Chapter 4.
Multiple Access Techniques and Wireless Standards

B. Razavi, *RF Microelectronics*, Prentice Hall

2008-2 RF IC 공학

범 진 욱

서강대학교 전자공학과

Microelectronics Lab.

Contents

Mobile RF Communications

- **Mobile unit: mobile phone**
  - Terminal, hand-held unit
- **Base station: fixed expensive unit**
- **Forward channel or downlink**
  - Base station → Mobile unit
- **Reverse channel or uplink**
  - Mobile unit → Base station
- **Cellular System**
  - Mobile communication in cellular structure
  - Frequency reuse
  - "7-cell" reuse pattern: efficient frequency assignment
  - A base station in each cell
  - All base station is controlled by a "mobile telephone switching office" (MTSO)

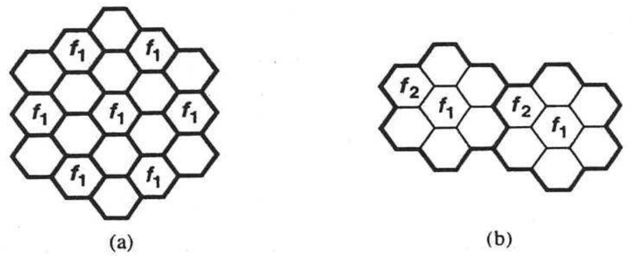

Figure 4.1 (a) Simple cellular system. (b) 7-cell reuse pattern.

Co-Channel Interference (CCI)

- **CCI**
  - How much two cells that use the same frequency interfere with each other
  - Depends on the ratio of the distance between two co-channel cells to the cell radius
  - Independent of the transmitted power
  - Ratio ~ 4.6 for 7 cell pattern
  - Signal-to-co-channel interference ratio ~18 dB
- **Handoff**
  - Change of base station

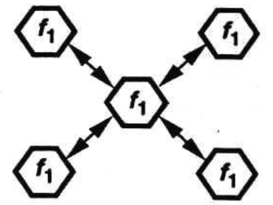

Figure 4.2 Co-channel interference.

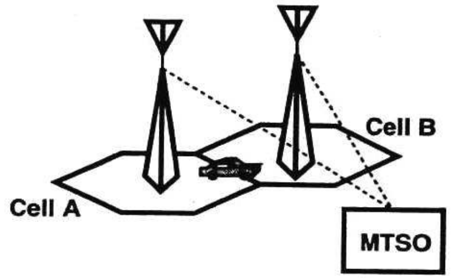

Figure 4.3 Problem of handoff.

Path loss and Multipath Fading

Path loss and Multipath Fading

- Signal travels through direct and indirect path
- Path Loss $\propto$ $(\text{distance})^{-4}$

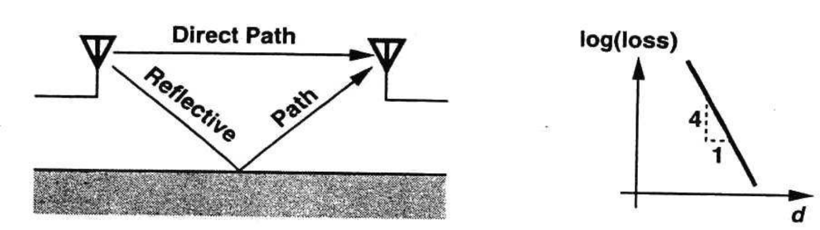

Figure 4.4 Indirect signal propagation and resulting loss profile.

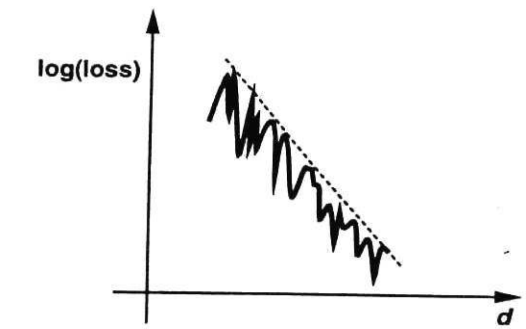

Figure 4.5 Multipath loss profile.

Diversity and Interleaving

- **Diversity**
  - Effect of fading can be lowered by adding redundancy
  - Space diversity (Antenna diversity)
    - Use of 2 or more antennas
  - Frequency diversity
    - Multiple carrier frequencies are used
  - Time diversity
    - Data is transmitted or received more than once.

- **Interleaving**
  - An interleaver scrambles the time order of the bits according to an algorithm known by the receiver to lower the errors related to multipath fading

Delay Spread

- **Delay spread**
  - Two signals in a multipath environment are equal in magnitude, but different in phase
  - $x(t)=A\cos\omega(t-\tau_1)+A\cos\omega(t-\tau_2)$
    $=2A\cos[(2\omega t-\omega\tau_1-\omega\tau_2)/2]\cos[\omega(\tau_1-\tau_2)/2]$
  - Delay spread $\Delta\tau=\tau_1-\tau_2$
  - Fade is related with delay spread.
  - Fade is frequency dependent. $\cos[\omega\Delta\tau/2]$
  - For a large delay spread, considerable variation in the spectrum
    - Rms delay spread as large as ~ μs → order of 100 kHz
    - Large delay spread also give rise to intersymbol interference.

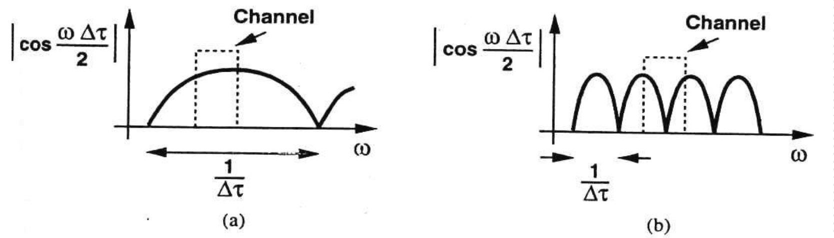

Figure 4.7 (a) Flat and (b) frequency-selective fading.

Contents

Time- and Frequency- Division Dultiplexing

- Duplexing: Two way communication
- TDD
  - Rx (receive), Tx (transmit) at the same frequency, but different time
  - High Rx, Tx isolation ~ 100 dB

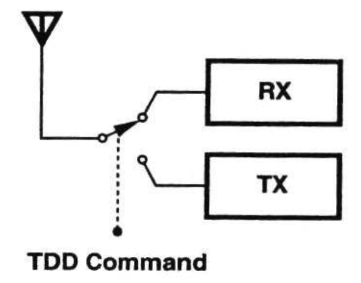

Figure 4.8 Time-division duplexing.

- FDD
  - Rx, Tx at different frequency
  - Duplexer filter: ~50 dB isolation, 2~3 dB insertion loss

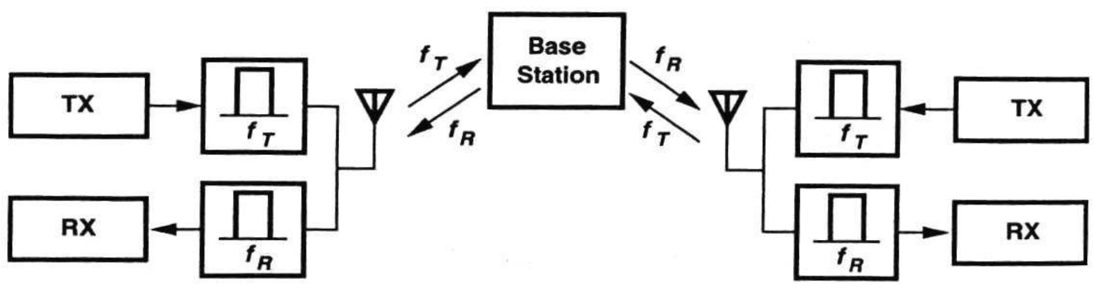

Figure 4.9 Frequency-division duplexing.

Frequency-Division Multiple Access (FDMA)

- Frequency band partitioned into many channels
- Each channel assigned to a single user
- FDMA with FDD: two channel assigned to each user

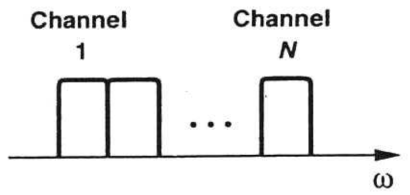

Figure 4.10 Frequency-division multiple access.

Time-Division Multiple Access (TDMA)

- A time slot (T_{sl}) assigned to each user
- Frame (T_F): Overall period for all of the time slot
- Advantages over FDMA
  - PA is on only during communication → Power save
  - Speech can be compressed in time by a large factor
    - Required BW is smaller, overall capacity is larger
  - Even with FDD, rx and tx are not on at the same time.
- Drawbacks
  - Complex: ADC, digital modem, time slot and frame synchronization are required.
    → not a problem

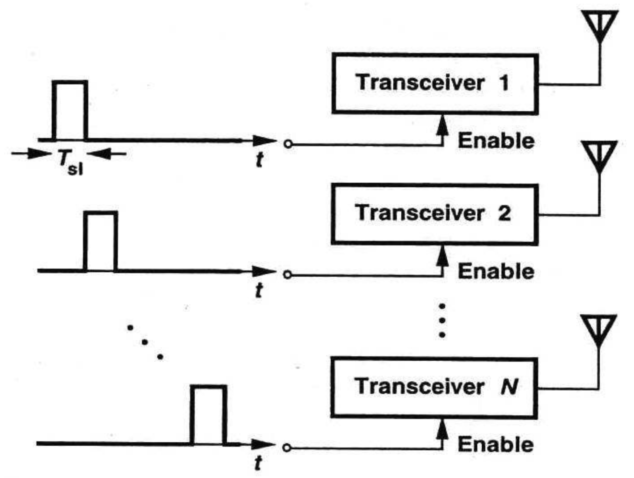

Figure 4.11 Time-division multiple access.

Code-Division Multiple Access (CDMA)

- **Signals overlap in time and frequency, but employ "orthogonal message"**
- **Similar to different language → CDMA**
  - Different time → TDMA
  - Different pitch → FDMA

Direct-Sequence CDMA

Orthogonal digital code

- Assigned to each Rx/Tx pair at the beginning of communication
- Each bit in baseband is translated into the code before modulation
- Orthogonal code generation based on Walsh’s recursive equation

$$W_1 = 0$$

$$W_{2n} = \begin{bmatrix} W_n & W_n \\ W_n & \overline{W_n} \end{bmatrix} \longrightarrow W_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}, \; W_4 = \begin{bmatrix} W_2 & W_2 \\ W_2 & \overline{W_2} \end{bmatrix}$$

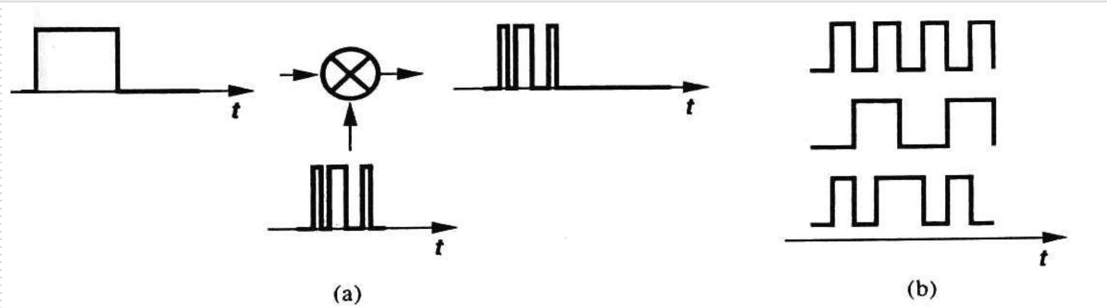

Figure 4.12 (a) Encoding operation in DS-CDMA; (b) examples of Walsh code.

DS-CDMA – cont.

- **Rx: demodulated signal decoded by multiplying the same Walsh code**
- **Encoding: increase BW → poor spectral efficiency?**
- **CDMA allows widened spectra of many users**
  - Special case of spread spectrum (SS) communication
- **DS-SS CDMA**
  - direct-sequence spread spectrum CDMA

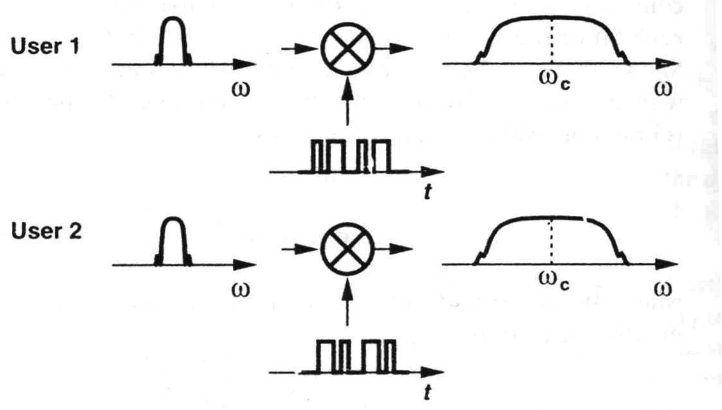

Figure 4.13 Overlapping spectra in CDMA.

DS-CDMA – cont.

- **Spreading sequence or Pseudo-random noise**
  - Each pulse in spreading sequence is called chip
  - Rate of the sequence : chip rate
    - cf. bit rate: baseband data rate
- **Decoding (Despreading)**

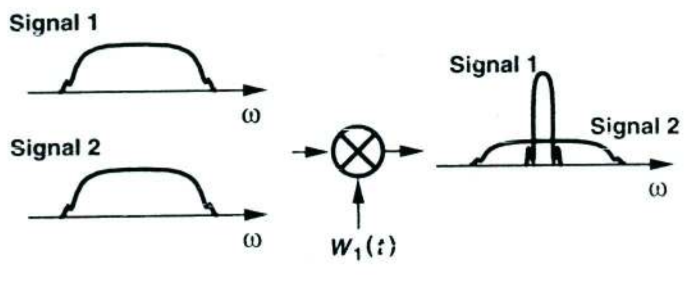

Figure 4.14 Despreading operation.

- **CDMA Soft capacity limit**
  - Increase in number of users raises the noise floor

Power control in DS-CDMA

- **Interferer with strong signal raises noise floor**
  - High power transmitter can halt all the communication

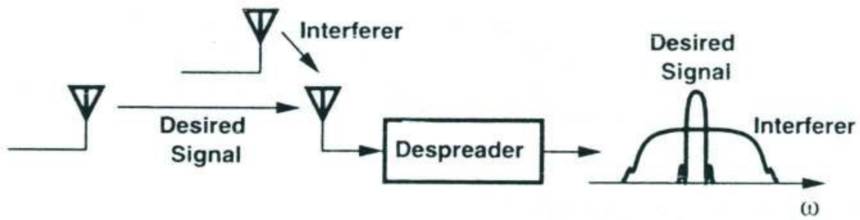

Figure 4.15 Effect of strong interferer in CDMA.

- **CDMA transmitters should have equal power**
  - Rx at base station periodically sends a power adjustment request.
    - Received signal level are controlled within 1 dB.
- **Complex power control**
  - Helps to save power dissipation

Frequency-Hoping CDMA

- FDMA with pseudorandom channel allocation
- Short-term spectrum of a transmitter may overlap with those of others.
- Overall trajectory of the spectrum distinguishes each transmitter.

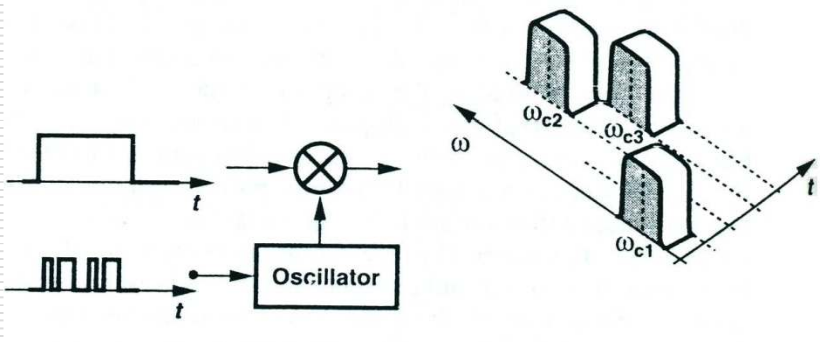

Figure 4.16 Frequency-hopping CDMA.

- Less sensitive to different received power levels
- FH requires fast settling in the control loop of the oscillator.

Contents

Advanced Mobile Phone Service (AMPS)

- Earliest wireless standard
- FDMA with analog FM and FDD
- 30 kHz per channel
- Receive band: 869-894 MHz (25 MHz)
- Transmit band: 824-849 MHz (25 MHz)
- 830 users simultaneously
- Rx and Tx band: 20 MHz apart
  - Low loss duplexer
- Voice+ control and supervision signal
  - Transmitted over the same channel

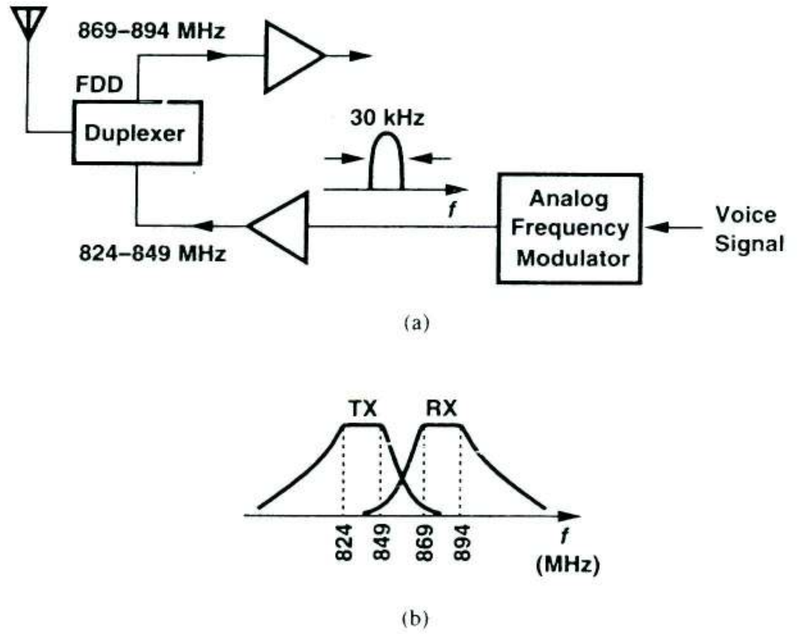

Figure 4.17 (a) AMPS air interface. (b) duplexer characteristics.

North American Digital Standard (NADC)

- **First digital cellular system in US**
- **TDMA with π/4-DQPSK and FDD**
- **Compatible with AMPS**
  - Identical Rx and Tx bands, and channel spacing with AMPS
  - 6 times the capacity of AMPS
  - 48.6 kb/s
  - 1 frame (1944 bits) → 6 slots (324 bits: 260 data+64 control)
  - Rx and Tx time slot offset by 1.85 ms
    - No leakage power problem from Tx to Rx
- **IS-54**

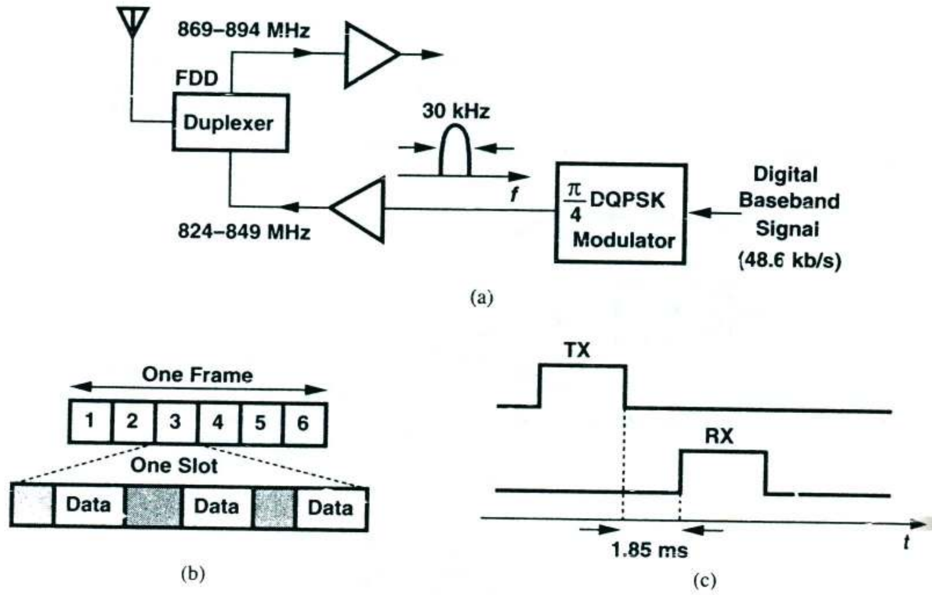

Figure 4.18 NADC (a) air interface, (b) frame structure, (c) TX and RX time slots.

Globl System for Mobile Communication (GSM)

- Unified wireless standard for Europe
- GSM supports voice, fax, and ISDN.
- TDMA/FDD with GMSK
- Transmit band: 890-915 MHz
- Receive band: 935-960 MHz
- Channel BW: 200 kHz, 270 kb/s per user
- Total capacity 1000

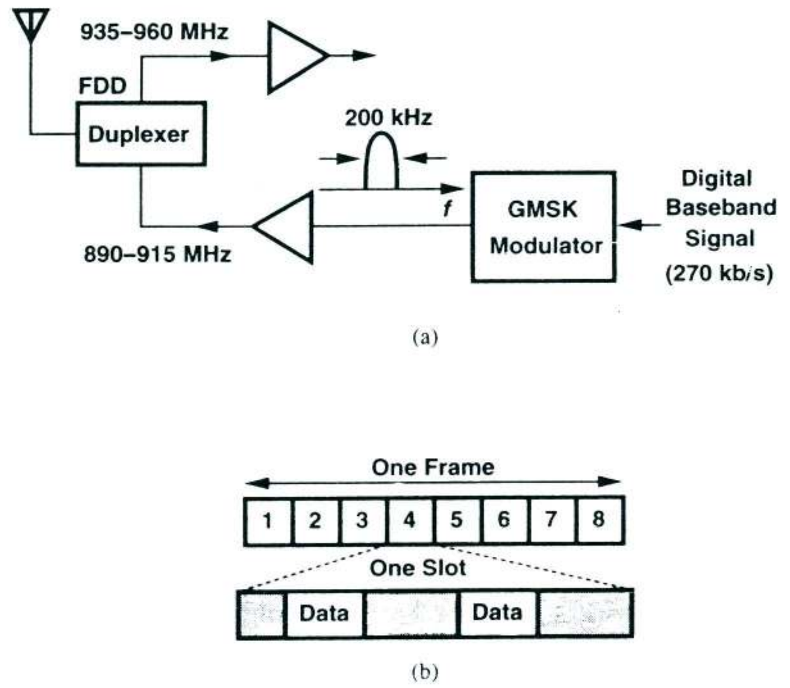

Figure 4.19 GSM (a) air interface and (b) frame structure.

Qualcomm CDMA

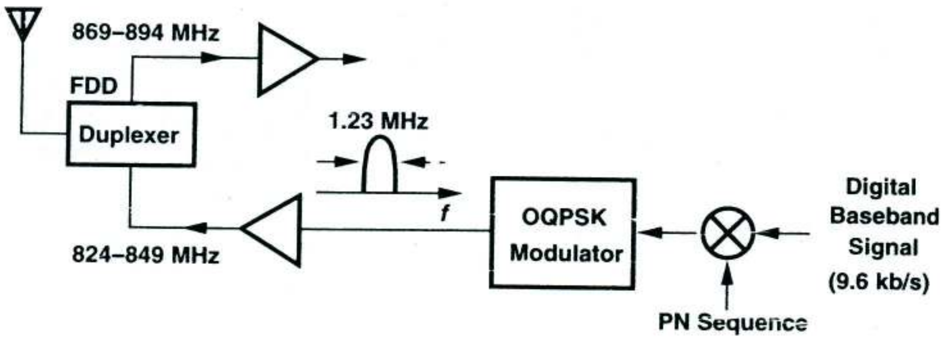

Figure 4.20 IS–95 air interface.

- **DS-CDMA**
- **IS-95 (→ IS-98 →)**
  - OQPSK/FDD
  - 9.6 kb/s spread to 1.23 MHz
  - Coherent detection
    - Pilot tone at the beginning for phase synchronization
  - Power control
    - 1 dB received power level variation
    - Open-loop procedure at the beginning → rough, fast
      - Received power from BS + transmitted power = -73 dBm
      - P_{bs}-k+P_m=-73 dBm   k: attenuation, Pm: mobile power
      - P_m-k=-P_{bs}-73 dBm
    - Closed-loop power control
      - BS sends feedback signal to adjust the power every 1.25 ms

Frequency and Time Diversity

- **Frequency Diversity**
  - Multipath fading → notch in a channel transfer function
  - Spread spectrum 1.25 MHz: frequency diveristy
    - Only 25 % loss of band
- **Time Diversity**
  - Rake receiver
    - Delayed replicas combined with weighting factor α_j

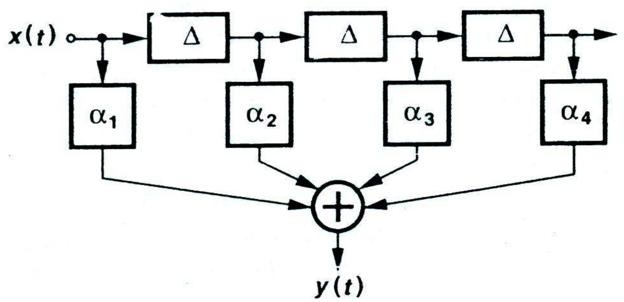

Figure 4.21 Rake receiver.

Variable Coding Rate and Soft Handoff

- **Variable Coding Rate**
  - Buffer slower data and transmit for a short period of time
  - Example: speech rate 2400 b/s
    - Data accumulation 50%
    - Data transmission 50 %
  - Reduces the average power transmitted
- **Soft Handoff**
  - Signal strength of adjacent channel is monitored at the same time
  - Switch to the next base station only if the signal is stronger

Digital European Cordless Telephone (DECT)

- TDMA/FDMA with TDD
- Cordless phone framework
- Allowed connection to GSM

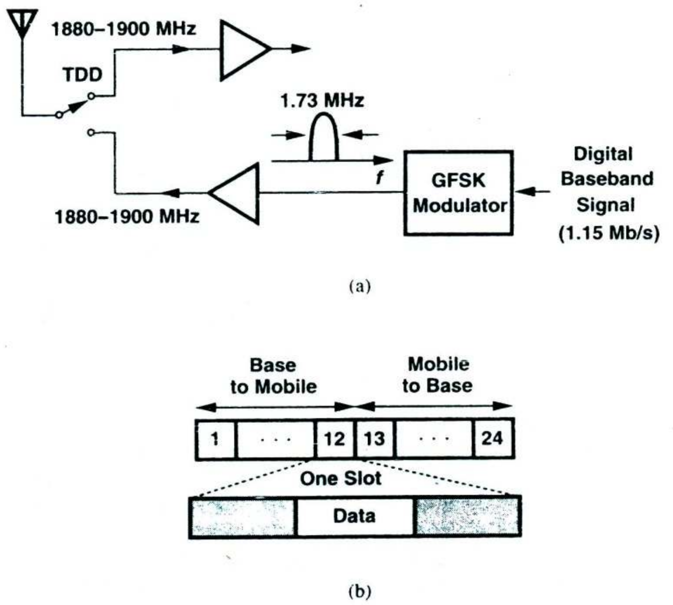

Figure 4.22 DECT (a) air interface and (b) frame structure.