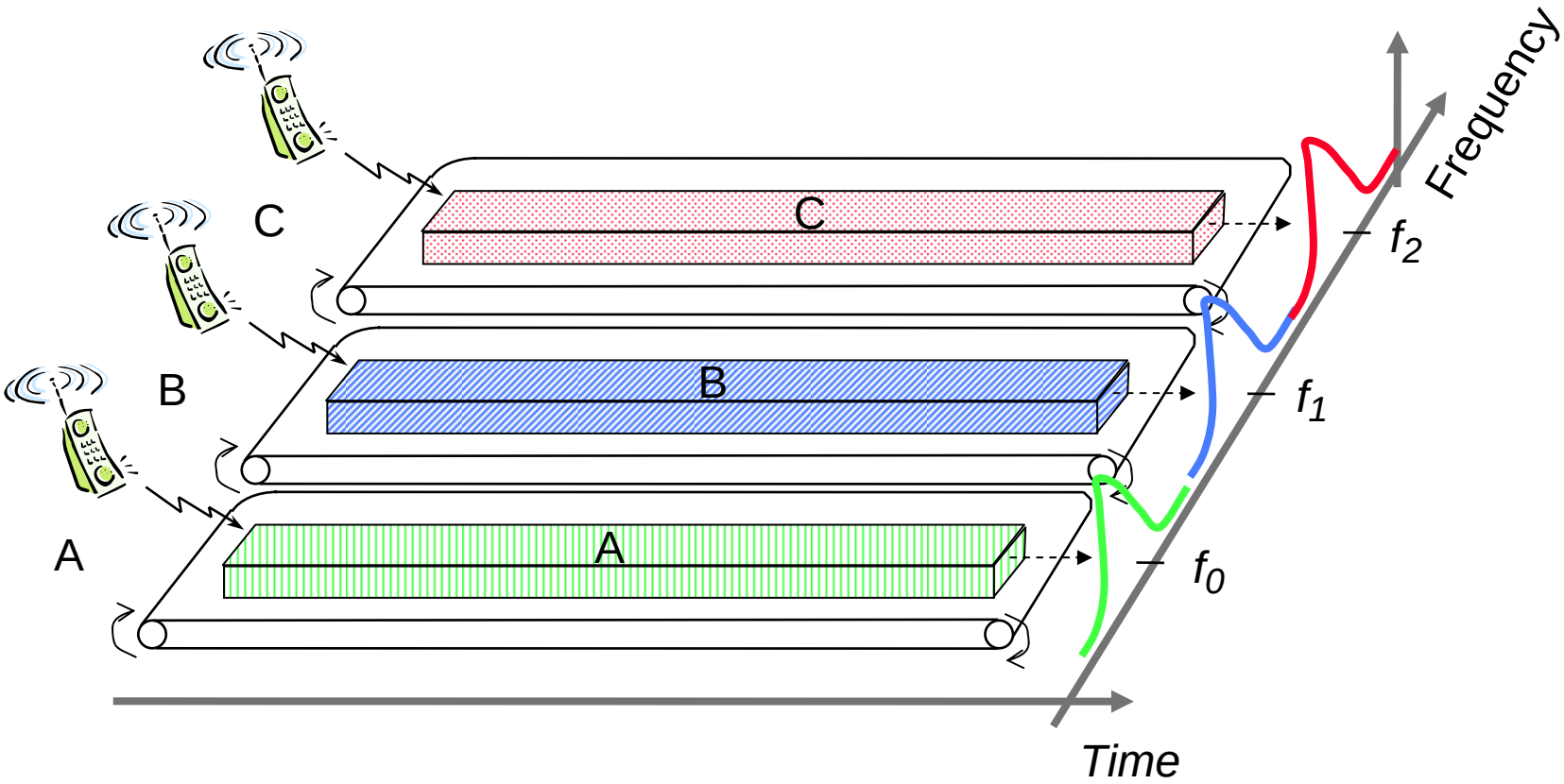
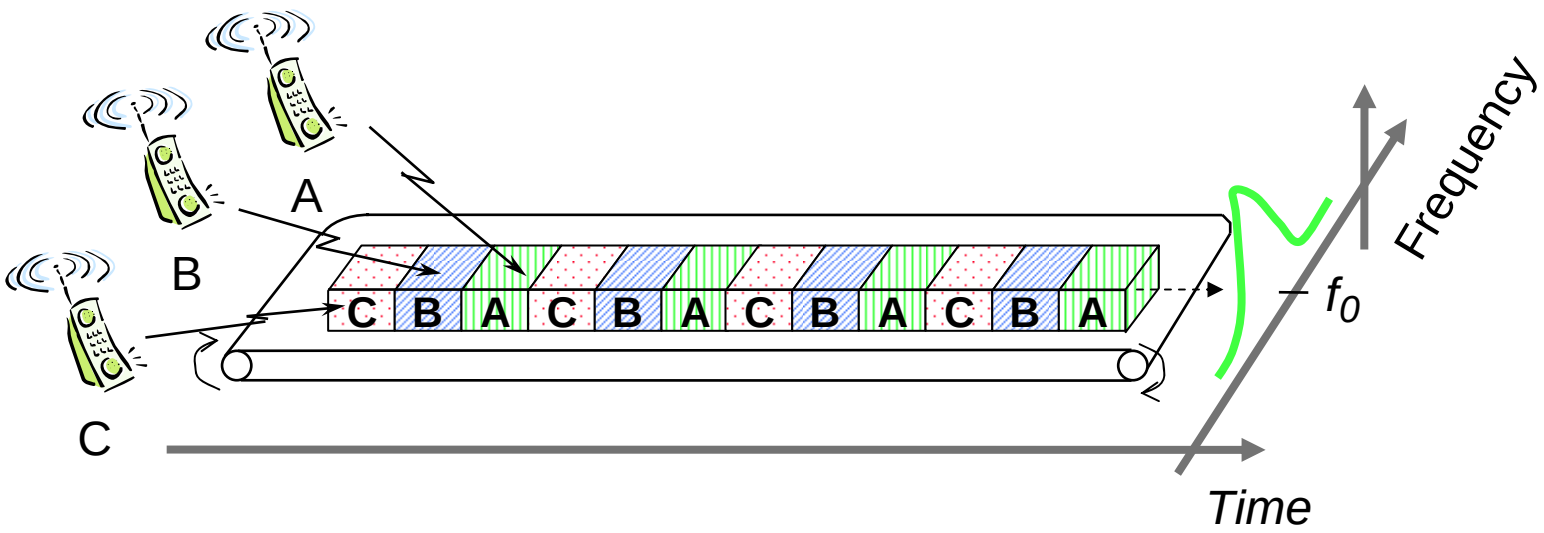
CDMA Technologies for Cellular Phone System

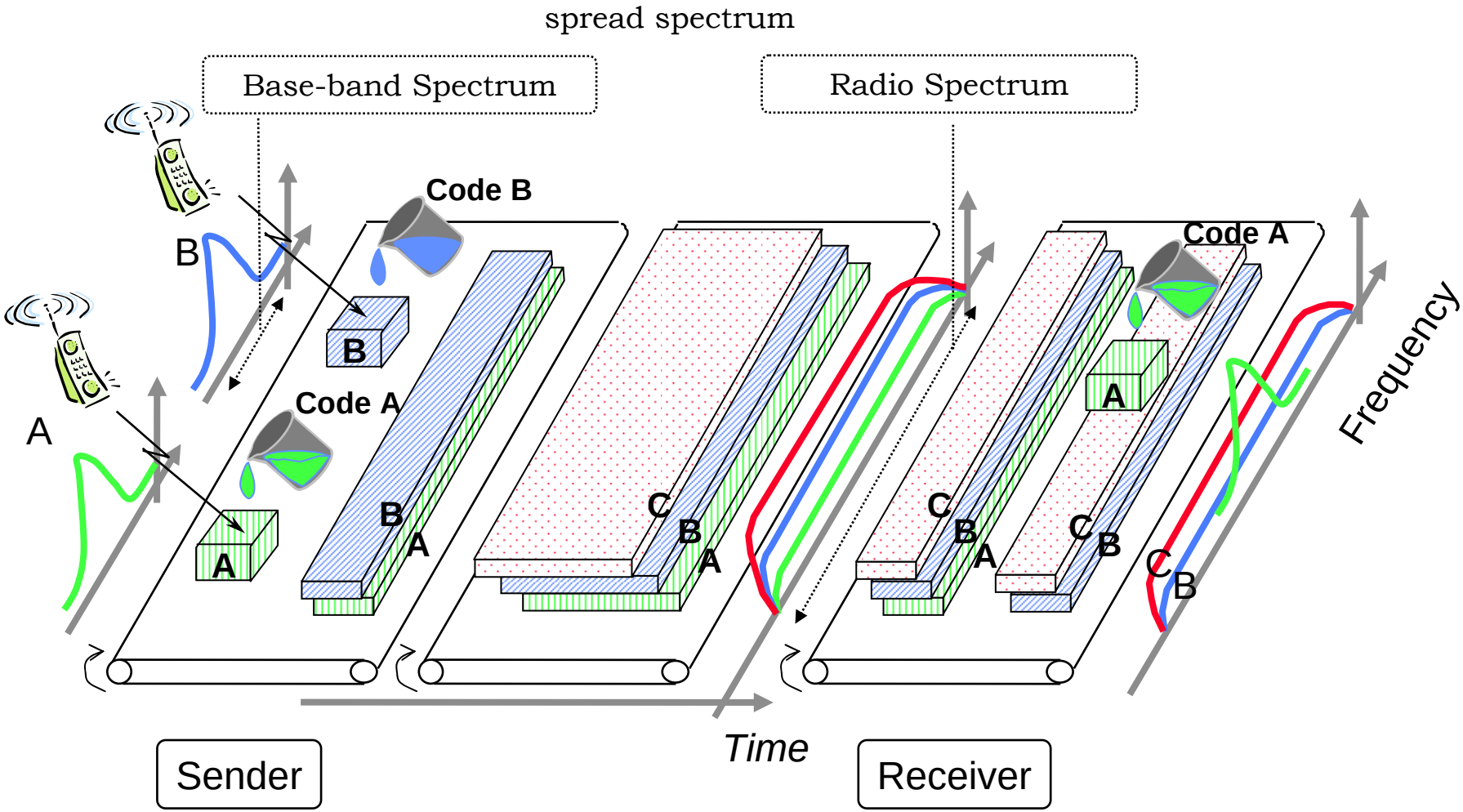
FDMA Overview



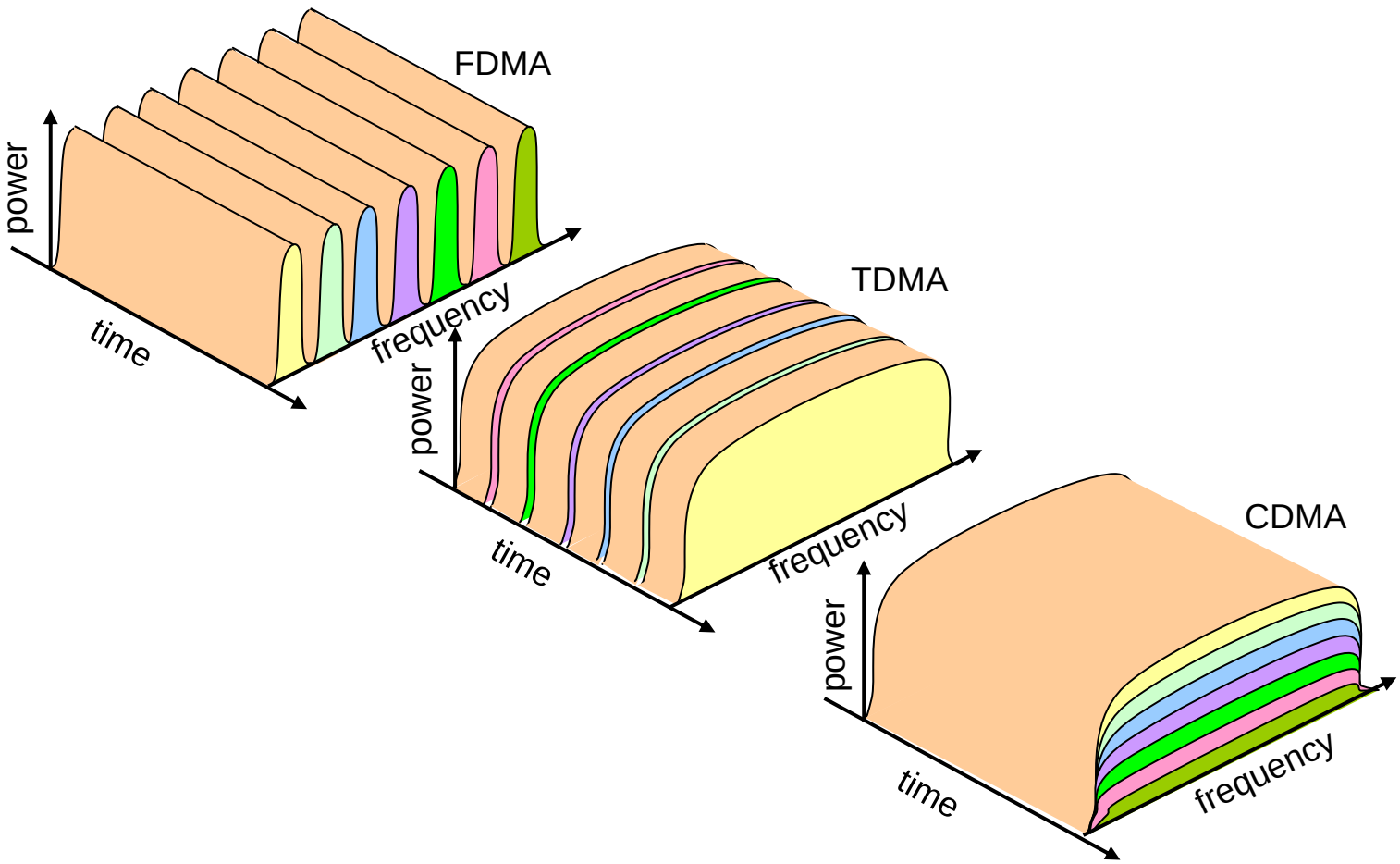
TDMA Overview



What is CDMA ?


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

Summary of Multiple Access



Spread Spectrum Technology

Shannon's theorem on channel capacity

- $C < B \log_2 (1 + S/N)$

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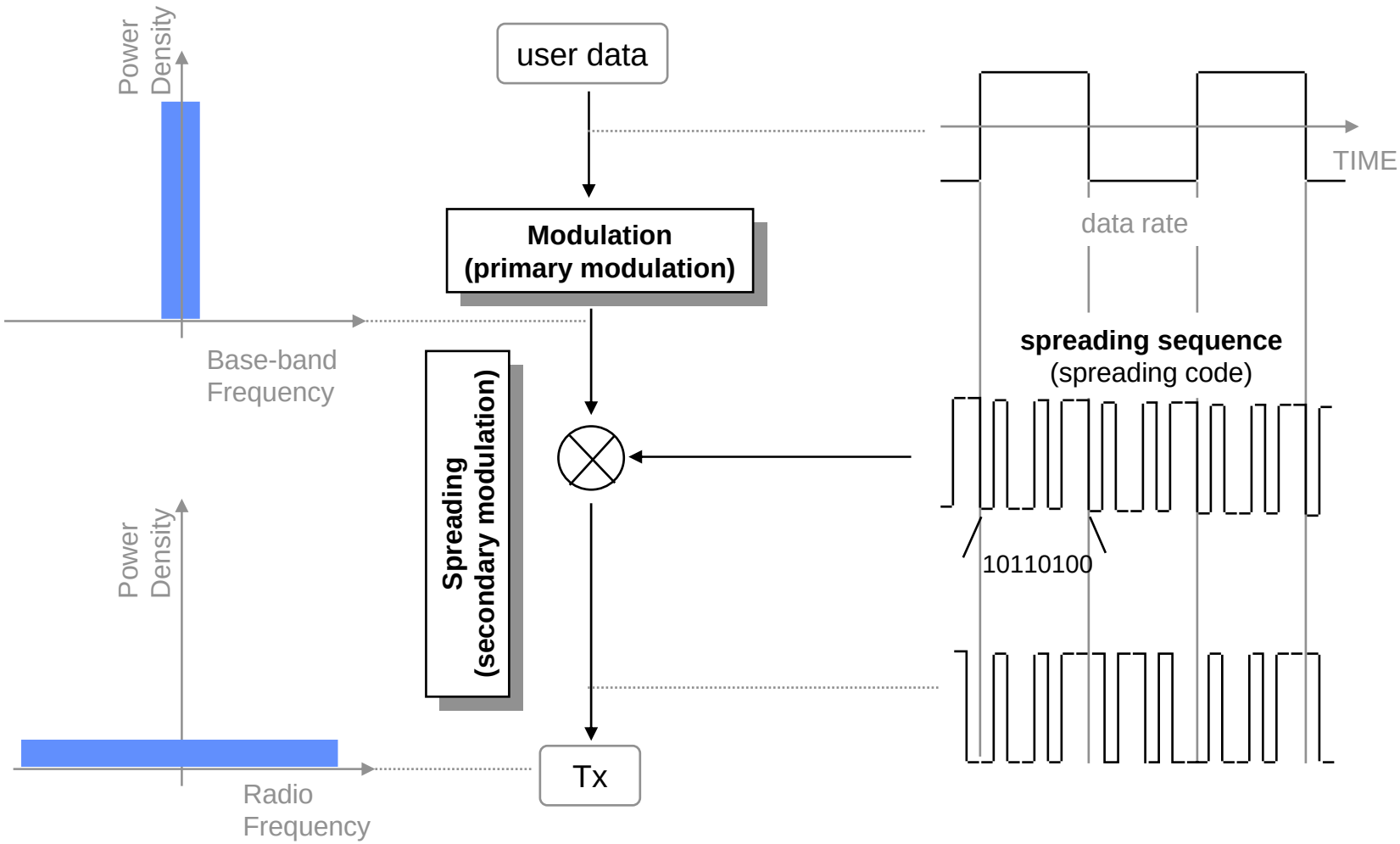
- B = Bandwidth S/N = Signal / Noise Level.
- C = channel capacity

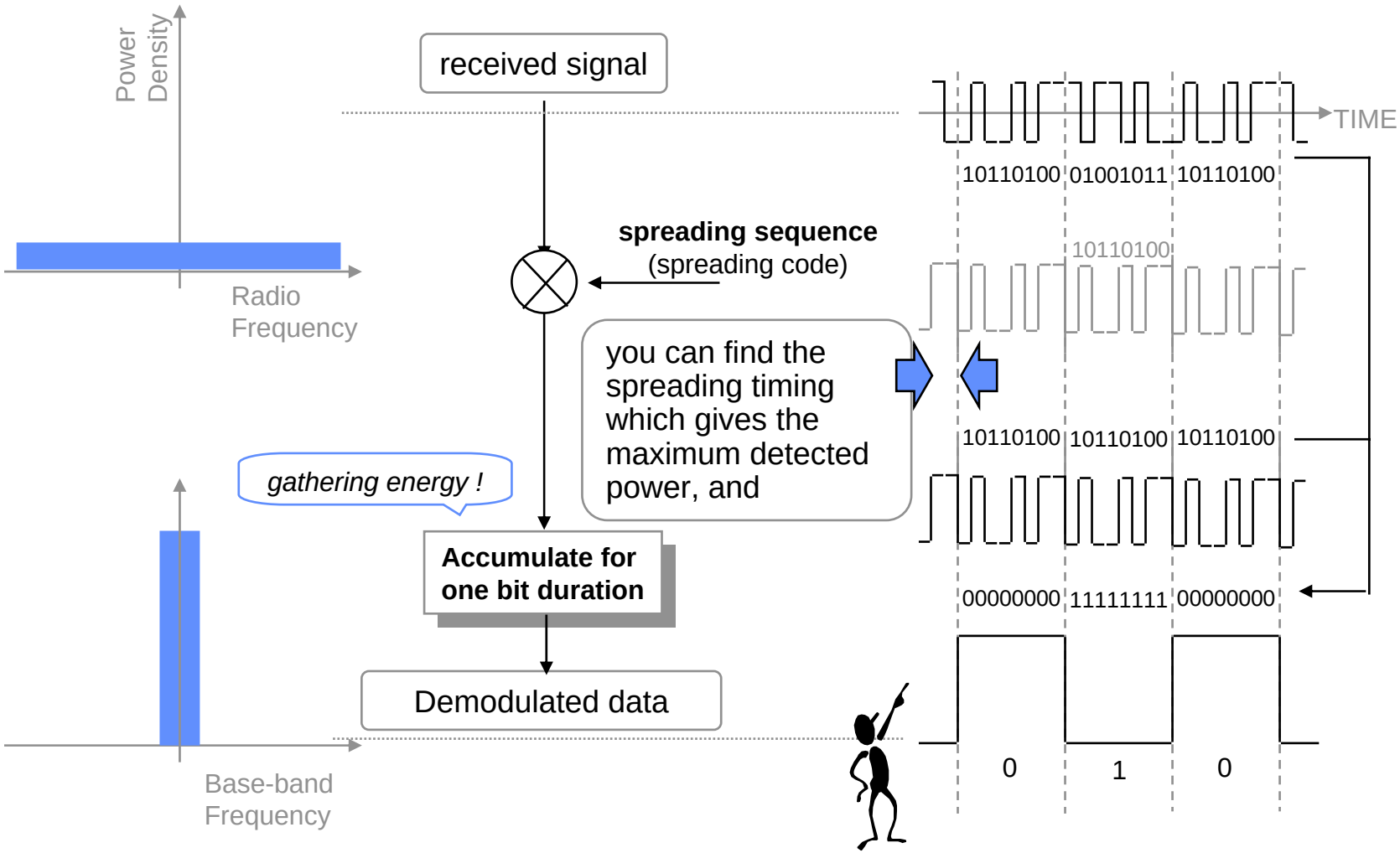
How to spread spectrum...

Direct Sequence (**DS**)



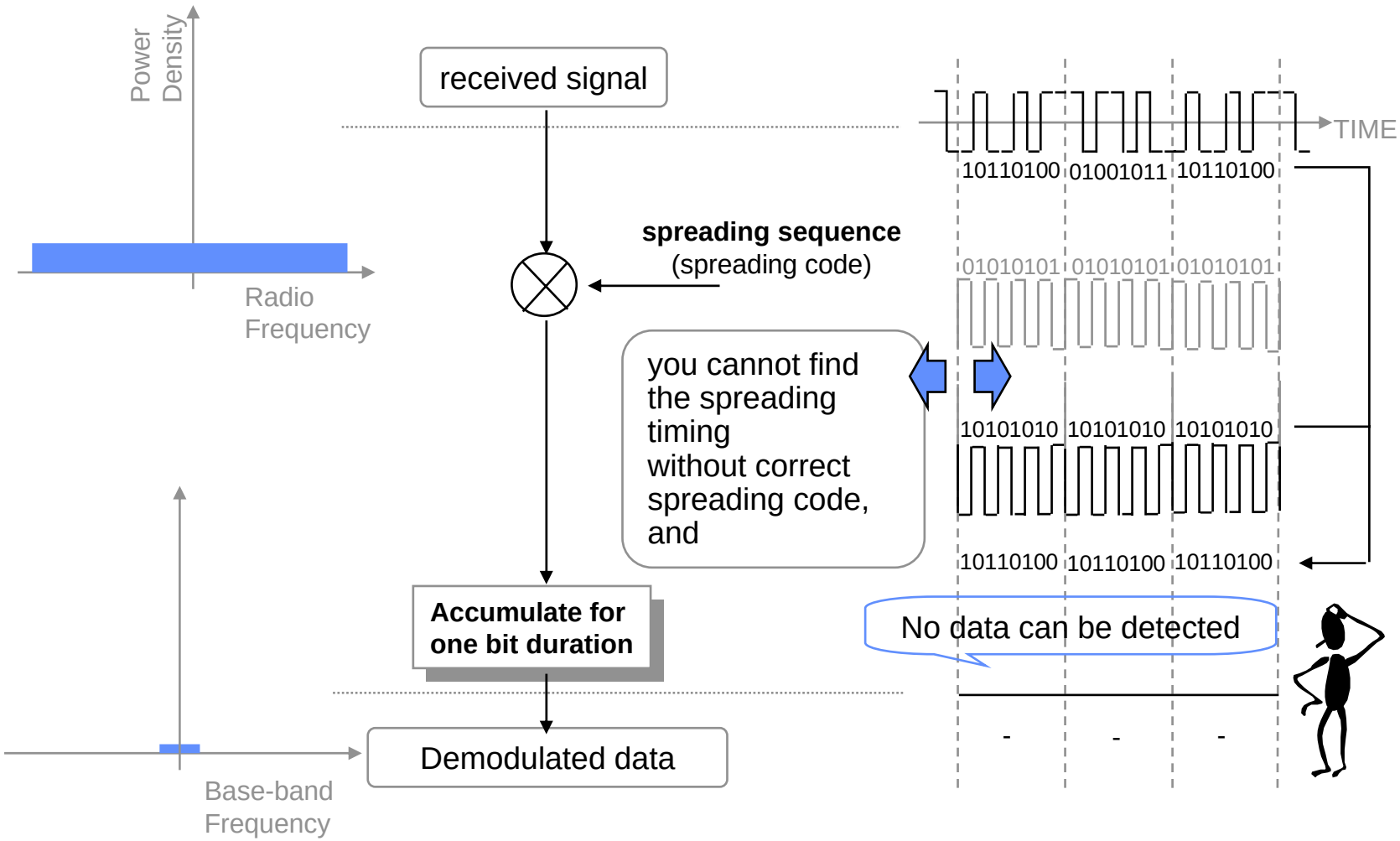
Demodulating DS Signals (1/2)

If you know the correct spreading sequence (code) ,



Demodulating DS Signals (2/2)

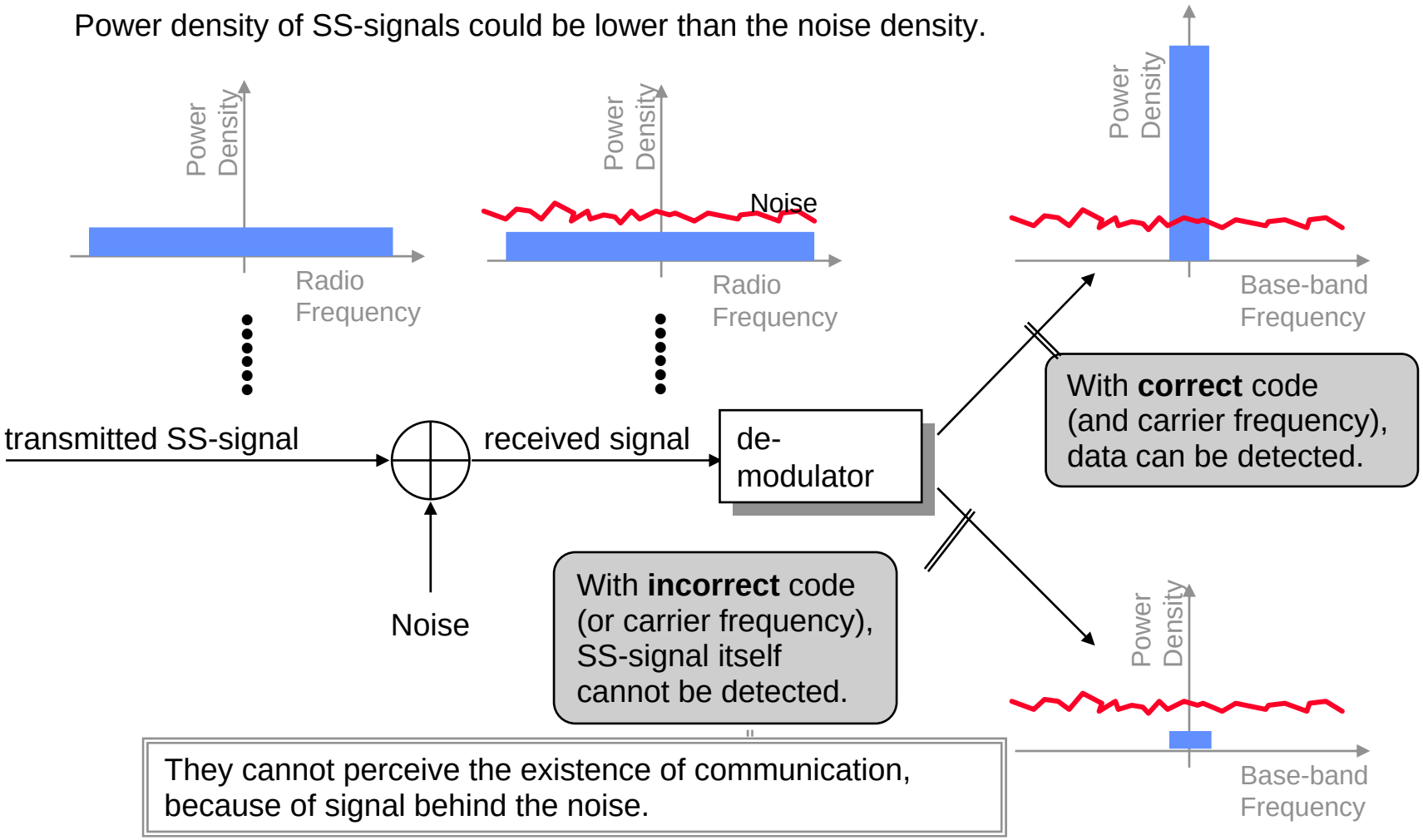
If you don't know the correct spreading sequence (code) •••



Feature of SS

Privacy, Security

Power density of SS-signals could be lower than the noise density.

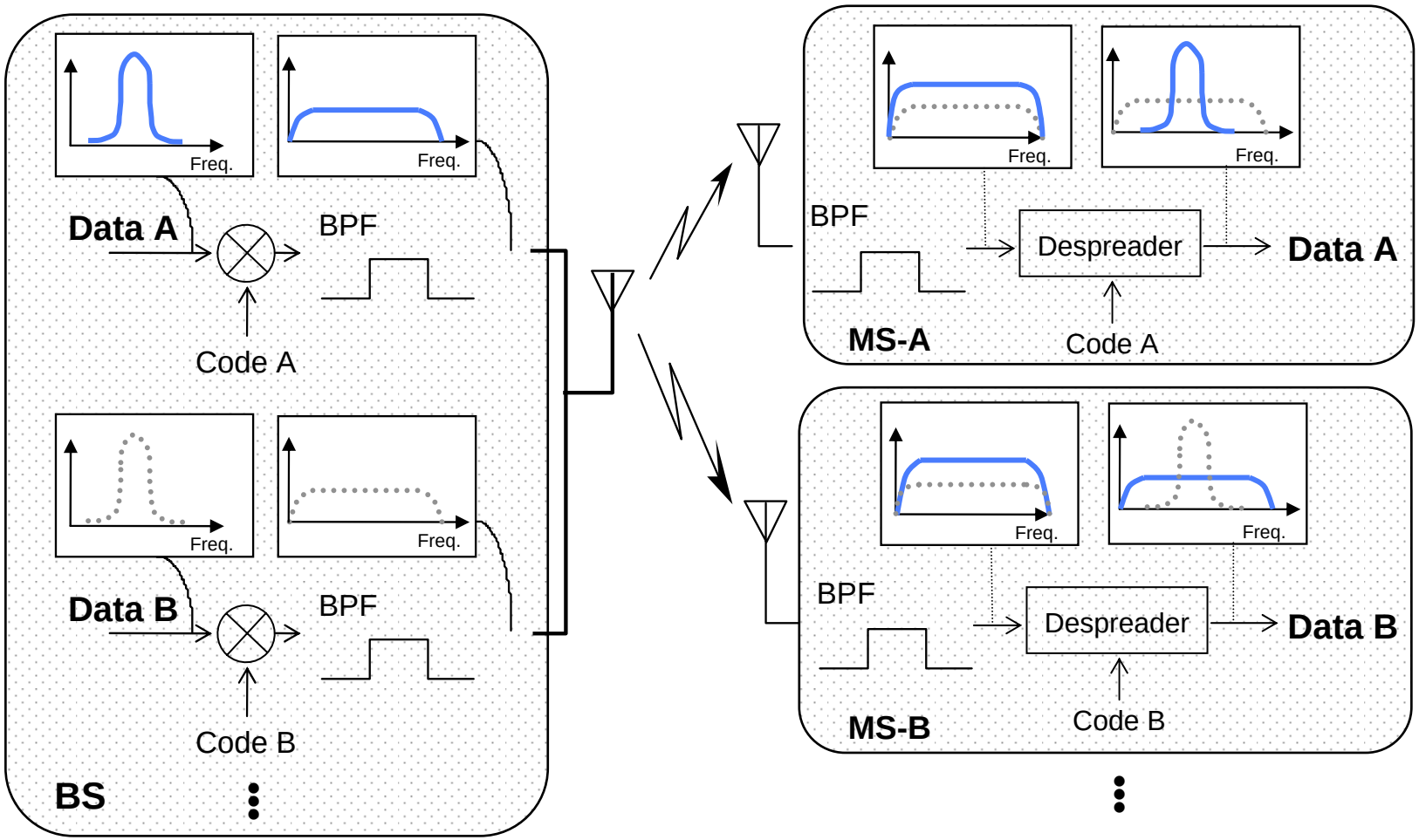


They cannot perceive the existence of communication, because of signal behind the noise.

DS-CDMA

DS-CDMA System Overview (Forward link)

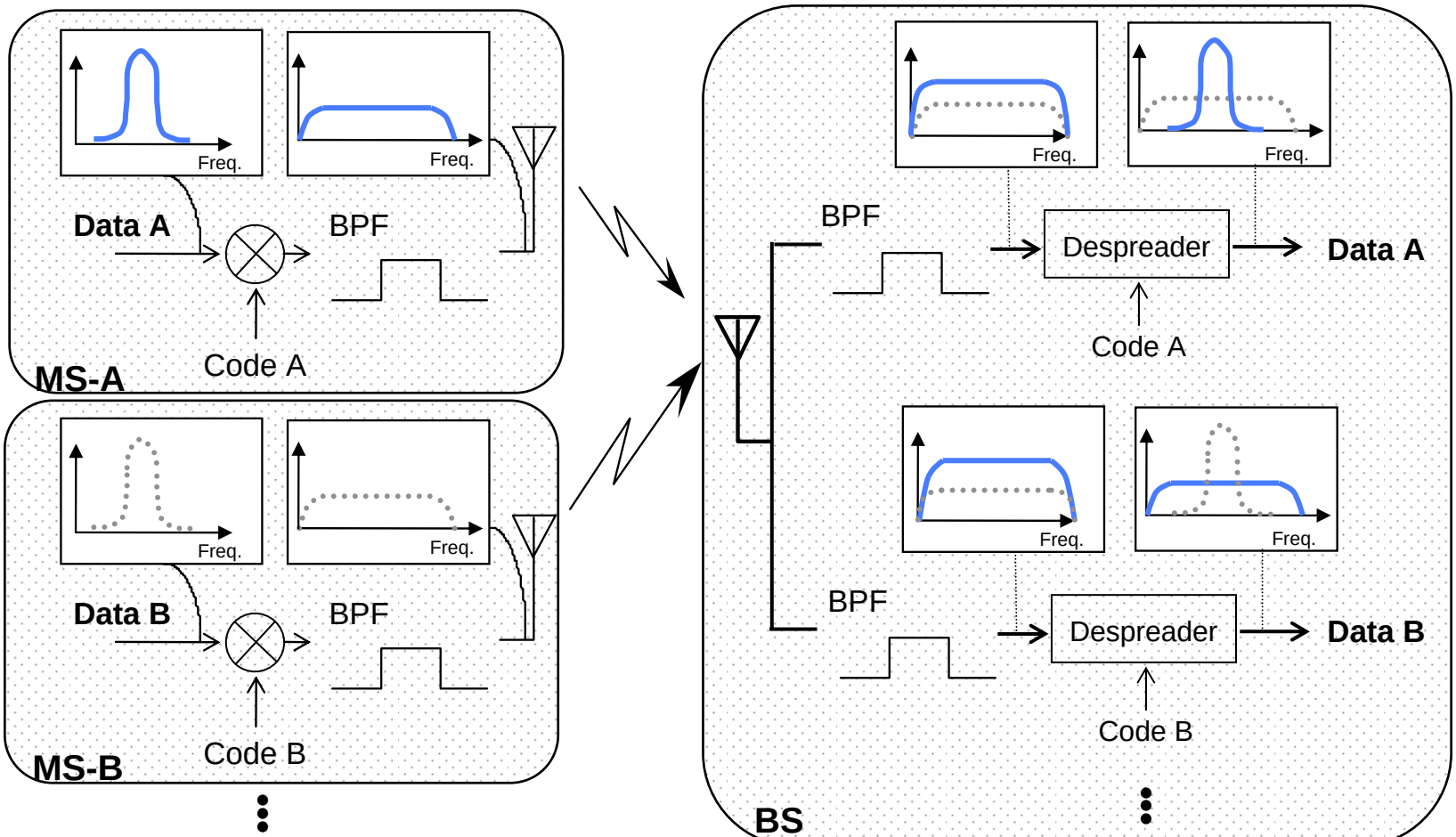
CDMA is a multiple spread spectrum.



Difference between each communication path is only the spreading code

DS-CDMA System Overview (Reverse Link)

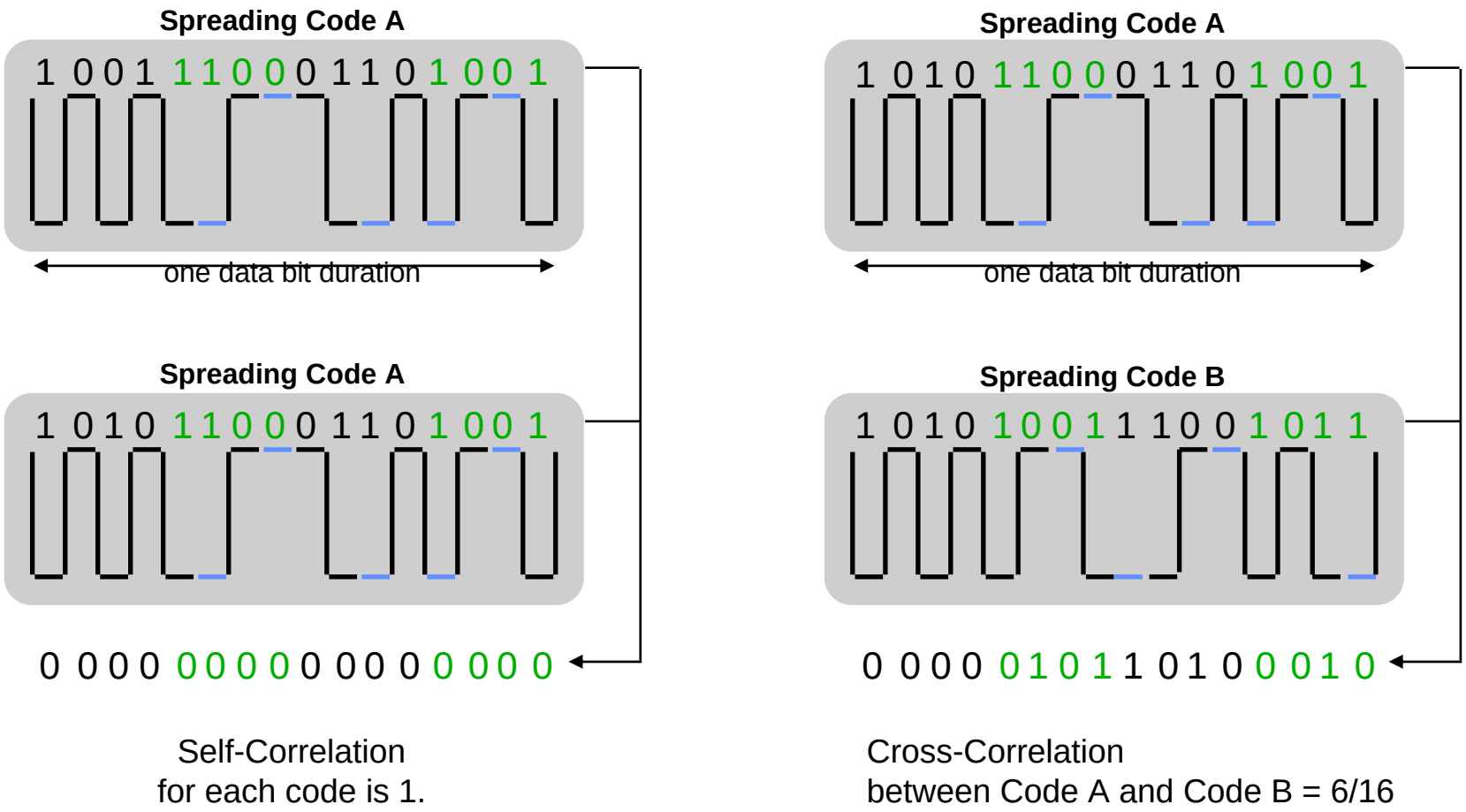
CDMA is a multiple spread spectrum.



Difference between each communication path is only the spreading code

Spreading Code

Cross-Correlation



Self-Correlation
for each code is 1.

Cross-Correlation
between Code A and Code B = 6/16

Preferable Codes

In order to minimize mutual interference in DS-CDMA ,
the spreading codes
with less cross-correlation should be chosen.

Synchronous DS-CDMA :

Orthogonal Codes are appropriate. (Walsh code etc.)

Asynchronous DS-CDMA :

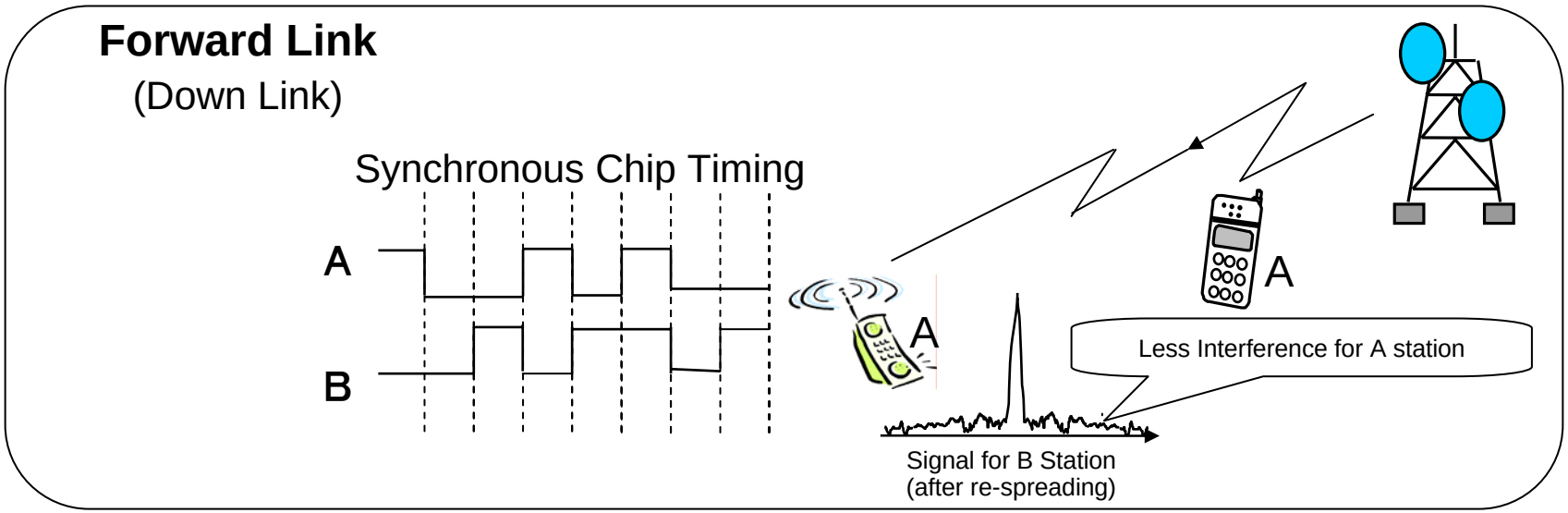
- Pseudo-random Noise (PN) codes / Maximum sequence
- Gold codes

Walsh Codes

- Set of Walsh codes of length *n* consists of the n rows of an $n \times n$ Walsh matrix:
  - $W_1 = (0)$ $\quad W_{2n} = \begin{pmatrix} W_n & W_n \\ W_n & \overline{W_n} \end{pmatrix}$
    - *n* = dimension of the matrix
  - Every row is orthogonal to every other row and to the logical not of every other row
  - Requires tight synchronization
    - Cross correlation between different shifts of Walsh sequences is not zero

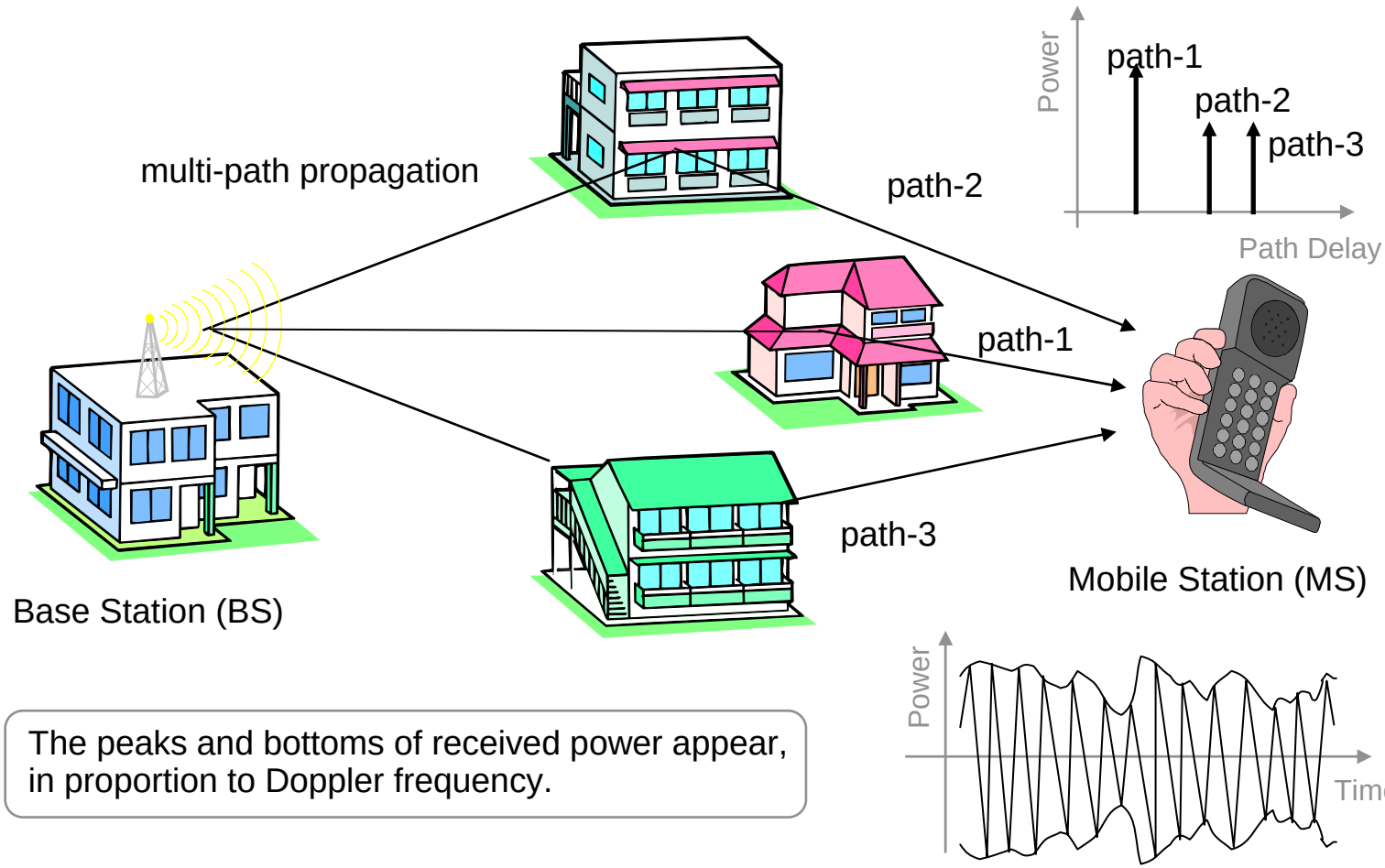
Synchronous DS-CDMA

Synchronous CDMA Systems realized in Point to Multi-point System.
e.g., Forward Link (Base Station to Mobile Station) in Mobile Phone.



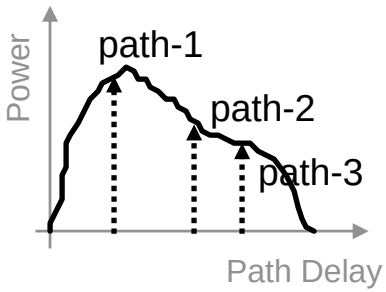
Features of CDMA

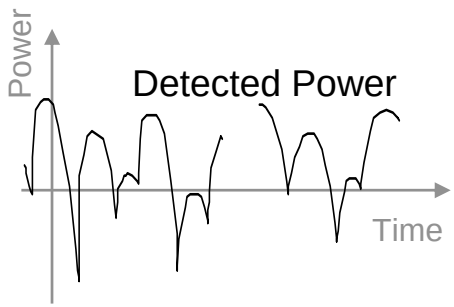
Mobile Propagation Environment ▪▪▪ Multi-path Fading



The peaks and bottoms of received power appear, in proportion to Doppler frequency.

Fading in non-CDMA System





With low time-resolution,
different signal paths cannot be discriminated.

•••

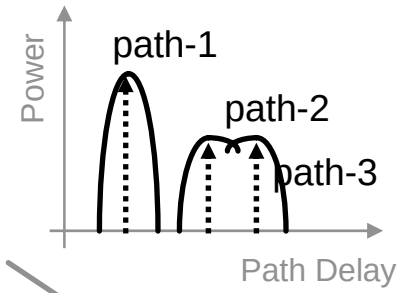
These signals sometimes strengthen,
and sometimes cancel out each other,
depending on their phase relation.
••• This is “fading”.

•••

In this case, signal quality is damaged
when signals cancel out each other.
In other words, signal quality is dominated
by the probability for detected power
to be weaker than minimum required level.
This probability exists with less than two paths.

In non-CDMA system, “fading” damages signal quality.

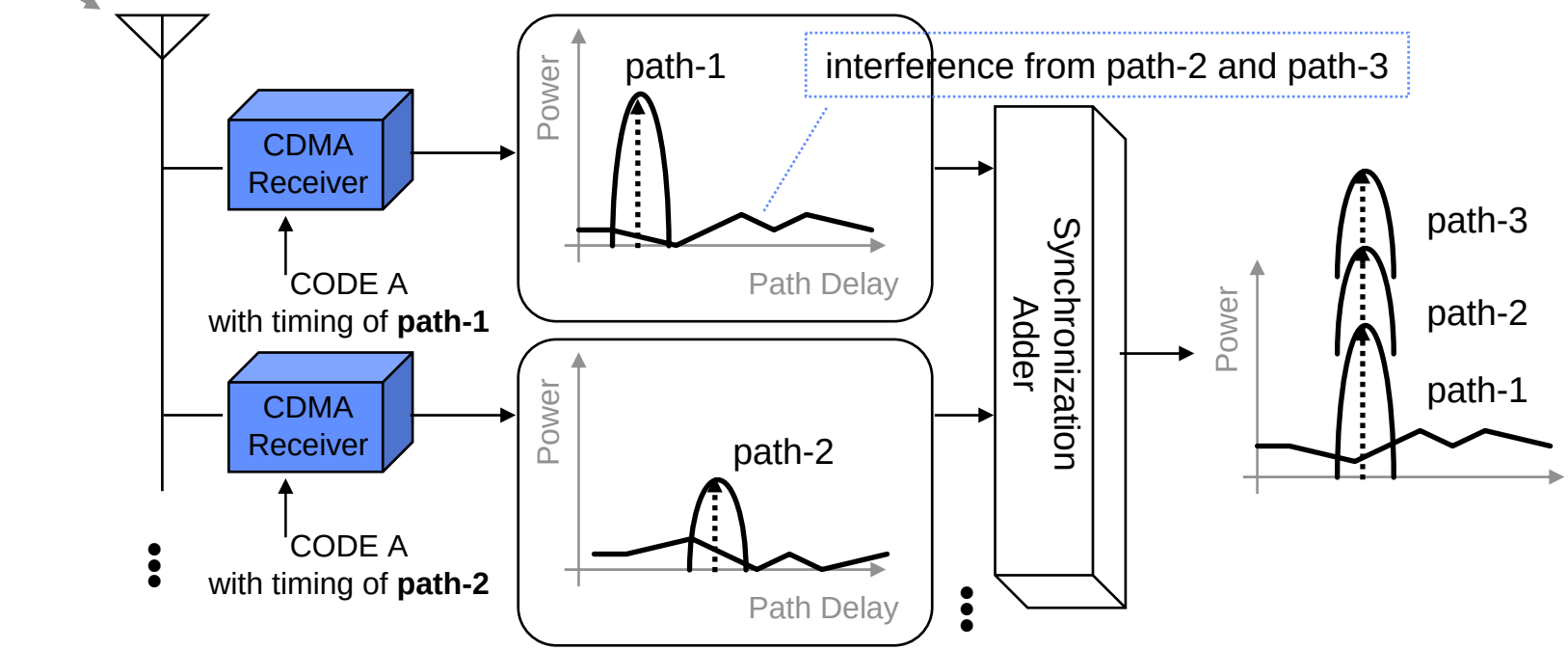
Fading in CDMA System ...



Because CDMA has high time-resolution,
different path delay of CDMA signals
can be discriminated.

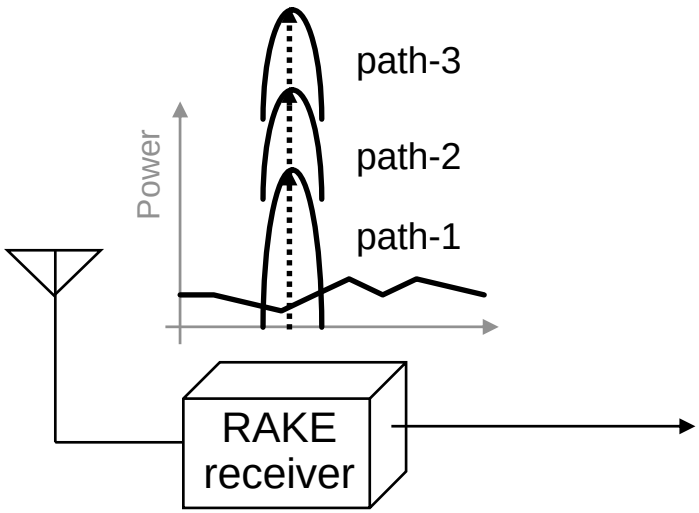
•••

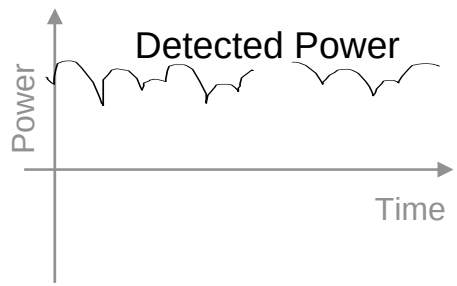
Therefore, energy from all paths can be summed
by adjusting their phases and path delays.
••• This is a principle of RAKE receiver.



Fading in CDMA System (continued)

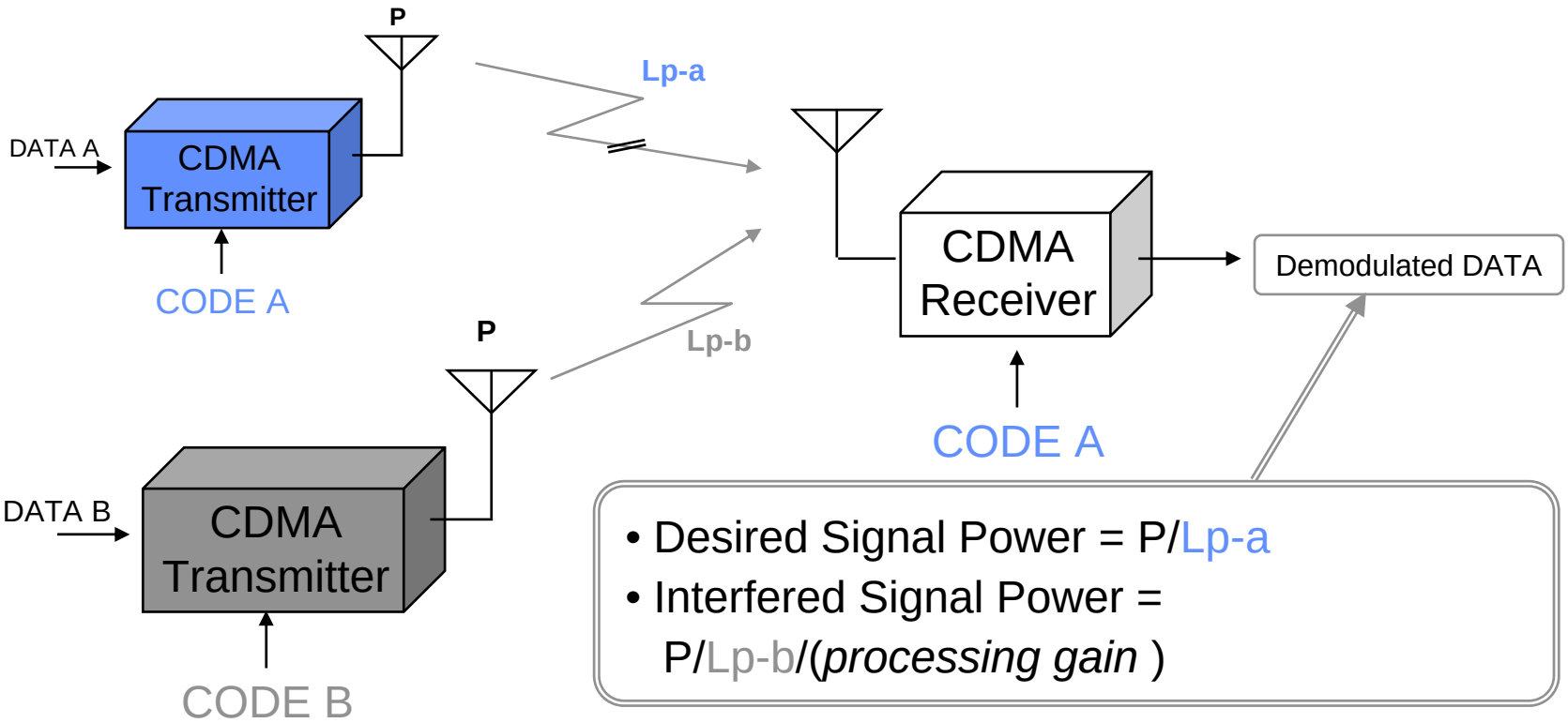
In CDMA system, multi-path propagation improves the signal quality by use of RAKE receiver.





Less fluctuation of detected power, because of adding all energy .

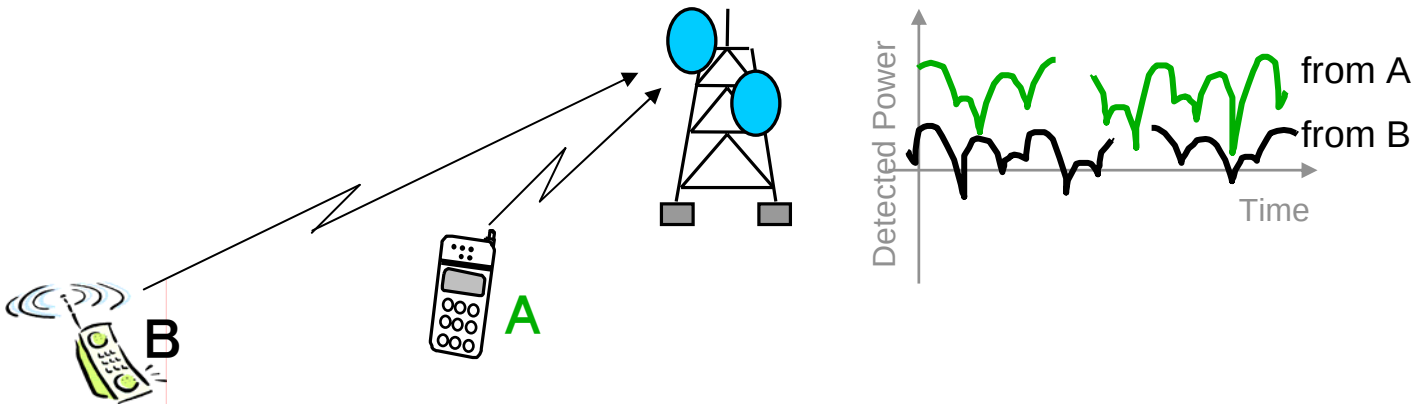
Near-Far Problem



When user B is close to the receiver and user A is far from the receiver, Lp-a could be much bigger than Lp-b.
In this case, desired signal power is smaller than the interfered power.

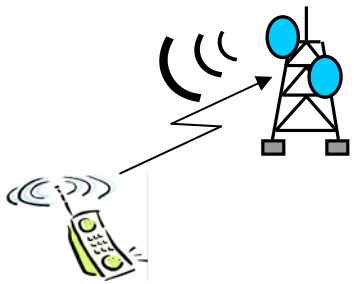
Power Control...

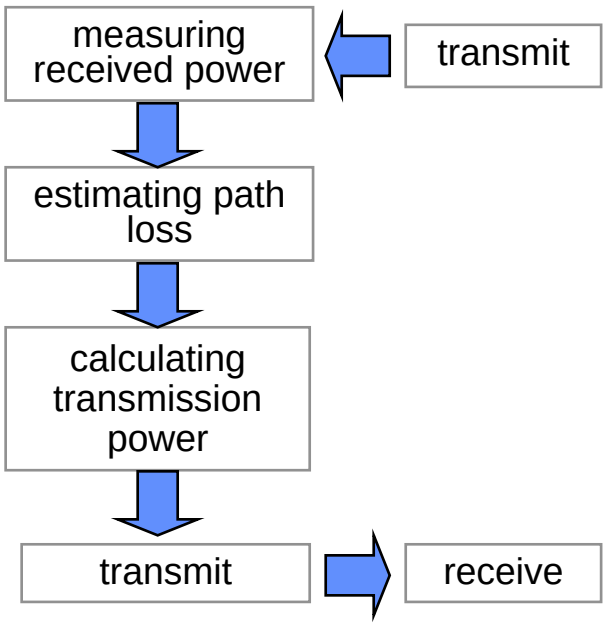
When all mobile stations transmit the signals at the same power (MS),
the received levels at the base station are different from each other,
which depend on the distances between BS and MSs.
Moreover, the received level fluctuates quickly due to fading.
In order to maintain the received level at BS, power control technique must be employed in CDMA systems.



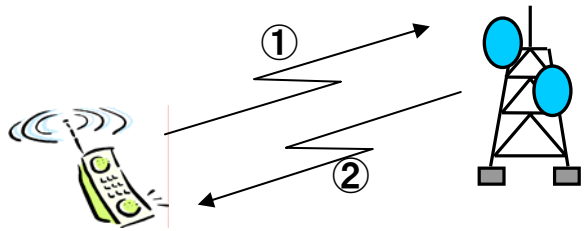
Power Control (continued)

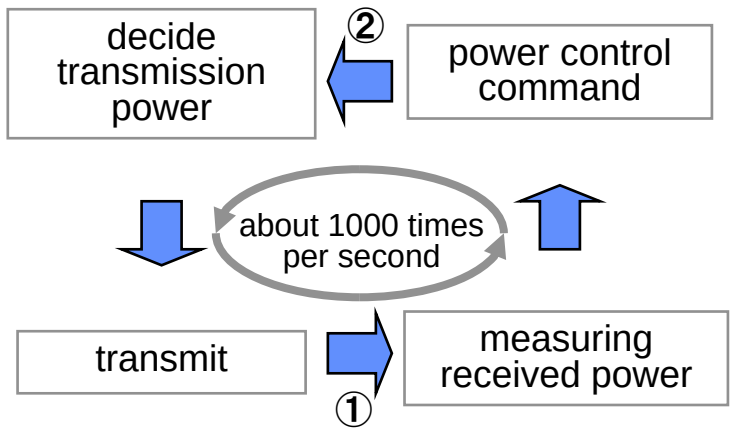
Open Loop Power Control





Closed Loop Power Control



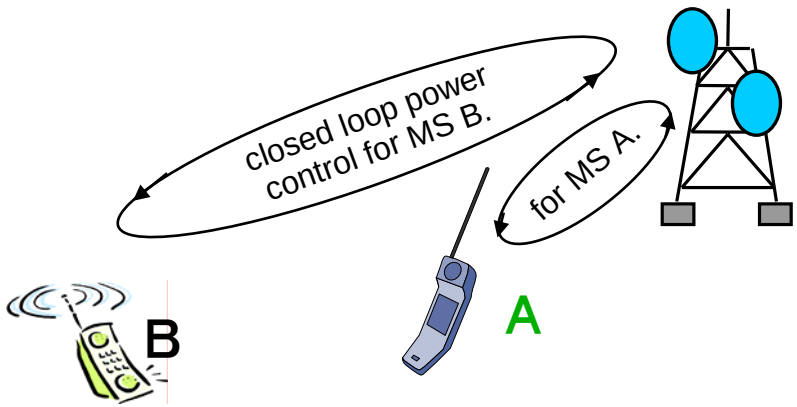


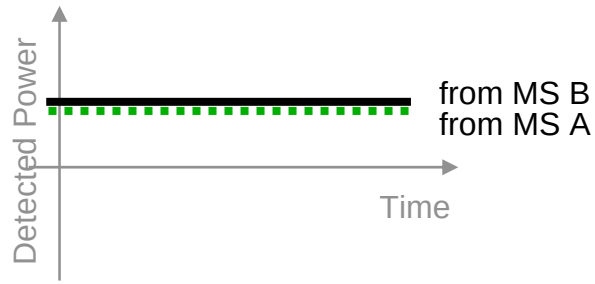
Effect of Power Control

Effect of Power Control

- Power control is capable of compensating the fading fluctuation.
- Received power from all MS are controlled to be equal.

... Near-Far problem is mitigated by the power control.

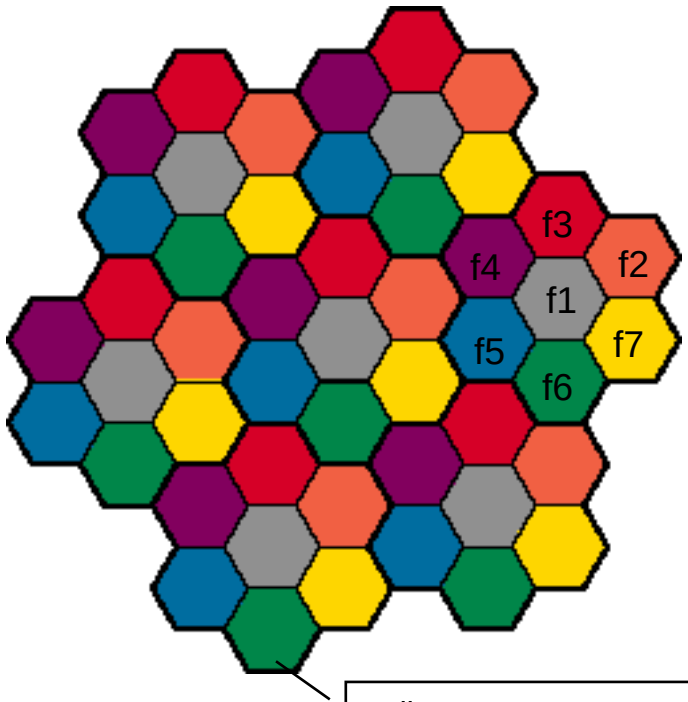




Frequency Allocation (1/2)

In FDMA or TDMA,

radio resource is allocated not to interfere among neighbor cells.



- Neighbor cells cannot use the same (identical) frequency band (or time slot).
- The left figure shows the simple cell allocation with seven bands of frequency.
- In actual situation, because of complicated radio propagation and irregular cell allocation, it is not easy to allocate frequency (or time slot) appropriately.

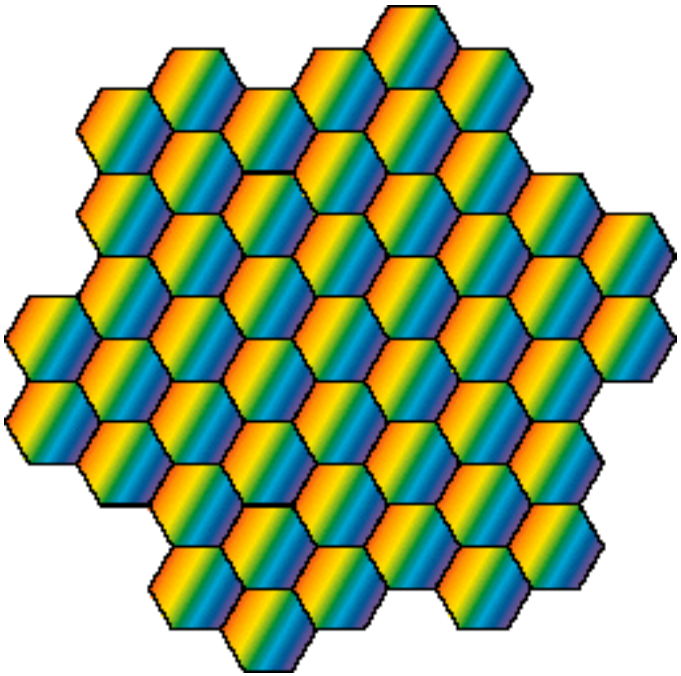
cell :
a “cell” means covered area by one base station.

Frequency Allocation (2/2)

In CDMA,

identical radio resource can be used among all cells,

because CDMA channels use same frequency simultaneously.



- Frequency allocation in CDMA is not necessary.
- In this sense, CDMA cellular system is easy to be designed.

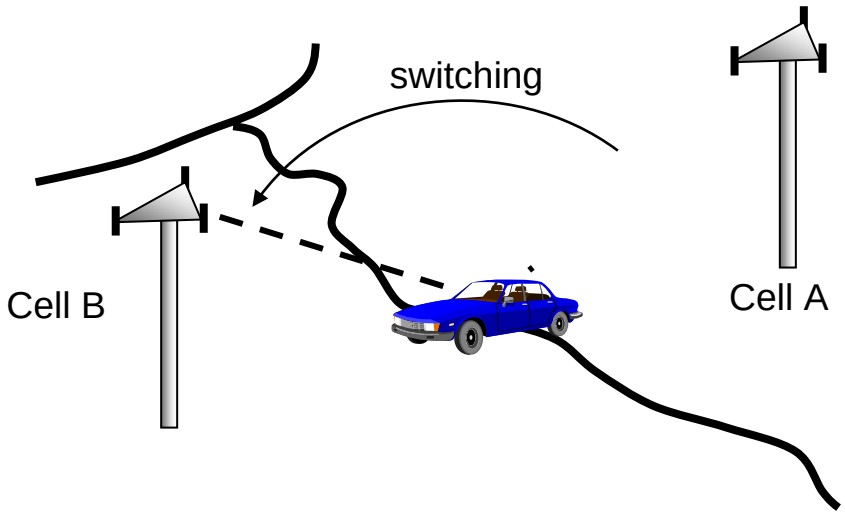
Soft Handoff (1/2)

Handoff :

- Cellular system tracks mobile stations in order to maintain their communication links.
- When mobile station goes to neighbor cell, communication link switches from current cell to the neighbor cell.

Hard Handoff :

- In FDMA or TDMA cellular system, new communication establishes after breaking current communication at the moment doing handoff. Communication between MS and BS breaks at the moment switching frequency or time slot.

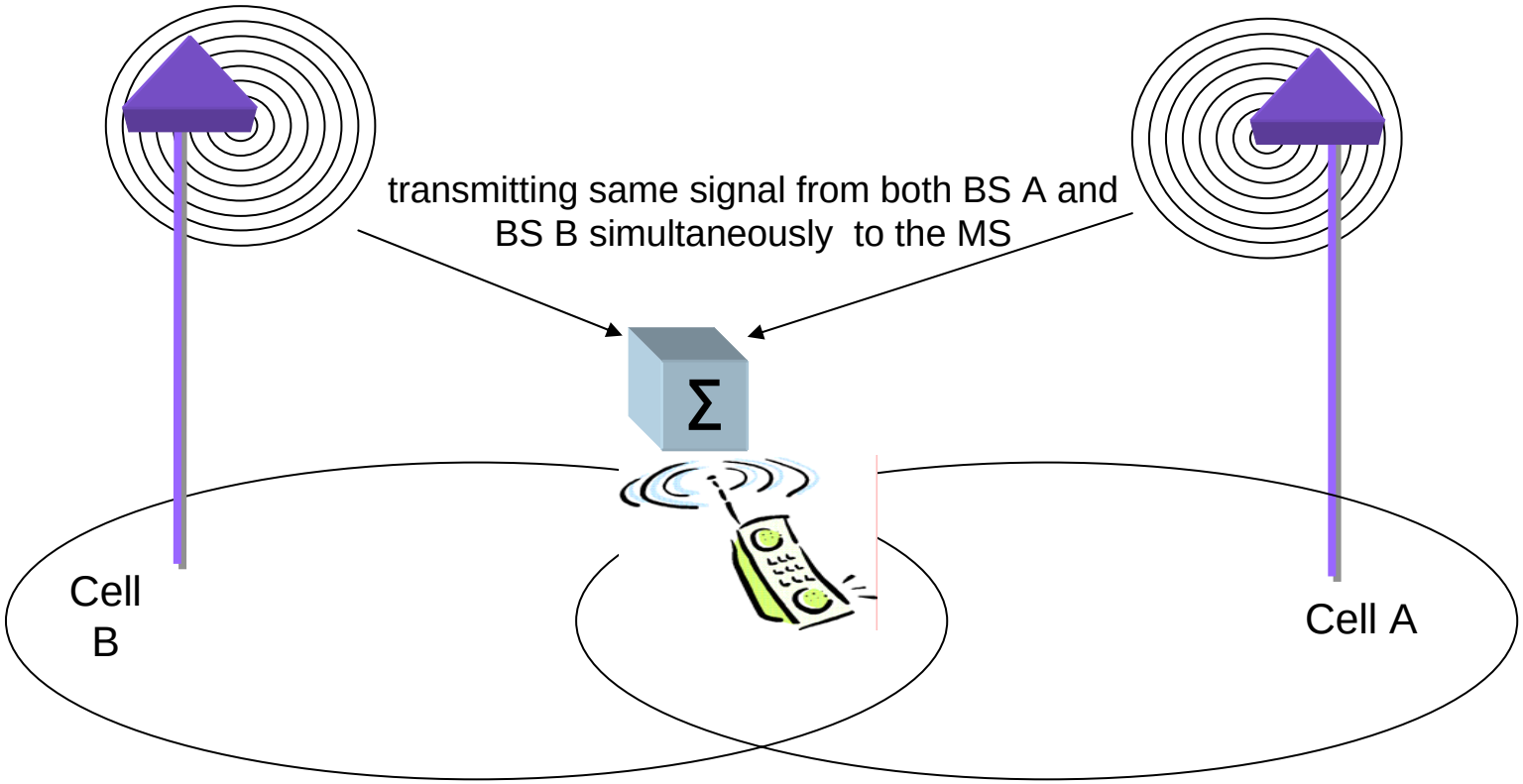


Hard handoff : connect (new cell B) after break (old cell A)

Soft Handoff (2/2)

Soft Handoff :

- In CDMA cellular system, communication does not break even at the moment doing handoff, because switching frequency or time slot is not required.



Soft handoff : break (old cell A) after connect (new cell B)