



# ECS455: Chapter 4

## Multiple Access

### 4.8 IS-95

Dr.Prapun Suksompong

www.prapun.com

**Office Hours:**

| | | |
|---|---|---|
| Library (Rangsit) | Mon | 16:20-16:50 |
| BKD 3601-7 | Wed | 9:20-11:20 |

# Evolution of cellular network

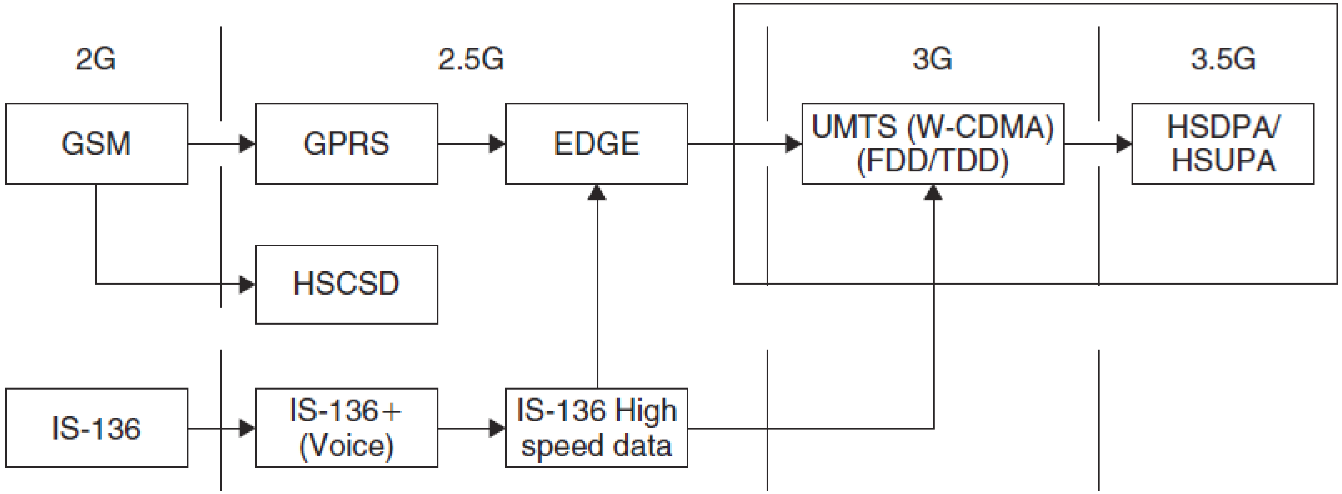



**Figure 1.1** *Evolution of 2G networks based on TDMA technology.*

[Abu-Rgheff, 2007]

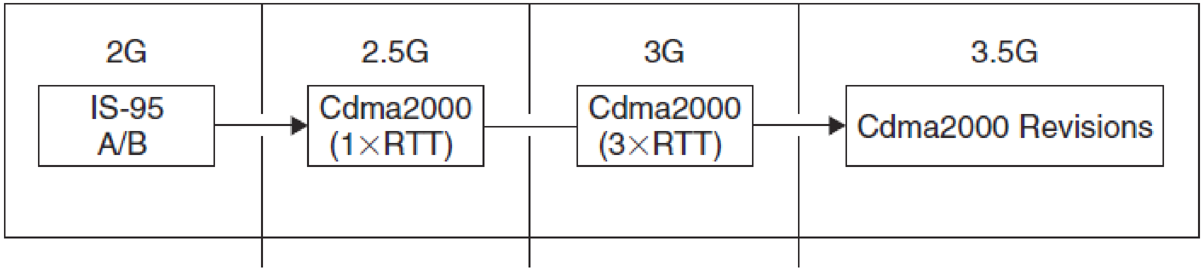


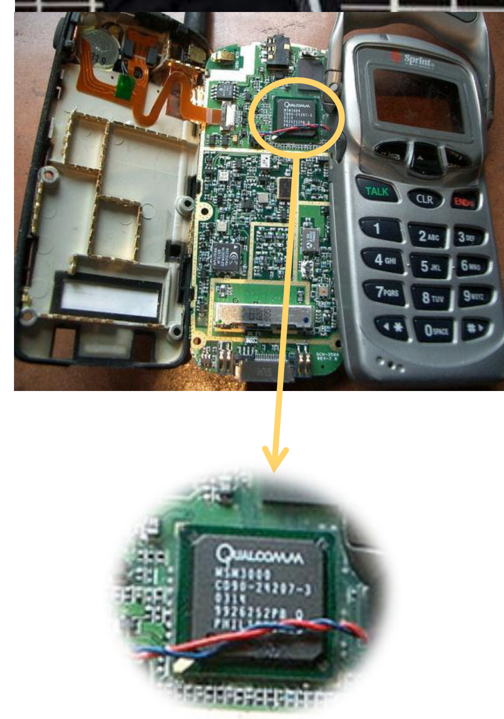

**Figure 1.2** *Evolution of 2G networks based on CDMA technology.*

# IS-95 System

cdmaOne

- Based on direct sequence CDMA (**DS-CDMA**)
  - **First** CDMA-based digital cellular standard.
- The brand name for IS-95 is cdmaOne.
  - Also known as TIA-EIA-95.
- Proposed by Qualcomm in 1989 and adopted in 1993.
  - North America
- Replaced by IS-2000 (CDMA2000)
- **1.25 MHz Channel BW**
- 1.228 Mb/s chip rate
- Walsh functions of "order 64" are extensively used in the IS-95 system.
- Remarks
  - IS-95B = cdmaOne
    - Upgrade IS-95A
  - Can carry data at rates up to **14.4 kbps** for IS-95A and **115 kbps** for IS-95B.





# 64-ary Walsh Functions

**Table 5.8 Walsh functions of order 64, as indexed in IS-95 ($W_i$ is the Walsh notation, and $H_i$ is the Hadamard notation)**

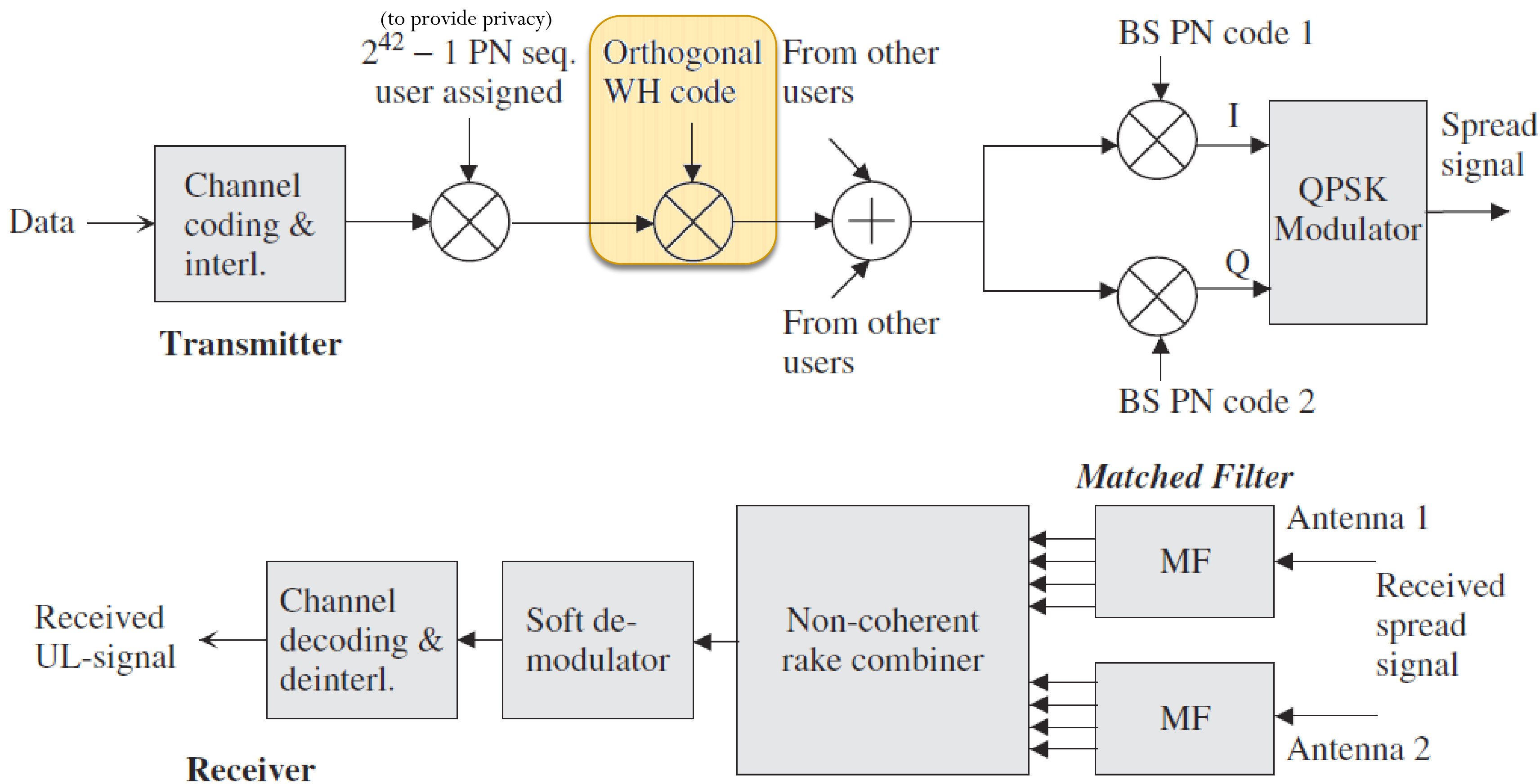
| | | | | | |
|---|---|---|---|---|---|
| $W_0$ | $H_0$ | 0000000000000000 | 0000000000000000 | 0000000000000000 | 0000000000000000 |
| $W_{63}$ | $H_1$ | 0101010101010101 | 0101010101010101 | 0101010101010101 | 0101010101010101 |
| $W_{31}$ | $H_2$ | 0011001100110011 | 0011001100110011 | 0011001100110011 | 0011001100110011 |
| $W_{32}$ | $H_3$ | 0110011001100110 | 0110011001100110 | 0110011001100110 | 0110011001100110 |
| $W_{15}$ | $H_4$ | 0000111100001111 | 0000111100001111 | 0000111100001111 | 0000111100001111 |
| $W_{48}$ | $H_5$ | 0101101001011010 | 0101101001011010 | 0101101001011010 | 0101101001011010 |
| $W_{16}$ | $H_6$ | 0011110000111100 | 0011110000111100 | 0011110000111100 | 0011110000111100 |
| $W_{47}$ | $H_7$ | 0110100101101001 | 0110100101101001 | 0110100101101001 | 0110100101101001 |
| $W_7$ | $H_8$ | 0000000011111111 | 0000000011111111 | 0000000011111111 | 0000000011111111 |
| $W_{56}$ | $H_9$ | 0101010110101010 | 0101010110101010 | 0101010110101010 | 0101010110101010 |
| $W_{24}$ | $H_{10}$ | 0011001111001100 | 0011001111001100 | 0011001111001100 | 0011001111001100 |
| $W_{39}$ | $H_{11}$ | 0110011010011001 | 0110011010011001 | 0110011010011001 | 0110011010011001 |
| $W_8$ | $H_{12}$ | 0000111111110000 | 0000111111110000 | 0000111111110000 | 0000111111110000 |
| $W_{55}$ | $H_{13}$ | 0101101010100101 | 0101101010100101 | 0101101010100101 | 0101101010100101 |
| $W_{23}$ | $H_{14}$ | 0011110011000011 | 0011110011000011 | 0011110011000011 | 0011110011000011 |
| $W_{40}$ | $H_{15}$ | 0110100110010110 | 0110100110010110 | 0110100110010110 | 0110100110010110 |
| $W_3$ | $H_{16}$ | 0000000000000000 | 1111111111111111 | 0000000000000000 | 1111111111111111 |
| $W_{60}$ | $H_{17}$ | 0101010101010101 | 1010101010101010 | 0101010101010101 | 1010101010101010 |
| $W_{28}$ | $H_{18}$ | 0011001100110011 | 1100110011001100 | 0011001100110011 | 1100110011001100 |
| $W_{35}$ | $H_{19}$ | 0110011001100110 | 1001100110011001 | 0110011001100110 | 1001100110011001 |
| $W_{12}$ | $H_{20}$ | 0000111100001111 | 1111000011110000 | 0000111100001111 | 1111000011110000 |
| $W_{51}$ | $H_{21}$ | 0101101001011010 | 1010010110100101 | 0101101001011010 | 1010010110100101 |
| $W_{19}$ | $H_{22}$ | 0011110000111100 | 1100001111000011 | 0011110000111100 | 1100001111000011 |
| $W_{44}$ | $H_{23}$ | 0110100101101001 | 1001011010010110 | 0110100101101001 | 1001011010010110 |
| $W_4$ | $H_{24}$ | 0000000011111111 | 1111111100000000 | 0000000011111111 | 1111111100000000 |
| $W_{59}$ | $H_{25}$ | 0101010110101010 | 1010101001010101 | 0101010110101010 | 1010101001010101 |
| $W_{27}$ | $H_{26}$ | 0011001111001100 | 1100110000110011 | 0011001111001100 | 1100110000110011 |
| $W_{36}$ | $H_{27}$ | 0110011010011001 | 1001100101100110 | 0110011010011001 | 1001100101100110 |
| $W_{11}$ | $H_{28}$ | 0000111111110000 | 1111000000001111 | 0000111111110000 | 1111000000001111 |
| $W_{52}$ | $H_{29}$ | 0101101010100101 | 1010010101011010 | 0101101010100101 | 1010010101011010 |
| $W_{20}$ | $H_{30}$ | 0011110011000011 | 1100001100111100 | 0011110011000011 | 1100001100111100 |
| $W_{43}$ | $H_{31}$ | 0110100110010110 | 1001011001101001 | 0110100110010110 | 1001011001101001 |
| $W_1$ | $H_{32}$ | 0000000000000000 | 0000000000000000 | 1111111111111111 | 1111111111111111 |
| $W_{62}$ | $H_{33}$ | 0101010101010101 | 0101010101010101 | 1010101010101010 | 1010101010101010 |
| $W_{30}$ | $H_{34}$ | 0011001100110011 | 0011001100110011 | 1100110011001100 | 1100110011001100 |
| $W_{33}$ | $H_{35}$ | 0110011001100110 | 0110011001100110 | 1001100110011001 | 1001100110011001 |
| $W_{14}$ | $H_{36}$ | 0000111100001111 | 0000111100001111 | 1111000011110000 | 1111000011110000 |
| $W_{49}$ | $H_{37}$ | 0101101001011010 | 0101101001011010 | 1010010110100101 | 1010010110100101 |
| $W_{17}$ | $H_{38}$ | 0011110000111100 | 0011110000111100 | 1100001111000011 | 1100001111000011 |
| $W_{46}$ | $H_{39}$ | 0110100101101001 | 0110100101101001 | 1001011010010110 | 1001011010010110 |
| $W_6$ | $H_{40}$ | 0000000011111111 | 0000000011111111 | 1111111100000000 | 1111111100000000 |
| $W_{57}$ | $H_{41}$ | 0101010110101010 | 0101010110101010 | 1010101001010101 | 1010101001010101 |
| $W_{25}$ | $H_{42}$ | 0011001111001100 | 0011001111001100 | 1100110000110011 | 1100110000110011 |
| $W_{38}$ | $H_{43}$ | 0110011010011001 | 0110011010011001 | 1001100101100110 | 1001100101100110 |
| $W_9$ | $H_{44}$ | 0000111111110000 | 0000111111110000 | 1111000000001111 | 1111000000001111 |
| $W_{54}$ | $H_{45}$ | 0101101010100101 | 0101101010100101 | 1010010101011010 | 1010010101011010 |
| $W_{22}$ | $H_{46}$ | 0011110011000011 | 0011110011000011 | 1100001100111100 | 1100001100111100 |
| $W_{41}$ | $H_{47}$ | 0110100110010110 | 0110100110010110 | 1001011001101001 | 1001011001101001 |
| $W_2$ | $H_{48}$ | 0000000000000000 | 1111111111111111 | 1111111111111111 | 0000000000000000 |
| $W_{61}$ | $H_{49}$ | 0101010101010101 | 1010101010101010 | 1010101010101010 | 0101010101010101 |
| $W_{29}$ | $H_{50}$ | 0011001100110011 | 1100110011001100 | 1100110011001100 | 0011001100110011 |
| $W_{34}$ | $H_{51}$ | 0110011001100110 | 1001100110011001 | 1001100110011001 | 0110011001100110 |
| $W_{13}$ | $H_{52}$ | 0000111100001111 | 1111000011110000 | 1111000011110000 | 0000111100001111 |
| $W_{50}$ | $H_{53}$ | 0101101001011010 | 1010010110100101 | 1010010110100101 | 0101101001011010 |
| $W_{18}$ | $H_{54}$ | 0011110000111100 | 1100001111000011 | 1100001111000011 | 0011110000111100 |
| $W_{45}$ | $H_{55}$ | 0110100101101001 | 1001011010010110 | 1001011010010110 | 0110100101101001 |
| $W_5$ | $H_{56}$ | 0000000011111111 | 1111111100000000 | 1111111100000000 | 0000000011111111 |
| $W_{58}$ | $H_{57}$ | 0101010110101010 | 1010101001010101 | 1010101001010101 | 0101010110101010 |
| $W_{26}$ | $H_{58}$ | 0011001111001100 | 1100110000110011 | 1100110000110011 | 0011001111001100 |
| $W_{37}$ | $H_{59}$ | 0110011010011001 | 1001100101100110 | 1001100101100110 | 0110011010011001 |
| $W_{10}$ | $H_{60}$ | 0000111111110000 | 1111000000001111 | 1111000000001111 | 0000111111110000 |
| $W_{53}$ | $H_{61}$ | 0101101010100101 | 1010010101011010 | 1010010101011010 | 0101101010100101 |
| $W_{21}$ | $H_{62}$ | 0011110011000011 | 1100001100111100 | 1100001100111100 | 0011110011000011 |
| $W_{12}$ | $H_{63}$ | 0110100110010110 | 1001011001101001 | 1001011001101001 | 0110100110010110 |

[Lee and Miller, 1998, Table 5.8]

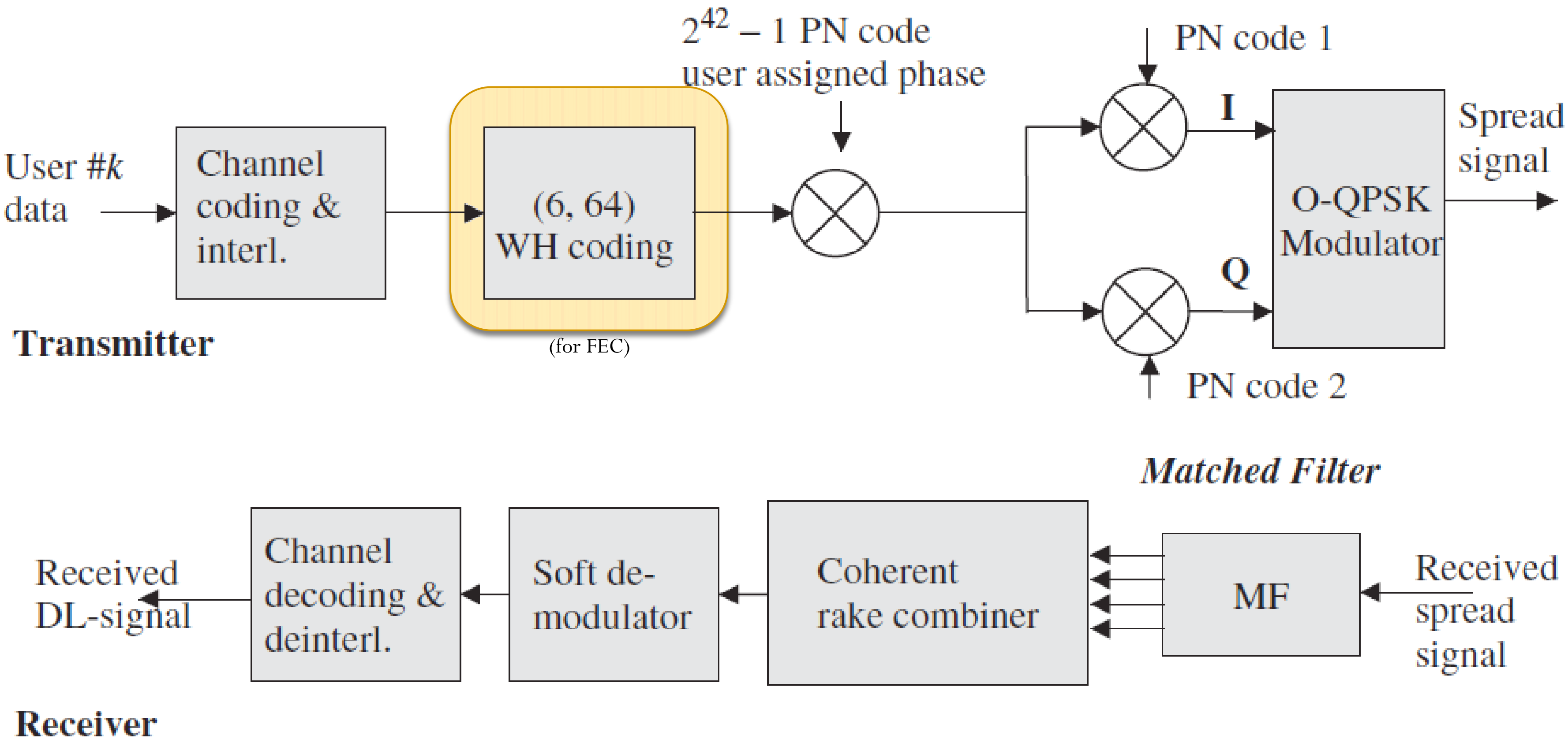
# Walsh Sequences in IS-95

- **Forward link (Downlink)**
  - QPSK with a chip rate of 1,228,800 per second.
  - The **multiple access scheme** is accomplished by the use of 64-bit spreading orthogonal **Walsh sequences** (functions).
    - The (coded and interleaved) traffic channel signal symbols are multiplied with distinct repeating Walsh sequences that are assigned to each channel for the duration of the call.
  - Every base stations is synchronized with a GPS receiver so transmissions are tightly controlled in time.
- **Reverse link (Uplink)**
  - The Walsh sequences are employed as an **orthogonal modulation code**, which depends only on the data pattern (not channel), forming a 64-ary orthogonal modulation system.

# IS-95 base station transceiver



# IS-95 terminal station transceiver



# IS-95

- The **reverse link** is subject to near-far effects.
- More powerful **error correction** is employed on the reverse link.
  - A rate 1/2 constraint length 9 convolutional code followed by an interleaver on the forward channel
  - A rate 1/3 constraint length 9 convolutional code followed by an interleaver is used on the reverse link.
    - Also with WH(6,64)
  - Interleaving is utilized to avoid large burst errors, which can be very detrimental to convolutional codes.
- **Power control**.
  - Use a subchannel on the forward link
  - Every 1.25 ms the base station receiver estimates the signal strength of the mobile unit.
  - If it is too high, the base transmits a 1 on the subchannel. If it is too low, it transmits a 0.
  - In this way, the mobile station adjusts its power every 1.25 ms as necessary so as to reduce interference to other users.

# IS-95: Increased Spectral Efficiency

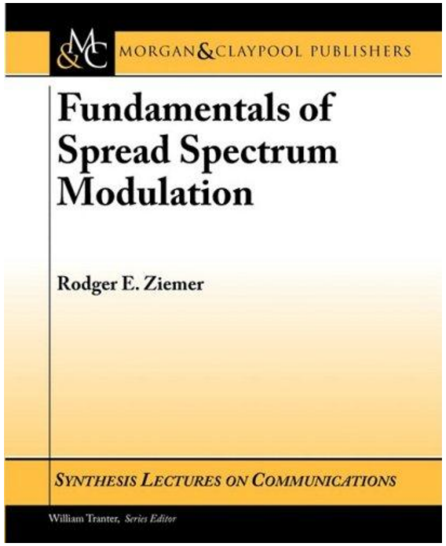
- Improve frequency reuse.
  - Narrow-band systems cannot use the same transmission frequency in adjacent cells because of the potential for interference.
  - CDMA has inherent resistance to interference.
    - N = 1 (theoretically)
    - Although users from adjacent cells will contribute to interference level, their contribution will be significantly less than the interference from the same cell users.
    - Frequency reuse efficiency increases by a factor of 4 to 6.
- When used to transmit voice signals, CDMA systems may exploit the fact that voice activity typically lies at somewhat less than 40%, thus reducing the amount of interference to 40% of its original value.

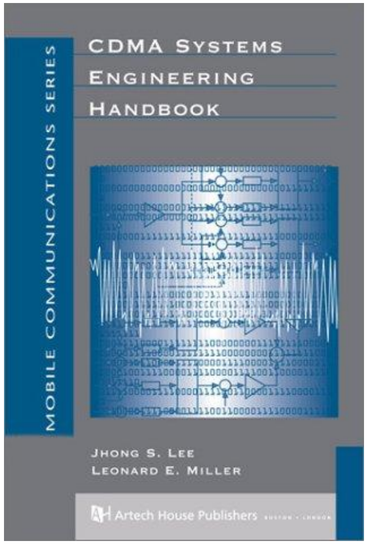
# QCELP

- Qualcomm code-excited linear prediction algorithm
- Used for voice encoding.
- The voice coder exploits gaps and pauses in speech.
- The data rate is variable.
- To keep the symbol rate constant, whenever the bit rate falls below the peak bit rate of 9600 kbit/s, repetition is used to fill the gaps.
  - For example, if the output of the voice coder (and subsequently the convolutional coder) falls to 2400 bit/s, the output is repeated three times before it is sent to the interleaver.
  - Takes advantage of this repetition time by reducing the output power during three out of the four identical symbols by at least 20 dB.
  - In this way, the multiple-access interference is reduced.
- This voice activity gating reduces interference and increases overall capacity.

# References

- J. S. Lee and L. E. Miller, **CDMA Systems Engineering Handbook**, 1998.
  - Chapter 4 and 5
- R.E. Ziemer, **Fundamentals of Spread Spectrum Modulation**, 2007
  - Chapter 4




[TK5103.45 L44 1998]

| Cellular System | Multiple Access Technique |
| --- | --- |
| Advanced Mobile Phone System (AMPS) | FDMA/FDD |
| Global System for Mobile (GSM) | TDMA/FDD |
| US Digital Cellular (USDC) | TDMA/FDD |
| Pacific Digital Cellular (PDC) | TDMA/FDD |
| CT2 (Cordless Telephone) | FDMA/TDD |
| Digital European Cordless Telephone (DECT) | FDMA/TDD |
| US Narrowband Spread Spectrum (IS-95) | CDMA/FDD |
| W-CDMA (3GPP) | CDMA/FDD<br>CDMA/TDD |
| cdma2000 (3GPP2) | CDMA/FDD<br>CDMA/TDD |