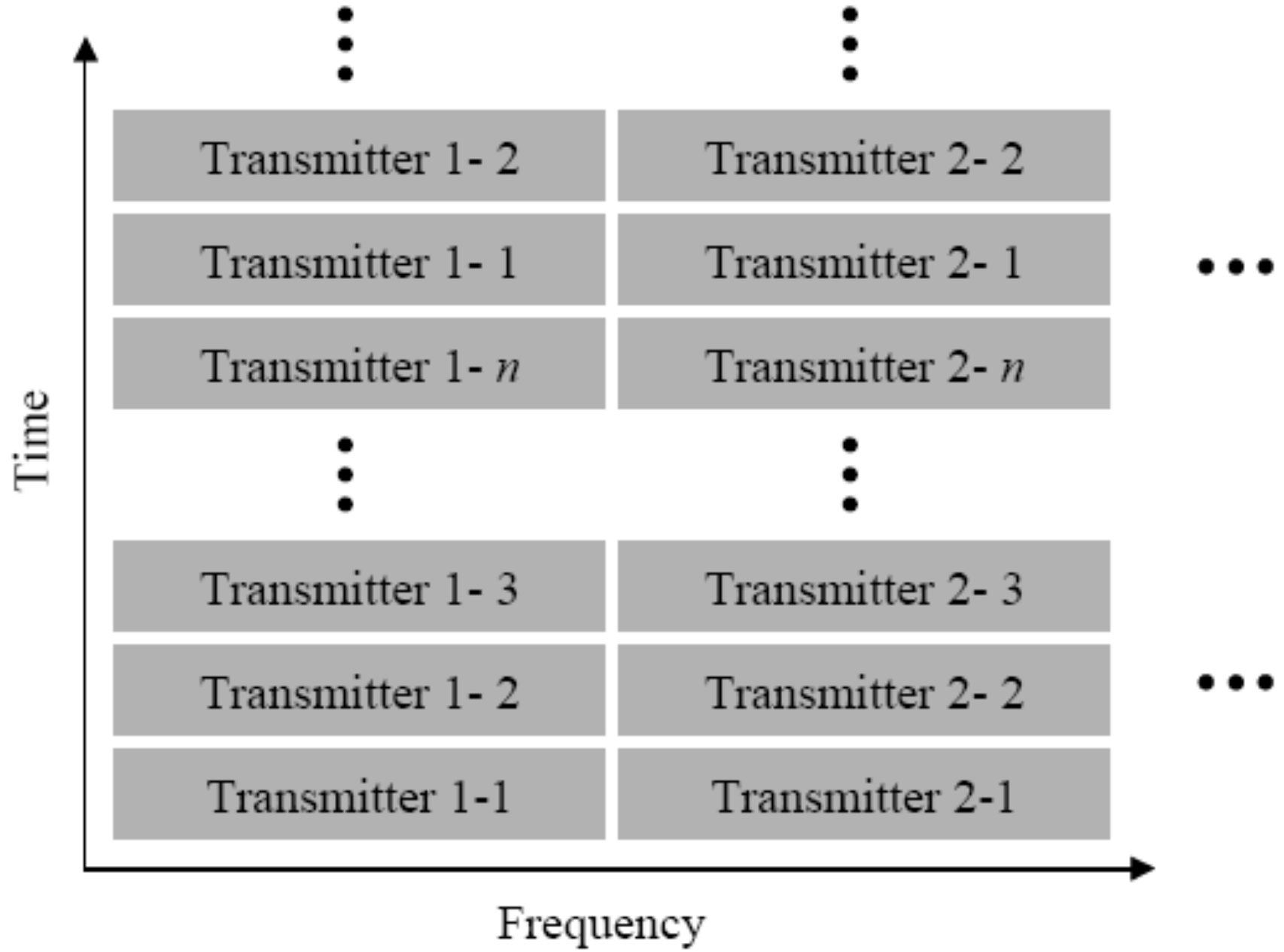
(b). Reverse channel

TDMA Frame Structure



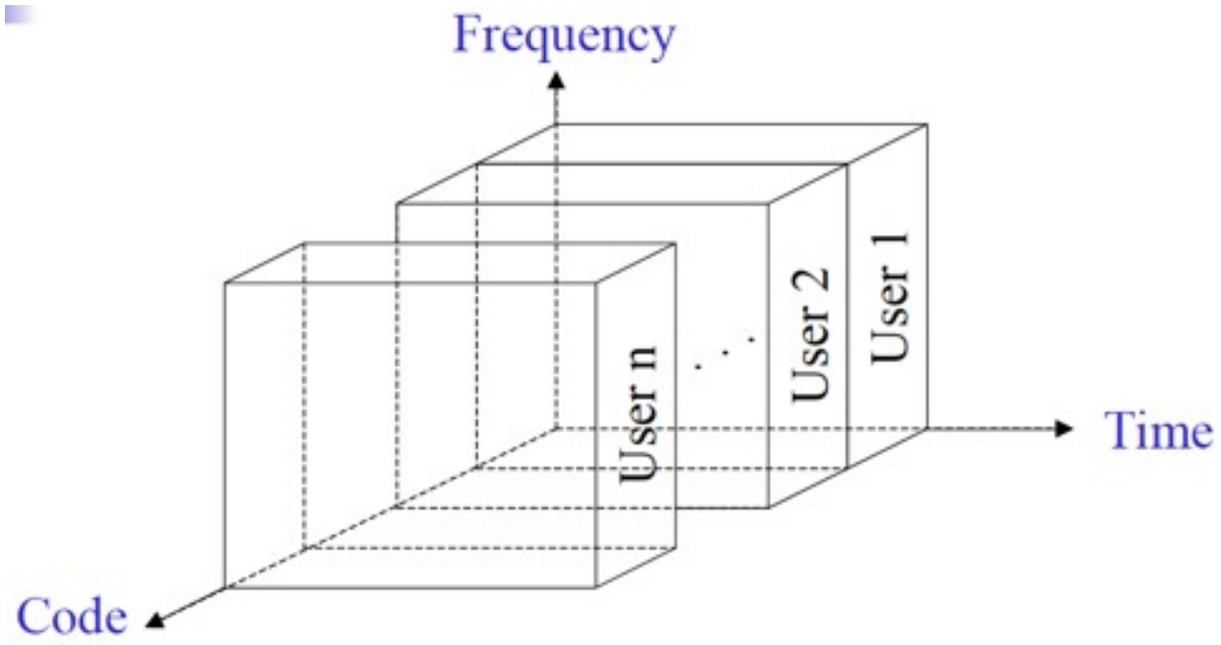

Frequency
Frame
Frame
Frame
#1
#2
...
#n
#1
#2
...
#n
#1
#2
...
#n
Time
Guard time
Head
Data

Combined used of Synchronous TDMA and FDMA

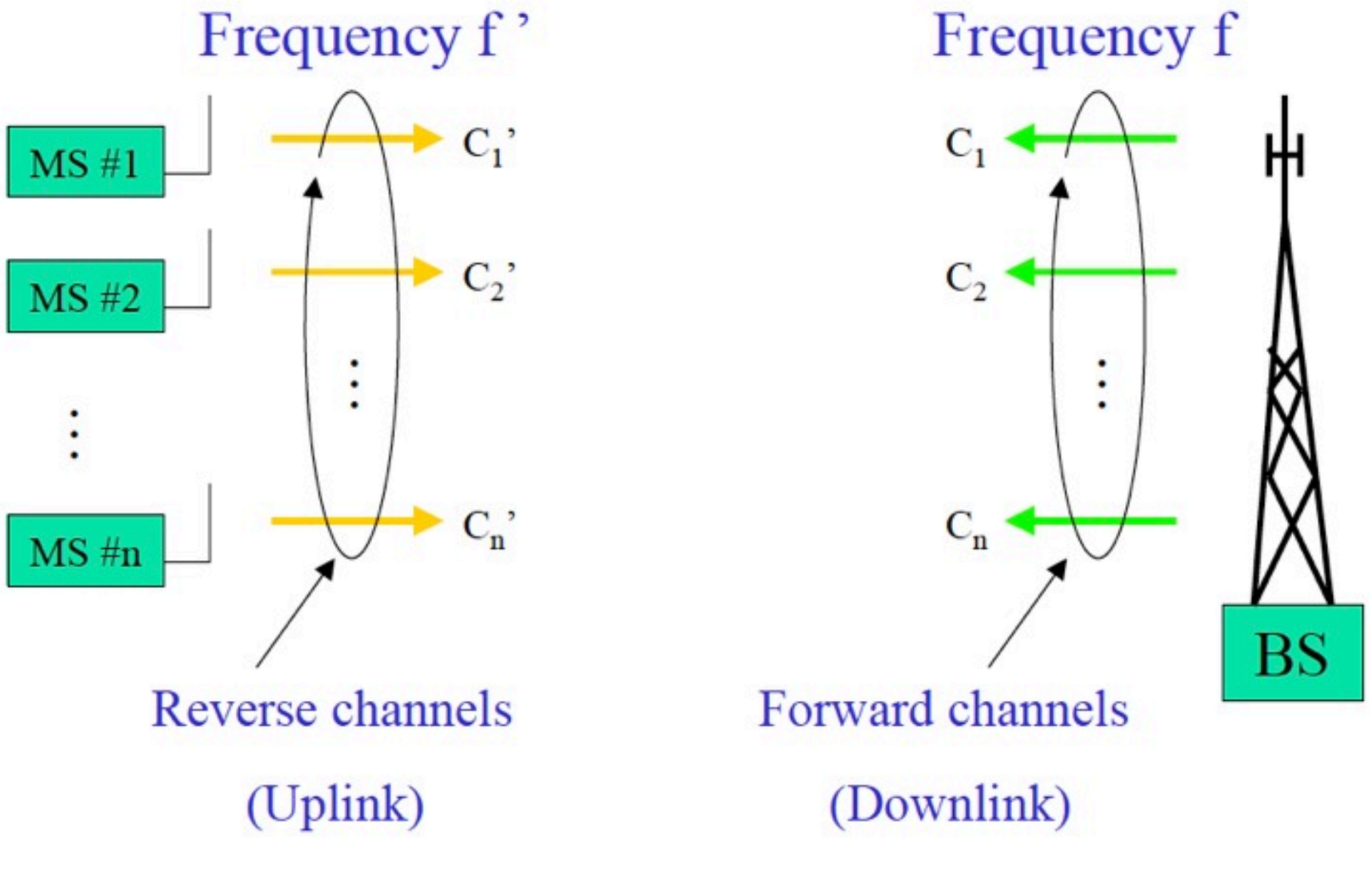


Code Division Multiple Access (CDMA)

- Users share bandwidth by using code sequences that are orthogonal to each other
- Some 2G systems use CDMA
- Most of 3G systems use CDMA



Code Division Multiple Access (CDMA)

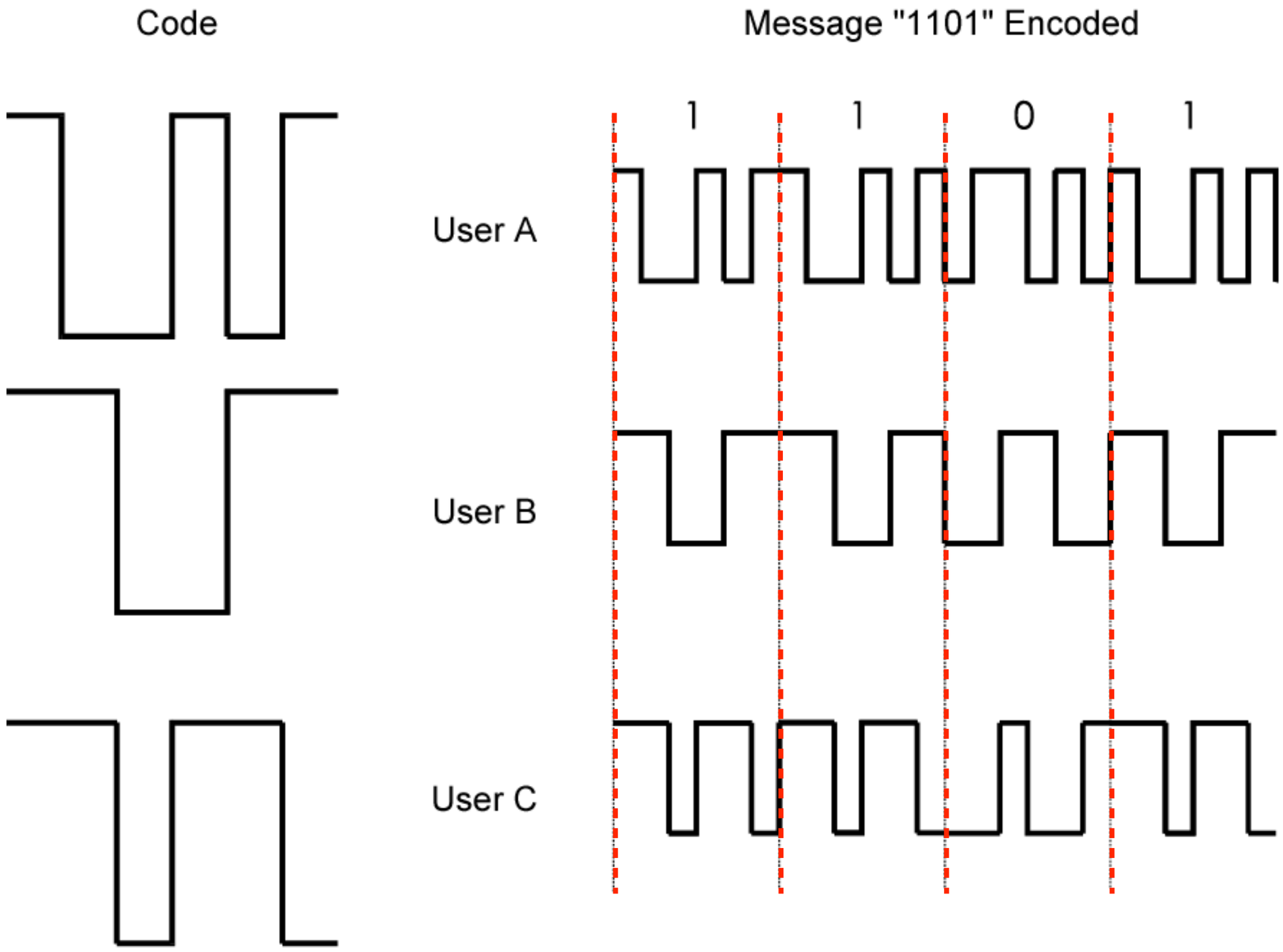


$C_i' \times C_j' = 0$, i.e., C_i' and C_j' are orthogonal codes

$C_i \times C_j = 0$, i.e., C_i and C_j are orthogonal codes

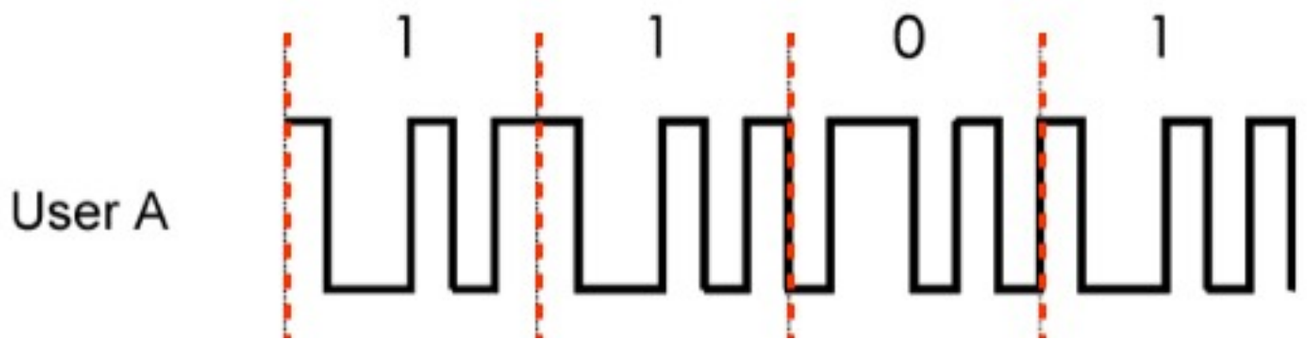
- Multiplexing technique (CDMA) used with spread spectrum
- Start with data signal rate (D), called bit data rate
- Break each bit into *k* chips according to fixed pattern specific to each user, called user's code
- New channel has chip data rate *kD* chips per second
- E.g. *k*=6, three users (*A*,*B*,*C*) 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 BS
- BS 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

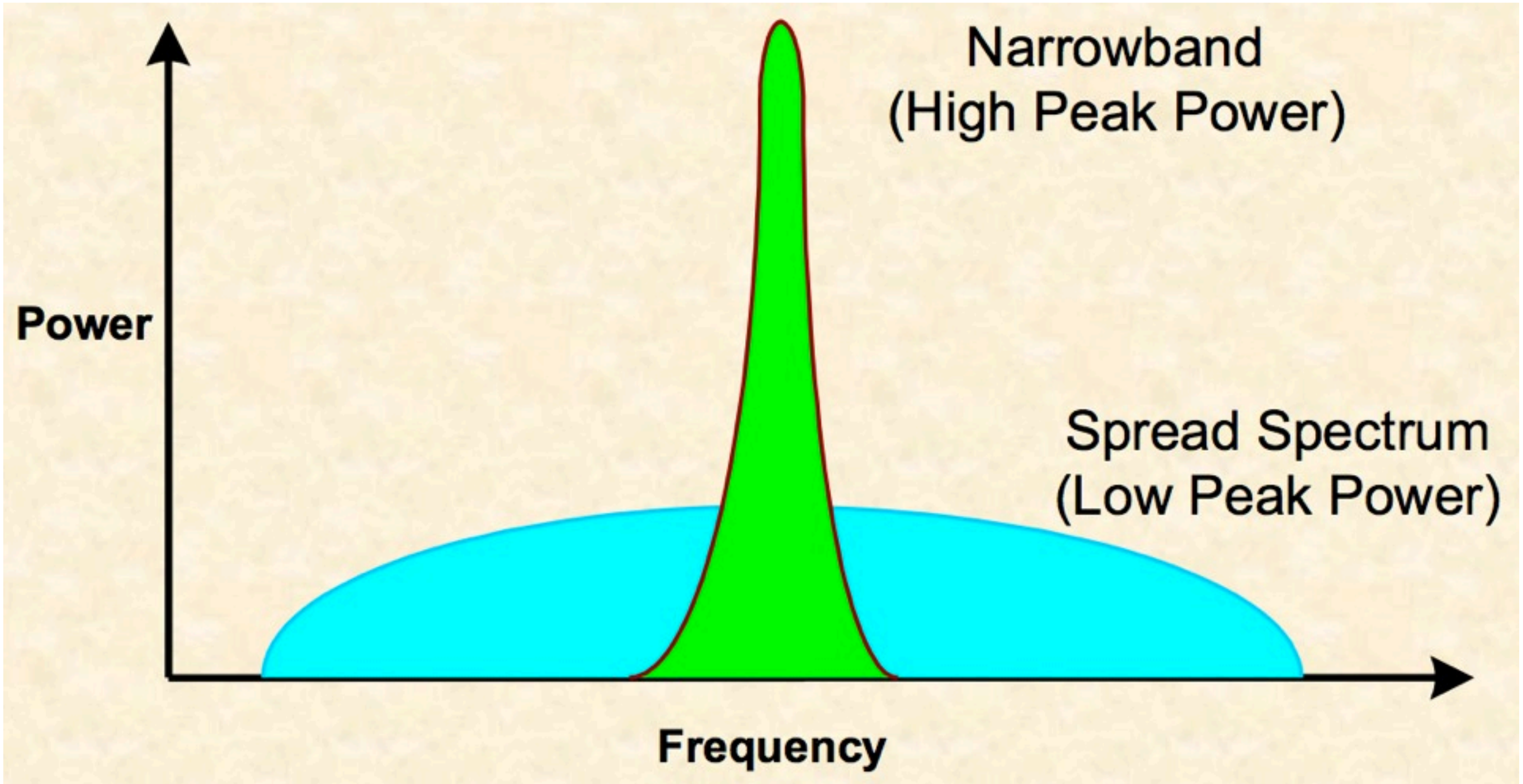


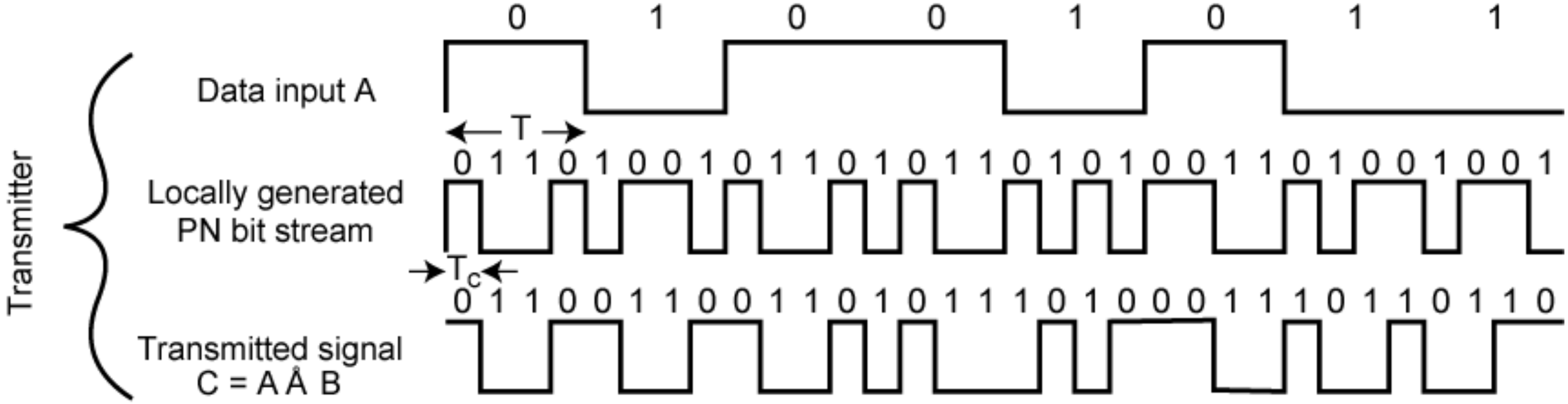
Spread Spectrum (SS) Multiple Access

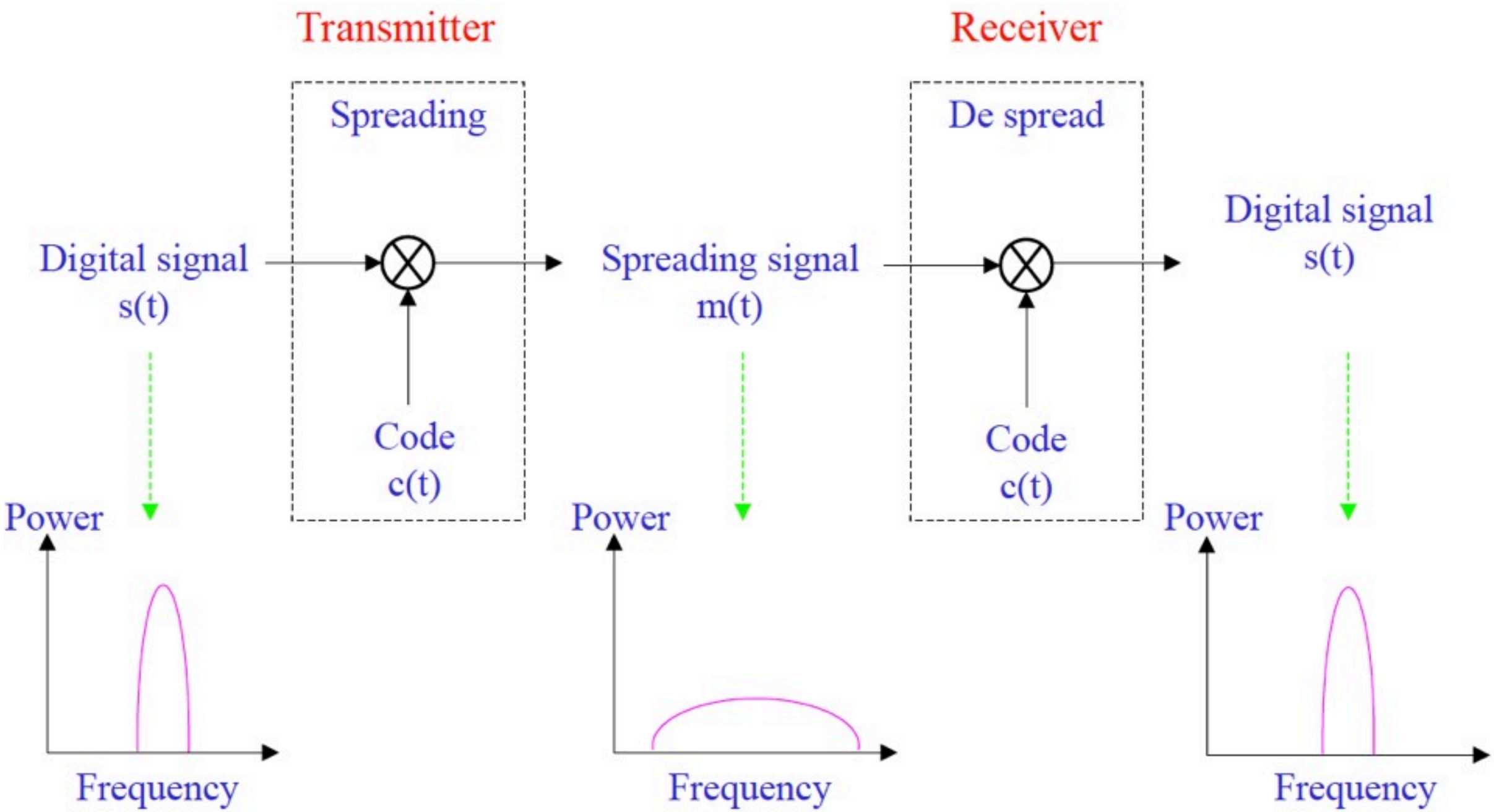
- A transmission technique in which a PN code, independent of information data, is employed as a modulation waveform to "spread" the signal energy over a bandwidth much greater than the signal information bandwidth
- At the receiver the signal is "despread" using a synchronized replica of the PN code
- Two SS techniques
  - ✓ Direct Sequence Spread Spectrum (DSSS)
  - ✓ Frequency Hopping Spread Spectrum (FHSS)

Direct Sequence Spread Spectrum (DSSS)

- A carrier is modulated by a digital code in which the code bit rate is much larger than the information signal bit rate
- These systems are also called pseudo-noise systems
- A short code system uses a *PN* code length equal to a data symbol
- A long system uses a *PN* code length that is much longer than a data symbol


Power
Narrowband
(High Peak Power)
Spread Spectrum
(Low Peak Power)
Frequency

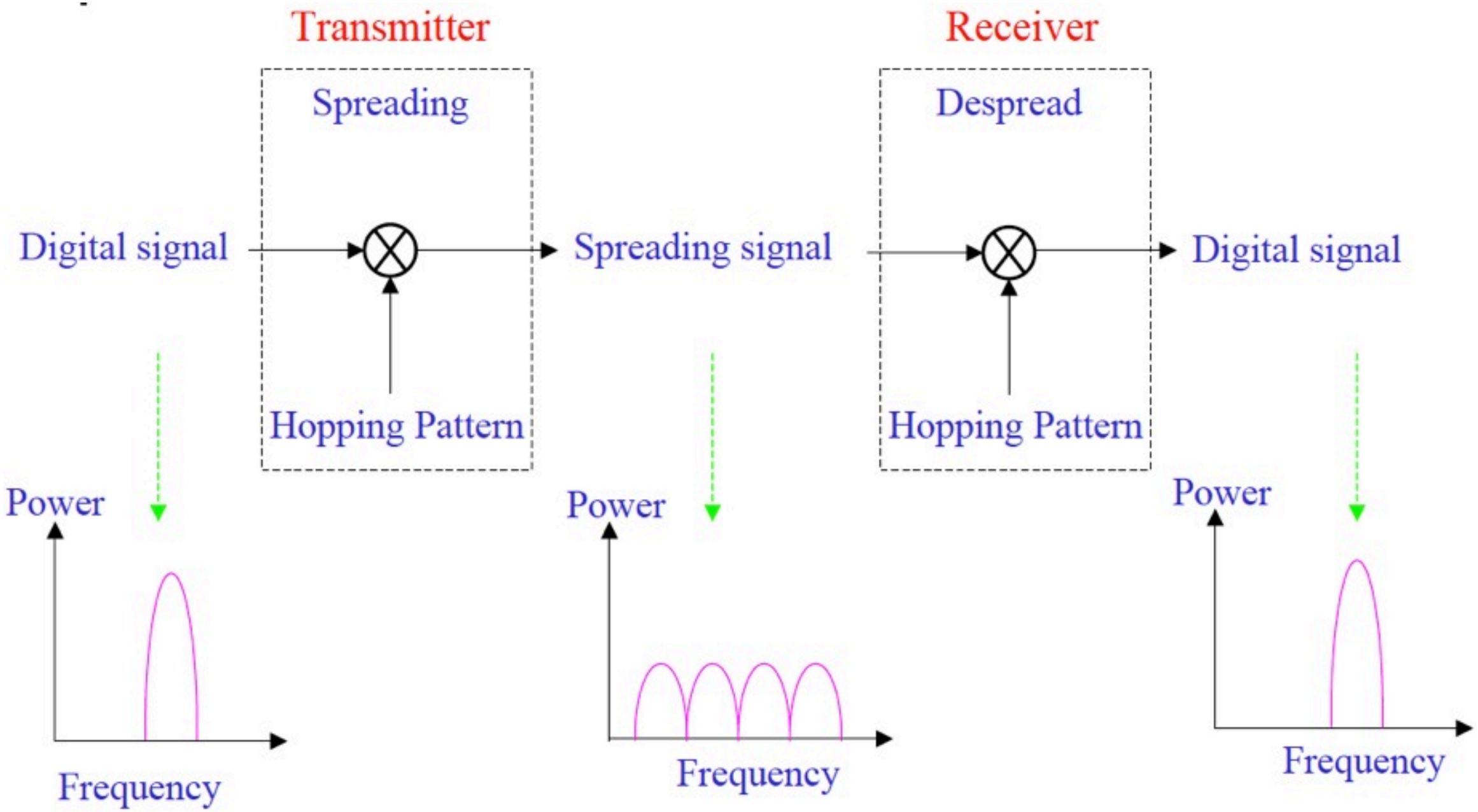

0 1 0 0 1 0 1 1
Data input A
T
0 1 1 0 1 0 0 1 0 1 1 0 1 0 1 1 0 1 0 1 0 0 1 1 0 1 0 0 1 0 0 1
Locally generated
PN bit stream
Tc
0 1 1 0 0 1 1 0 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0
Transmitted signal
C = A Å B
Transmitter
Received signal C
Locally generated
PN bit stream
identical to B
above
Data output
A = C Å B
Receiver


Transmitter
Receiver
Spreading
De spread
Digital signal
s(t)
Spreading signal
m(t)
Digital signal
s(t)
Code
c(t)
Code
c(t)
Power
Power
Power
Frequency
Frequency
Frequency

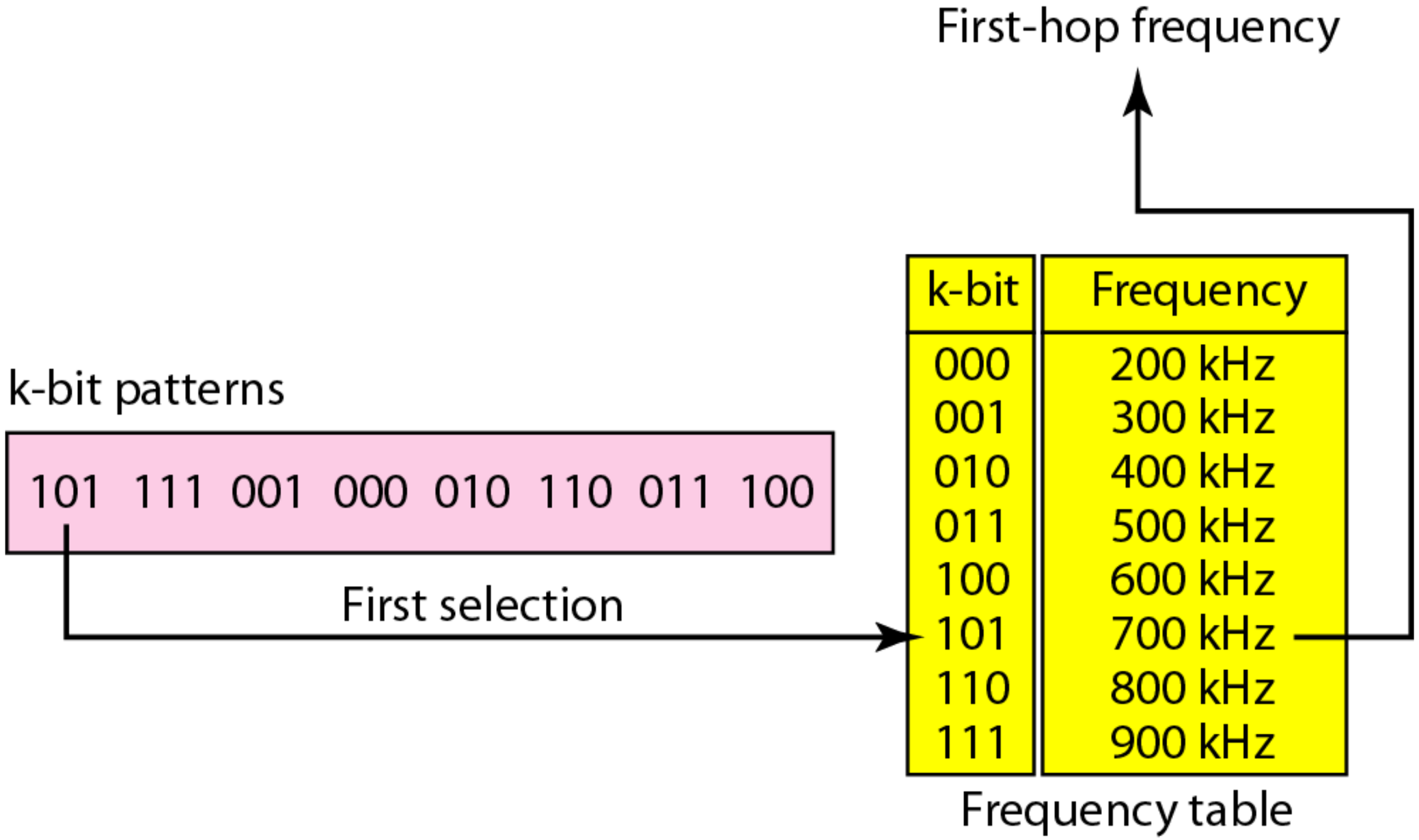
Frequency Hopping Spread Spectrum (FHSS)

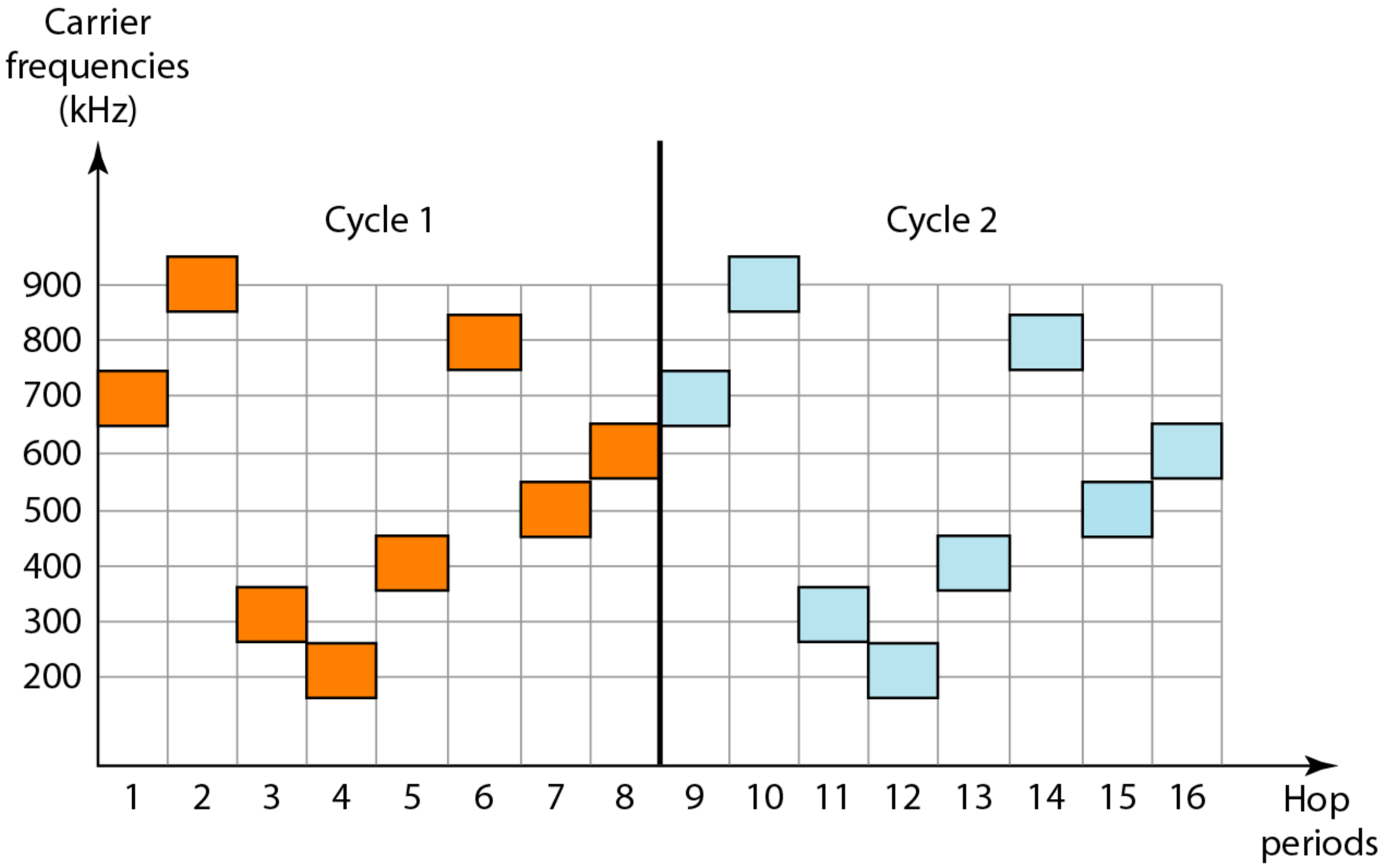
- It divides available bandwidth into *N* channels and hops between these channels according to the *PN* sequence (Pseudo-Noise sequence)
- *PN* sequences
  - ✓ Periodic but appear random within one period
  - ✓ Very easy to generate
  - ✓ Generated using LFSR (Linear Feedback Shift Registers)
  - ✓ Easy to re-generate and synchronize at the receiver

-


Transmitter
Spreading
Digital signal
Spreading signal
Hopping Pattern
Power
Frequency
Receiver
Despread
Digital signal
Hopping Pattern
Power
Frequency
Power
Frequency

Example of Frequency Hopping Pattern




Carrier frequencies (kHz)
Cycle 1
Cycle 2
900
800
700
600
500
400
300
200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Hop periods