ICT course:

Mobile Wireless Communications

Lecturers:
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Course Schedule

- Lectures:

1. Introduction
2. Characteristics of mobile radio environment:
   - Propagation
   - Fading and mitigations
3. Cellular concept
4. Channel assignment (optional)
5. Modulation techniques
6. Multiple Access techniques
7. Coding for error detection and correction
8. Applications – Mobile network Generations:
   - GSM
   - 3G/LTE-4G
   - 5G and future of mobile networks (discussion)

- Exercises
- References:

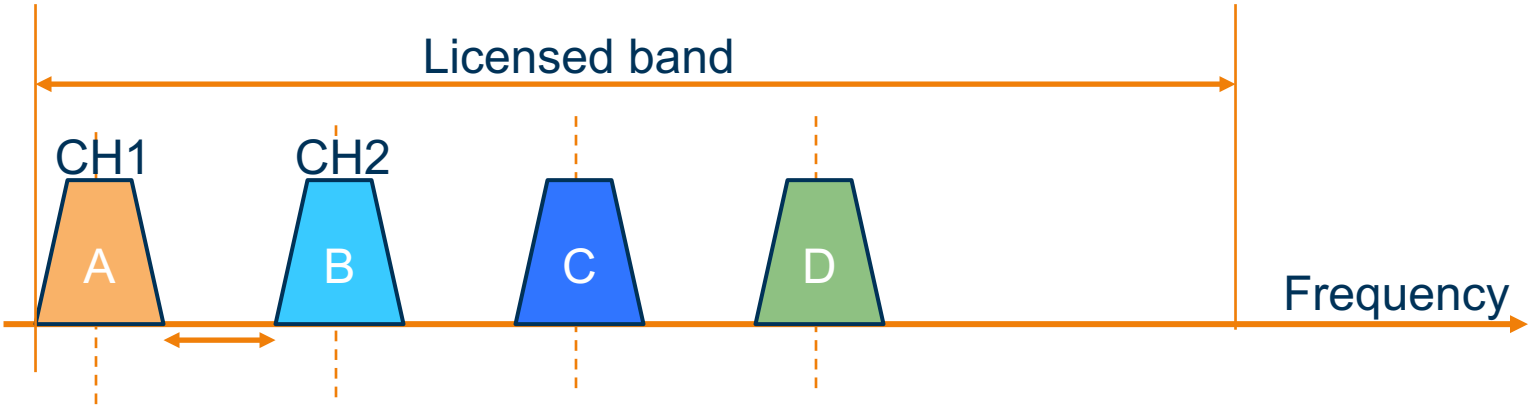
[1]. Mischa Schwartz: Mobile Wireless Communication, CAMBRIDGE UNIVERSITY PRESS, 1st Edition (2005)
[2]. Wireless Communications: Principles and Practice (2nd Edition) by Theodore S. Rappaport

Lecture 5: Multiple access techniques

- Introduction
- FDMA
- TDMA
- CDMA

- *Channel:* refers to a system resource allocated to a given mobile user enabling that user to communicate with the network with tolerable interference from other users
- In cellular system:
  - Frequency channel
  - Time slots within frequency bands
  - Codes

- FDMA:
  - A given frequency band is divided into frequency channels.
  - Each channel is allocated to a different system user or mobile terminal.

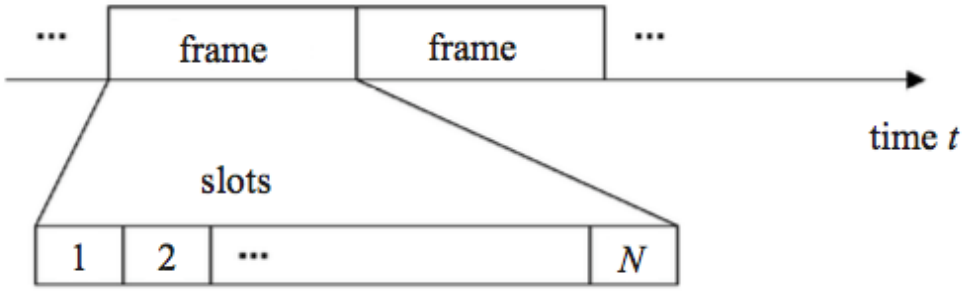


- *Frequency-division duplex (FDD):* The pairing of channels to provide two-way communication in either direction, uplink or downlink

- Broadcast model: one-way communication, all recipients sharing the same channel

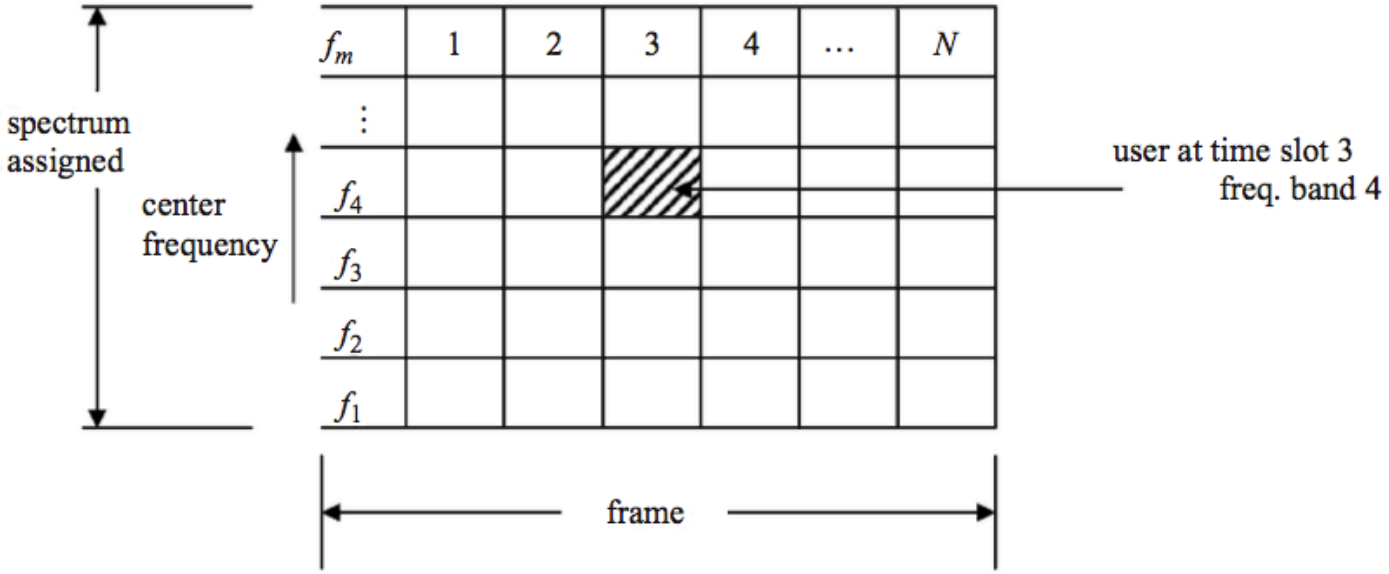
- Used in 1G: AMPS system (DL: 869-864 MHz, UL: 824-849 MHz)

- TDMA:
  - Assigning multiple users to one frequency channel
  - Used in 2G:
    - Circuit-switched system
    - Digital signals sent out on a given frequency channel or band are transmitted in specified time slots (“circuits”) in a repetitive **frame structure** operating at the carrier frequency assigned to that channel.
    - 1 user: 1 or several time slots per frame on a frequency
    - Digital signals: are modulated signals



TDMA slot structure

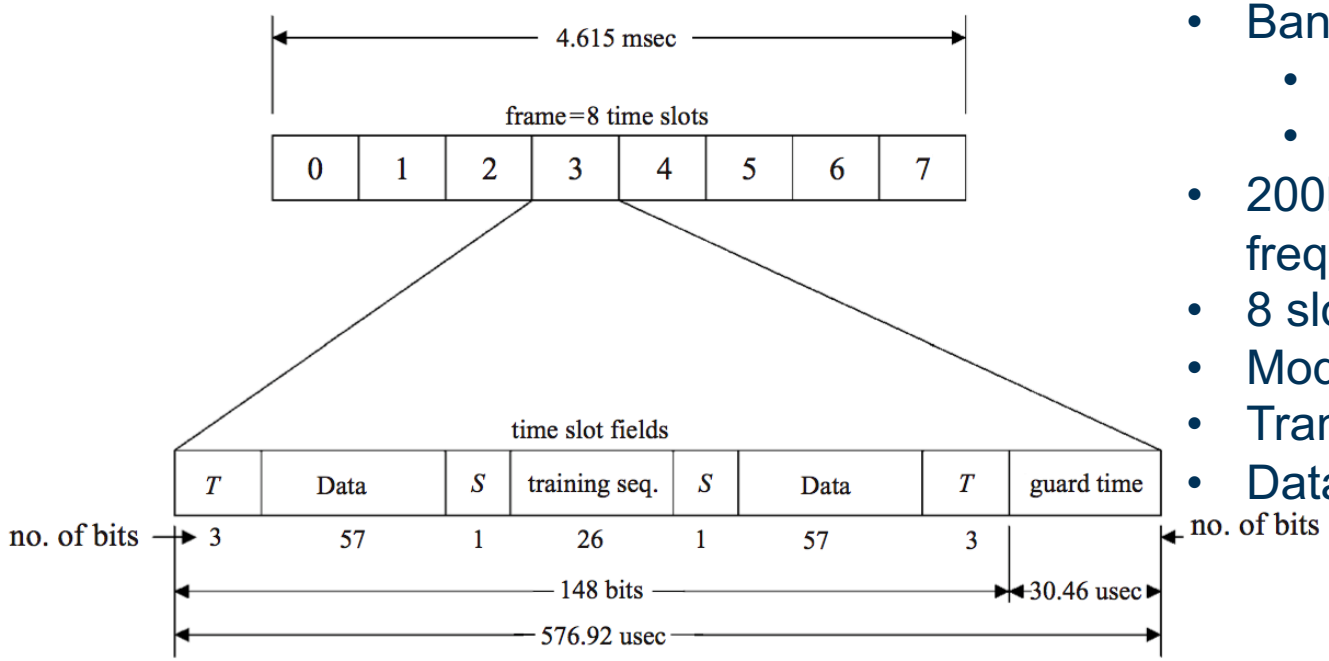
- FDMA/TDMA:



Channel assignment

Frame structure:

GSM Frame structure:

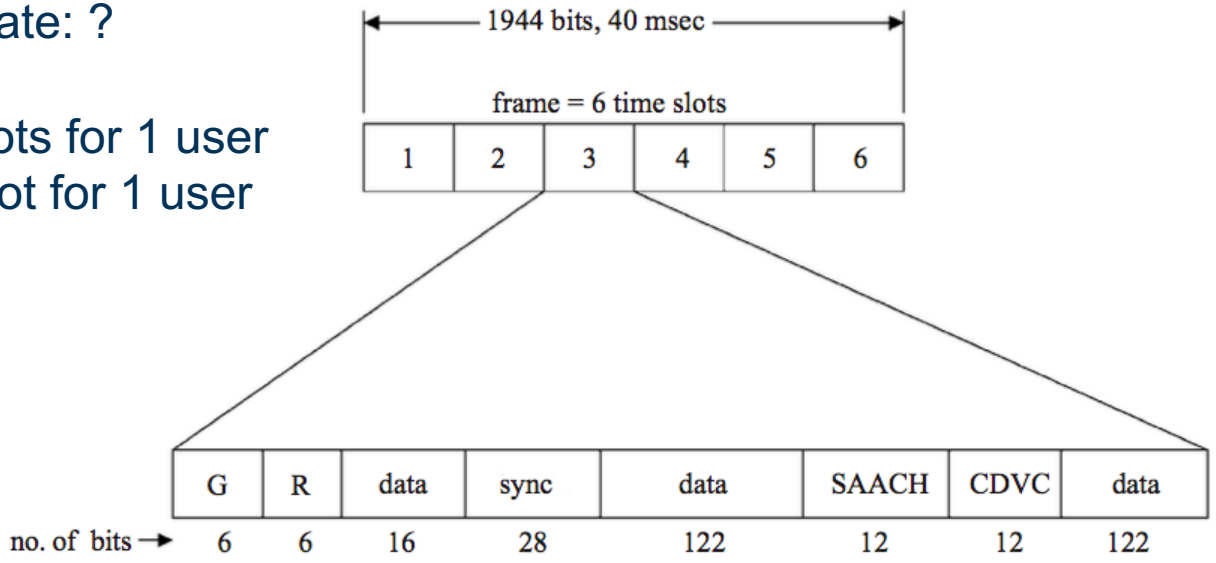


In Europe:

- Band:
  - UL: 890-915 MHz
  - DL: 935-960 MHz
- 200kHz x (124+1) frequencies (each direction)
- 8 slots per frame
- Modulation scheme: GMSK
- Transmission bit rate: ?
- Data rate: ?

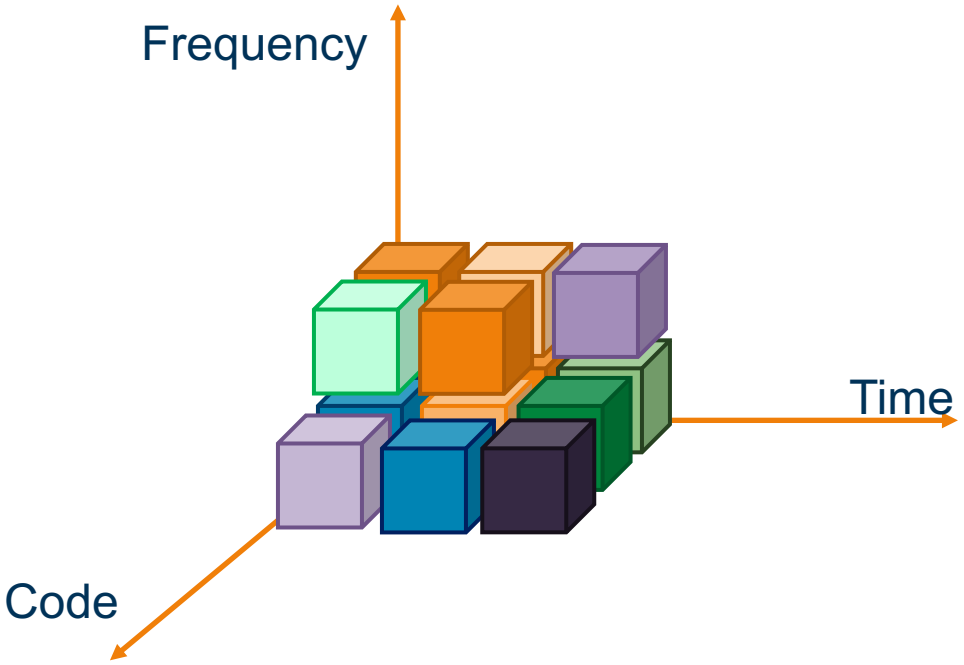
IS-136 Frame structure:

- Band: 25 MHz (each direction)
- 30kHz x 832 frequencies (each direction)
- 6 slots per frame
- Modulation scheme: DQPSK
- Transmission bit rate: ?
- Data rate: ?
  - Full rate: 2 slots for 1 user
  - Half rate: 1 slot for 1 user

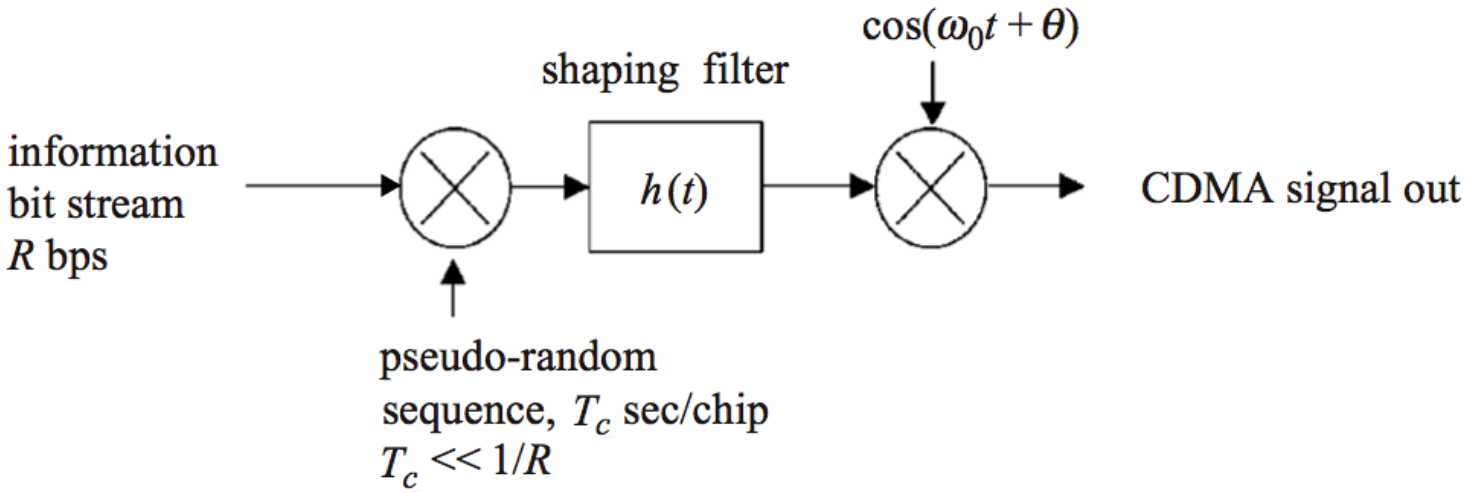


Uplink

- CDMA:
  - Assigning each user a distinct digital *code:*
    - Codes are selected so as to be "**orthogonal**" to one another
    - Multiple users can thus transmit simultaneously
  - *A code:* pseudo-random sequence (pseudo-noise)
    - *each bit: a chip, length* $T_c \ll 1/R$ (information bit length)
  - Used in 2G (IS-95) and 3G
  - Based on spread-spectrum technology



- Spread-spectrum:
  - Information BW: R
  - PN BW: $W \approx \frac{1}{T_c}$
  - Resulting
- Spreading gain: $\frac{W}{R}$



CDMA transmitter

- CDMA capacity: single-cell case
  - Power control is *critical* to the performance of CDMA systems
  - Consider UL:
    - K users/cell
    - 1 user has K-1 interfering users
    - Received signal bit energy: $E_b = \frac{P_r}{R}$
    - Interference: $I_0 = \frac{(K-1)P_r}{W}$
    - Number of users that may be accommodated:

$$K = \frac{W/R}{E_b/I_0} + 1$$

- Communication theory (optional)
  - probability of bit error considerations :
    - Modulation scheme → Probability of bit error → E_b/N_0
- Orthogonal vectors:
  - Two vectors $u(a,b)\ and\ v(c,d)$ are orthogonal if:

$$u \cdot v = 0$$

  - Dot product: summing the products of their respective components:

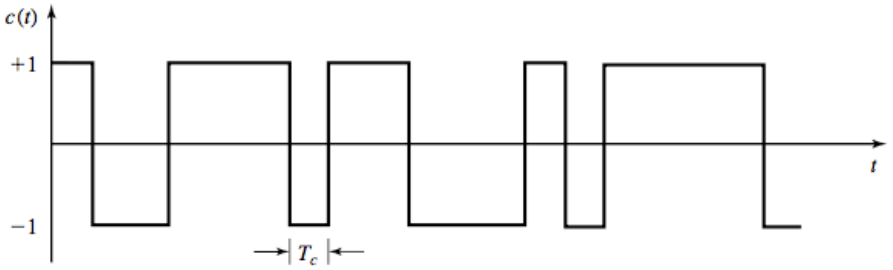
$$u \cdot v = ab + cd$$

Exercise 1:

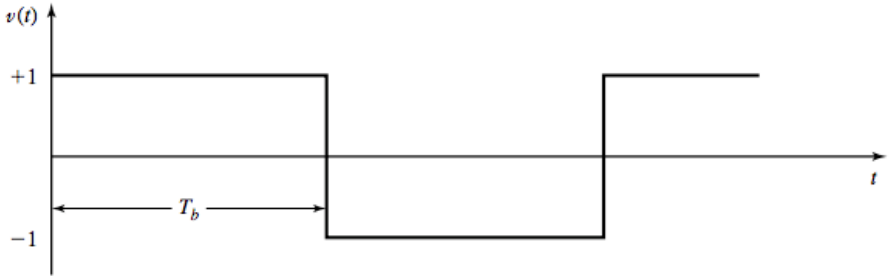
- Explain, in your own words, the distinction between *user information bit rate* and *transmission rate*.
- In particular, show that the GSM user rate is 22.8 kbps while the transmission rate is 270.833 kbps.
- Calculate the corresponding information bit rates and transmission rates for IS-136 (D-AMPS)

Exercise 2:

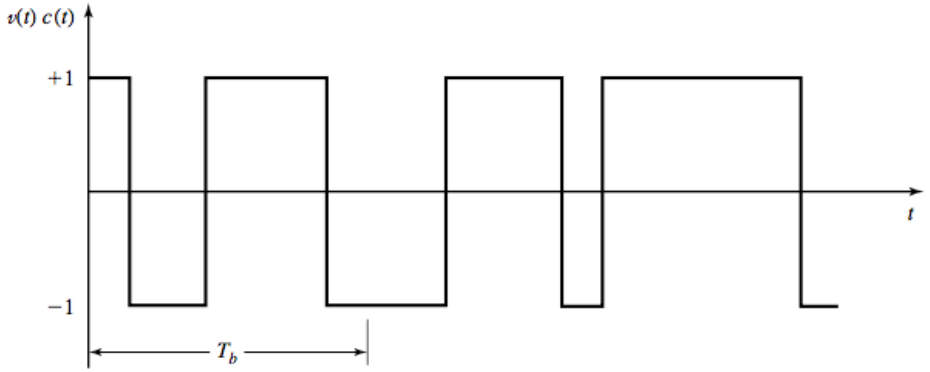
- The CDMA system IS-95 speech encoder operates at a bit rate of 9.6 kbps. Find the spreading gain if the chip rate is 1.2288 Mchips/sec. How many chips per bit does this represent? Superimpose a sketch of a sequence of chips on top of a sequence of bits.



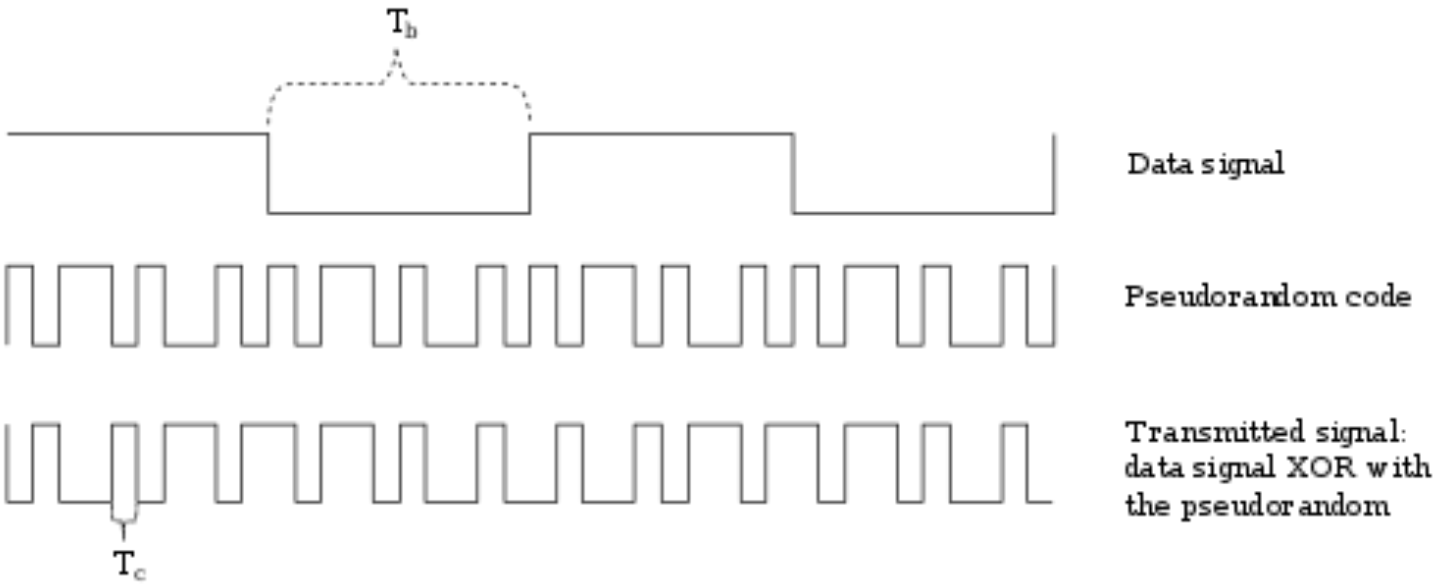
(a) PN signal



(b) Data signal



(c) Product signal


T_b
Data signal
Pseudorandom code
Transmitted signal: data signal XOR with the pseudorandom
T_c