CS 3205 COMPUTER NETWORKS

JAN-MAY 2020

LECTURE 10: 10TH FEB 2020

Text book and section(s) covered in this lecture:
Book Kurose and Ross – Sections 6.2

Wireless - CDMA

Section 6.2, 6.2.1

Additional resources used for CDMA:

https://www.cs.princeton.edu/courses/archive/spring18/cos463/lectures/L04-aloha.pdf

https://www.geeksforgeeks.org/java-cdma-code-division-multiple-access/

Wireless Link Characteristics (1)

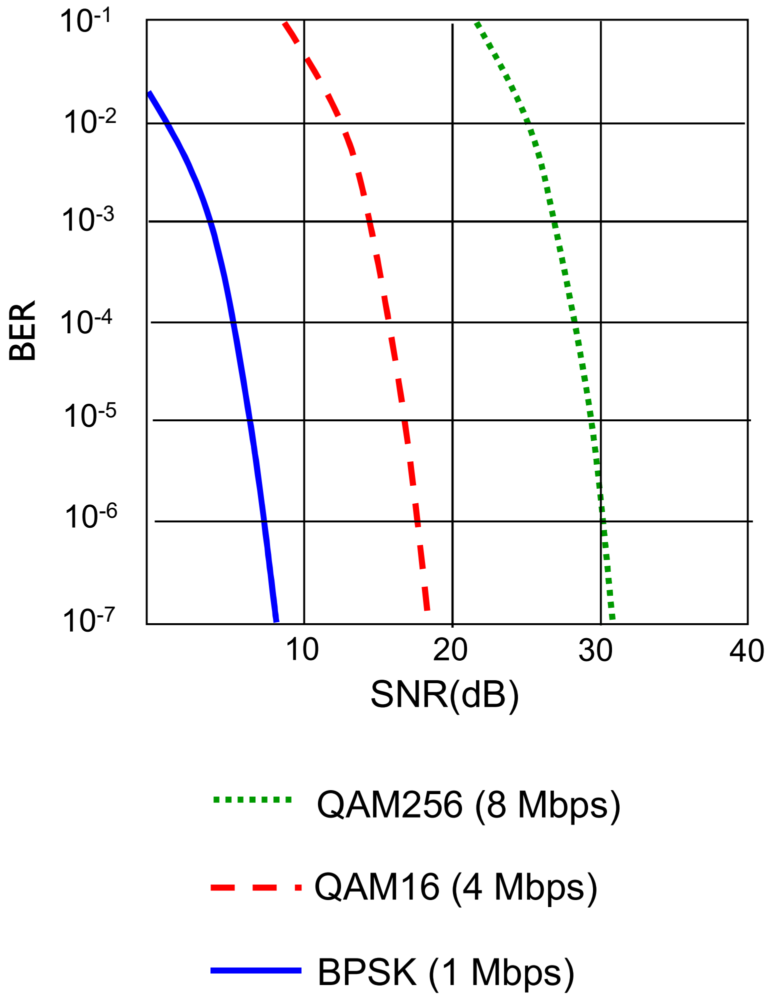
important differences from wired link ….

- *decreased signal strength:* radio signal attenuates as it propagates through matter (path loss)
- *interference from other sources:* standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
- *multipath propagation:* radio signal reflects off objects ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more "difficult"

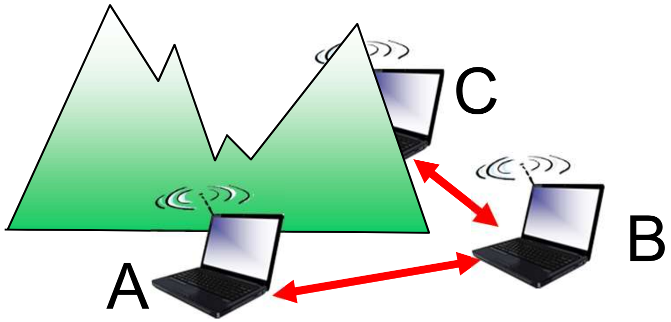
Wireless Link Characteristics (2)

- SNR: signal-to-noise ratio
  - larger SNR – easier to extract signal from noise (a "good thing")
- *SNR versus BER tradeoffs*
  - *given physical layer:* increase power -> increase SNR->decrease BER
  - *given SNR:* choose physical layer that meets BER requirement, giving highest thruput
    - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



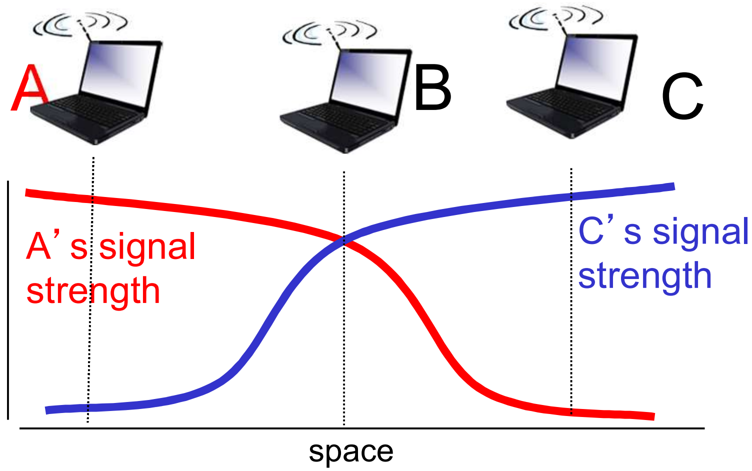
Wireless network characteristics

Multiple wireless senders and receivers create additional problems (beyond multiple access):



Hidden terminal problem

- B, A hear each other
- B, C hear each other
- A, C can not hear each other means A, C unaware of their interference at B

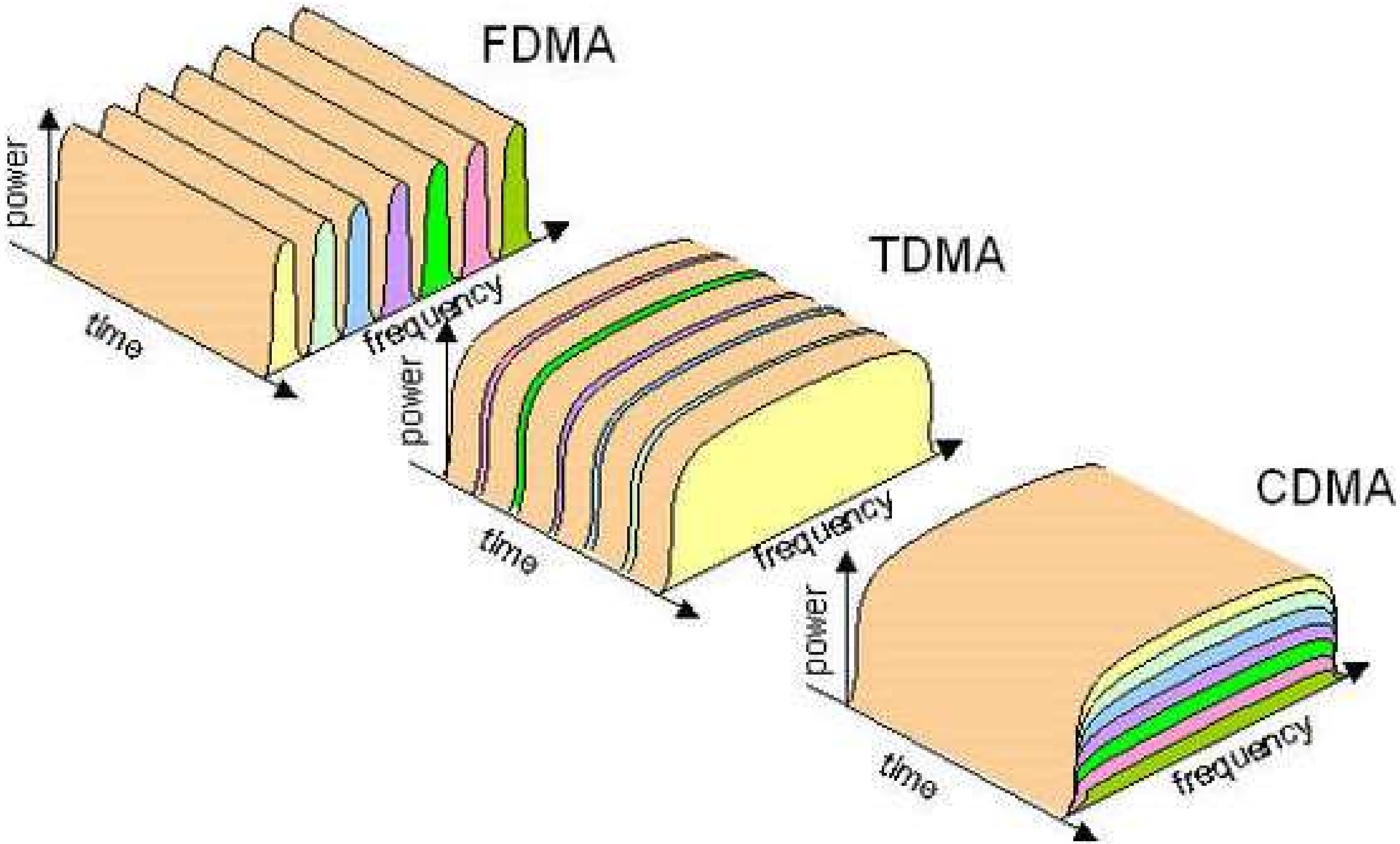


Signal attenuation:

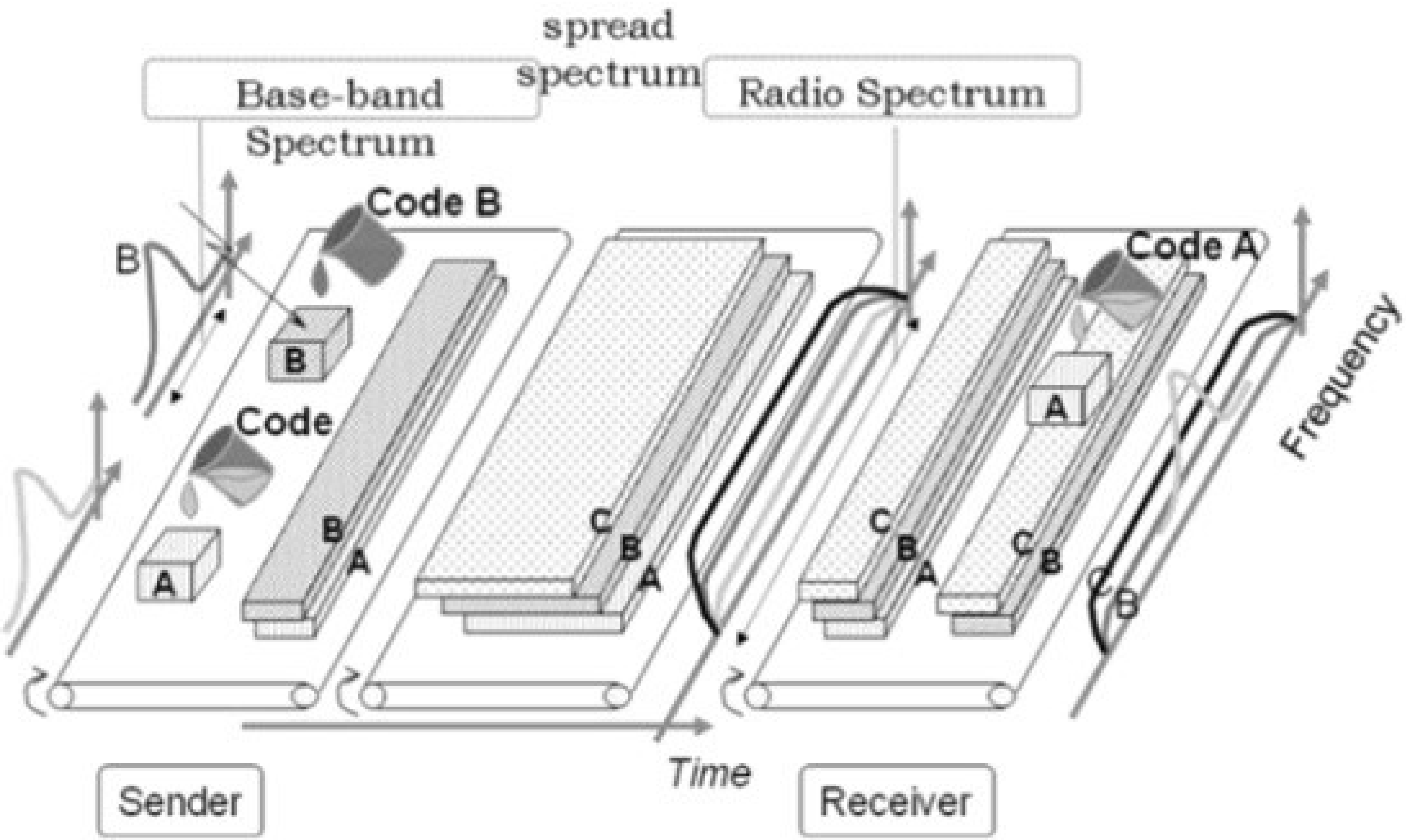
- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B

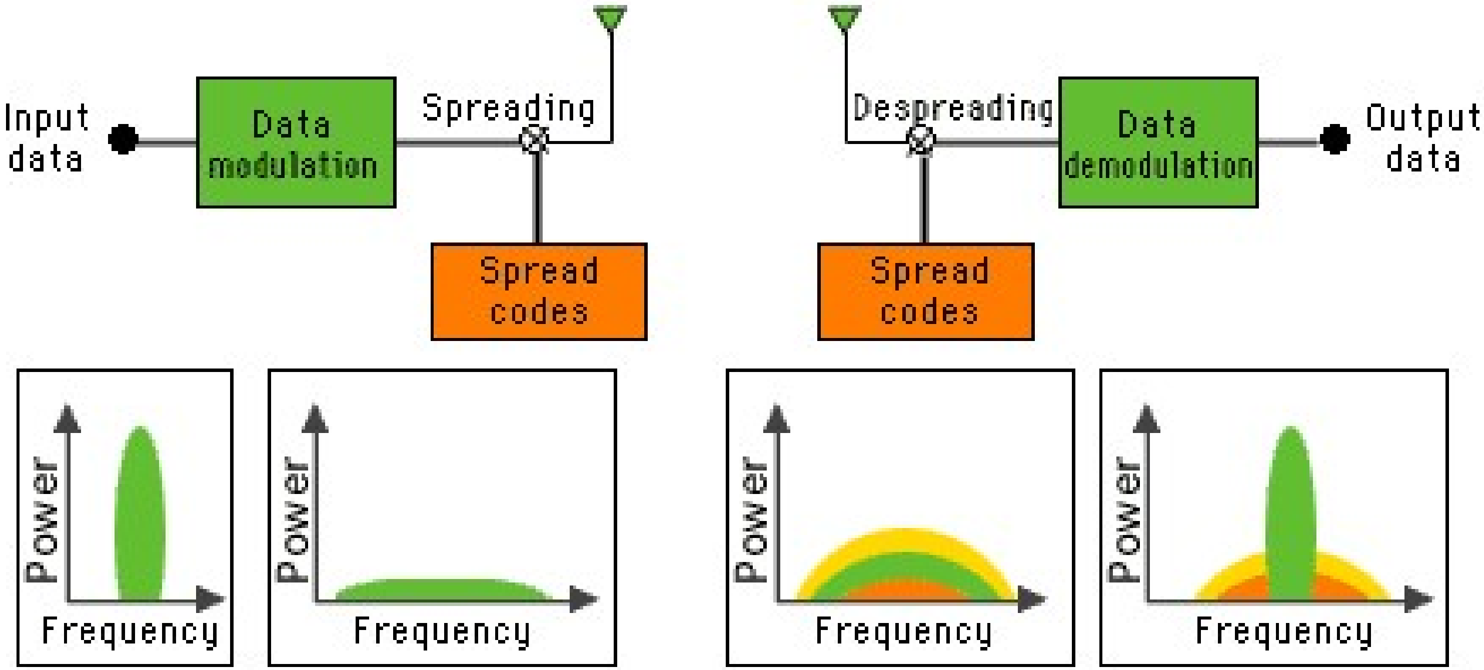
Code Division Multiple Access (CDMA)

- unique "code" assigned to each user; i.e., code set partitioning
  - all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
  - allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")
- *encoded signal* = (original data) X (chipping sequence)
- *decoding:* inner-product of encoded signal and chipping sequence



https://careershapers.wordpress.com/2014/03/10/difference-between-gsm-and-cdma-explained/


spread spectrum
Base-band Spectrum
Radio Spectrum
Code B
Code A
B
B
Code
A
B
A
C
B
A
C
B
A
A
C
B
C
B
Frequency
Time
Sender
Receiver



Spread Spectrum technique…

https://www.nttdocomo.co.jp/english/corporate/technology/rd/tech/network/multiple_access/05/index.html

How does CDMA work?

To see how CDMA works, we have to understand orthogonal sequences (also known as chips).

Let N be the number of stations establishing multiple access over a common channel.

Then the properties of orthogonal sequences can be stated as follows:

1. An orthogonal sequence can be thought of as a 1xN matrix.
   Eg: [+1 -1 +1 -1] for N = 4.
2. Scalar multiplication and matrix addition rules follow as usual.
   Eg: 3.[+1 -1 +1 -1] = [+3 -3 +3 -3]
   Eg: [+1 -1 +1 -1] + [-1 -1 -1 -1] = [0 -2 0 -2]
3. **Inner Product:** It is evaluated by multiplying two sequences element by element and then adding all elements of the resulting list.
   - Inner Product of a sequence with itself is equal to N
     [+1 -1 +1 -1].[+1 -1 +1 -1] = 1 + 1 + 1 + 1 = 4
   - Inner Product of two distinct sequences is zero
     [+1 -1 +1 -1].[+1 +1 +1 +1] = 1-1+1-1 = 0

To generate valid orthogonal sequences, use a **Walsh Table** as follows:

- **Rule 1:**

$$W_1 = [+1]$$

- **Rule 2:**

$$W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

Where $\overline{W_N}$ = Complement of W_N (Replace +1 by -1 and -1 by +1)

Example:

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

Each row of the matrix represents an orthogonal sequence.Hence we can construct sequences for N = 2^M. Now let's take a look at how CDMA works by using orthogonal sequences.

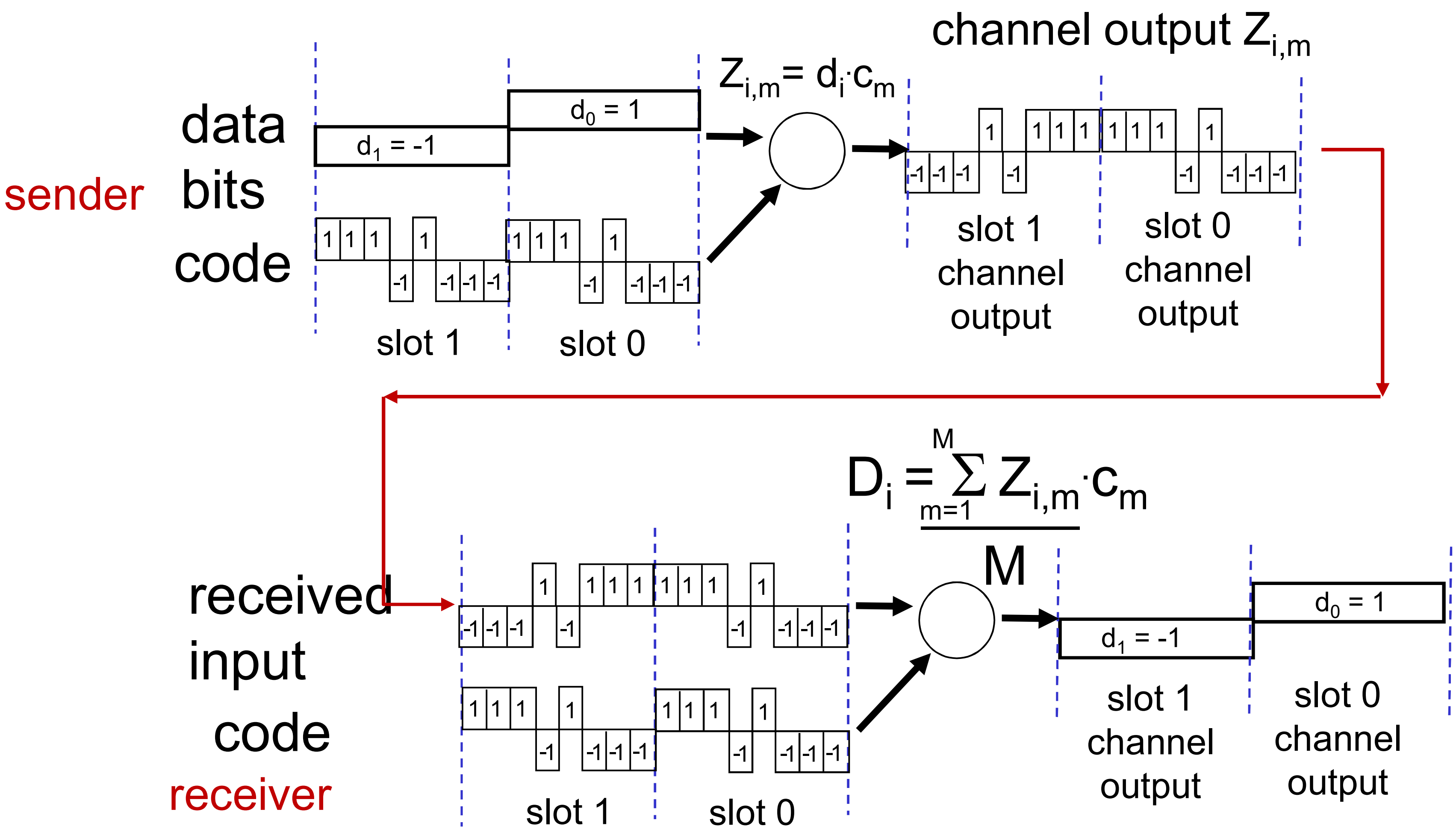
Procedure:

1. The station encodes its data bit as follows.
   - +1 if bit = 1
   - -1 if bit = 0
   - no signal(interpreted as 0) if station is idle
2. Each station is assigned a unique orthogonal sequence (code) which is N bit long for N stations
3. Each station does a scalar multiplication of its encoded data bit and code sequence.
4. The resulting sequence is then placed on the channel.
5. Since the channel is common, amplitudes add up and hence resultant channel sequence is sum of sequences from all channels.
6. If station 1 wants to listen to station 2, it multiplies (inner product) the channel sequence with code of station S2.
7. The inner product is then divided by N to get data bit transmitted from station 2.

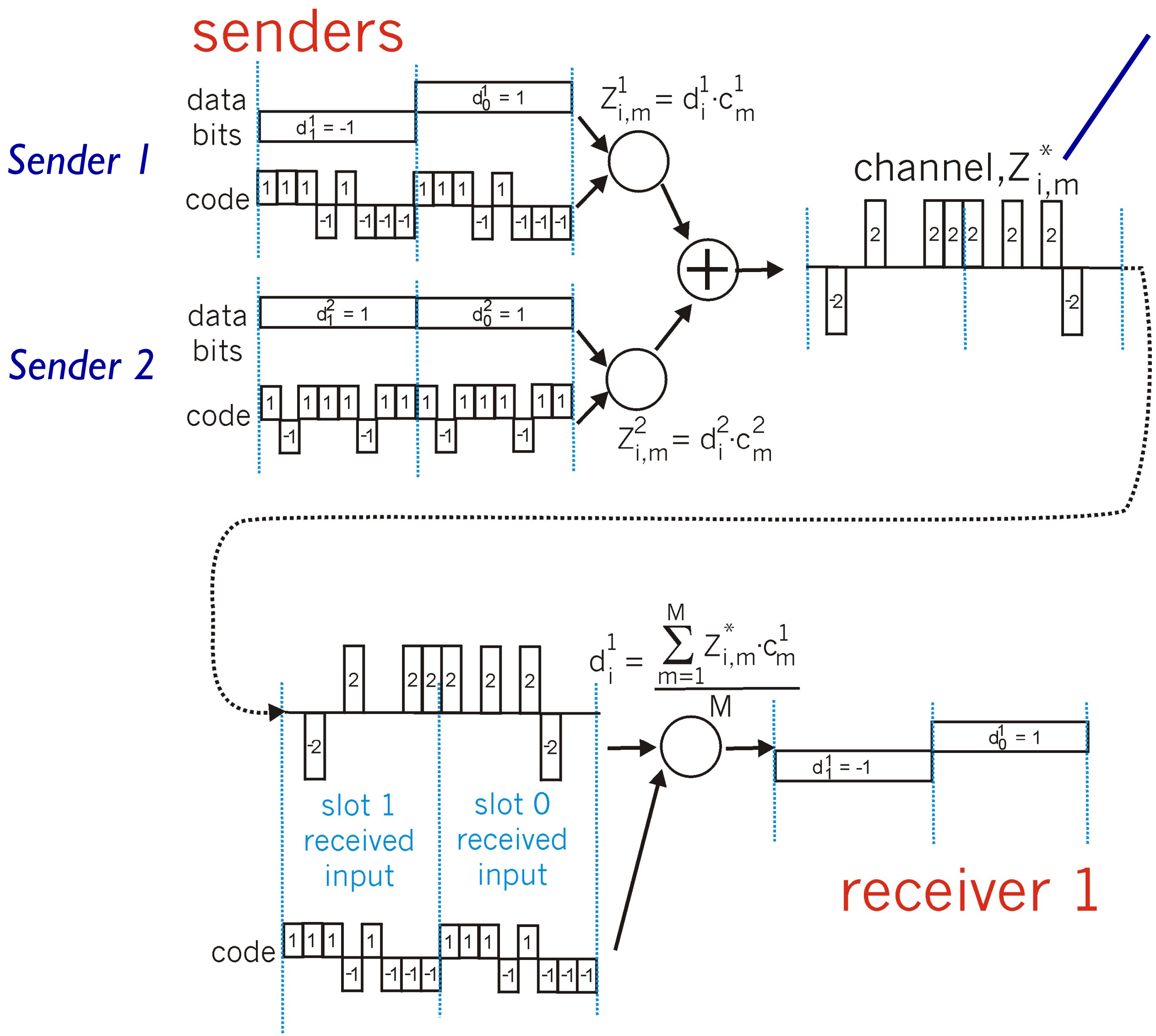
Example: Assume 4 stations S1, S2, S3, S4. We'll use 4×4 Walsh Table to assign codes to them.

```
C1 = [+1 +1 +1 +1]
C2 = [+1 -1 +1 -1]
C3 = [+1 +1 -1 -1]
C4 = [+1 -1 -1 +1]

Let their data bits currently be:
D1 = -1
D2 = -1
D3 = 0 (Silent)
D4 = +1

Resultant channel sequence = C1.D1 + C2.D2 + C3.D3 + C4.D4
                           = [-1 -1 -1 -1] + [-1 +1 -1 +1] + [0 0 0 0]
                                                   + [+1 -1 -1 +1]
                           = [-1 -1 -3 +1]

Now suppose station 1 wants to listen to station 2.
Inner Product = [-1 -1 -3 +1] x C2
              = -1 + 1 - 3 - 1 = -4

Data bit that was sent = -4/4 = -1.
```

CDMA encode/decode



CDMA: two-sender interference



channel sums together transmissions by sender 1 and 2

using same code as sender 1, receiver recovers sender 1's original data from summed channel data!

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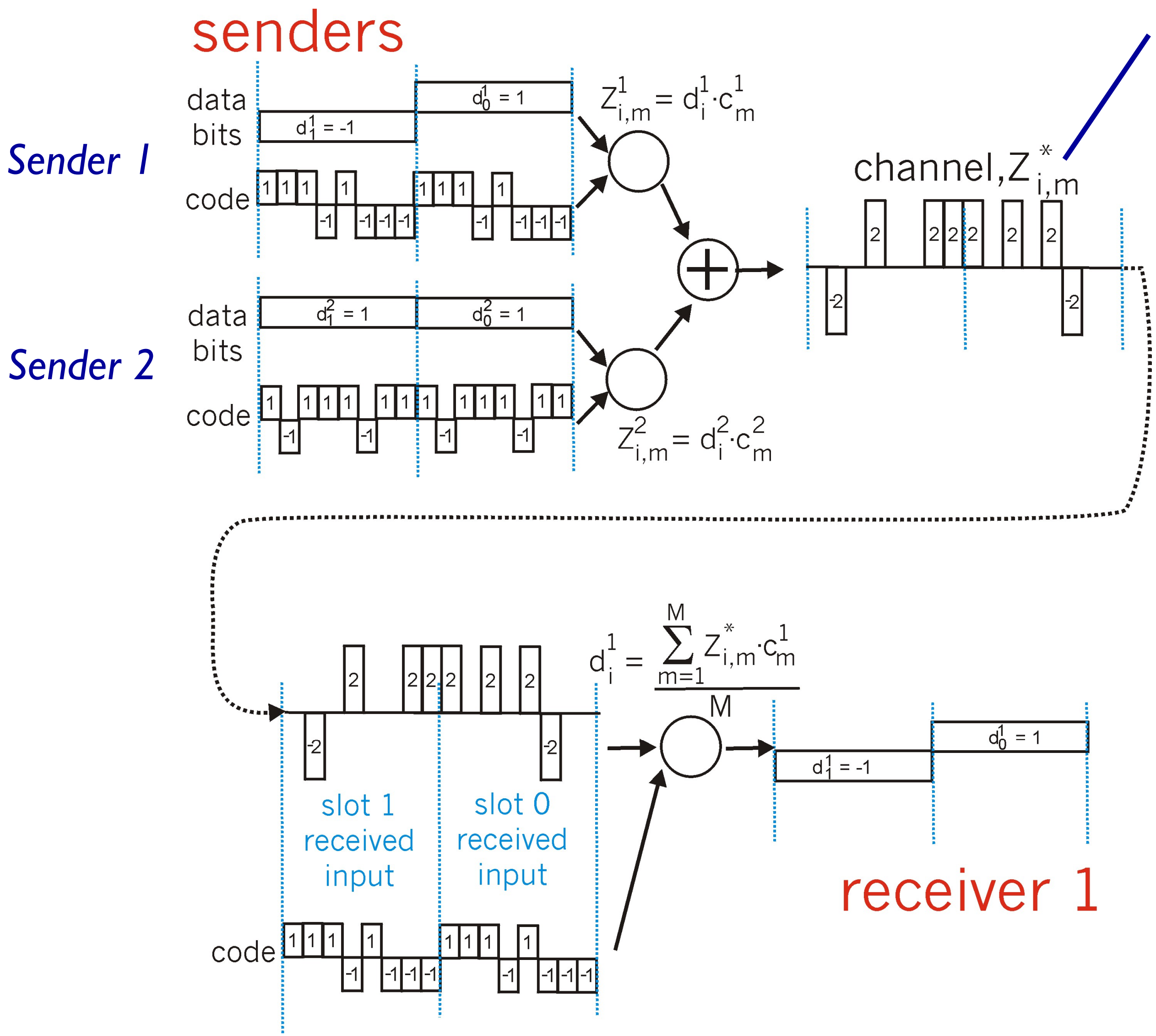

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