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# International summer students courses:
# "Plugged In: Modern Networks and Services in Telecommunication"

# CDMA One

*Presented by:*

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**CDMA One -** *Summer Students Course*

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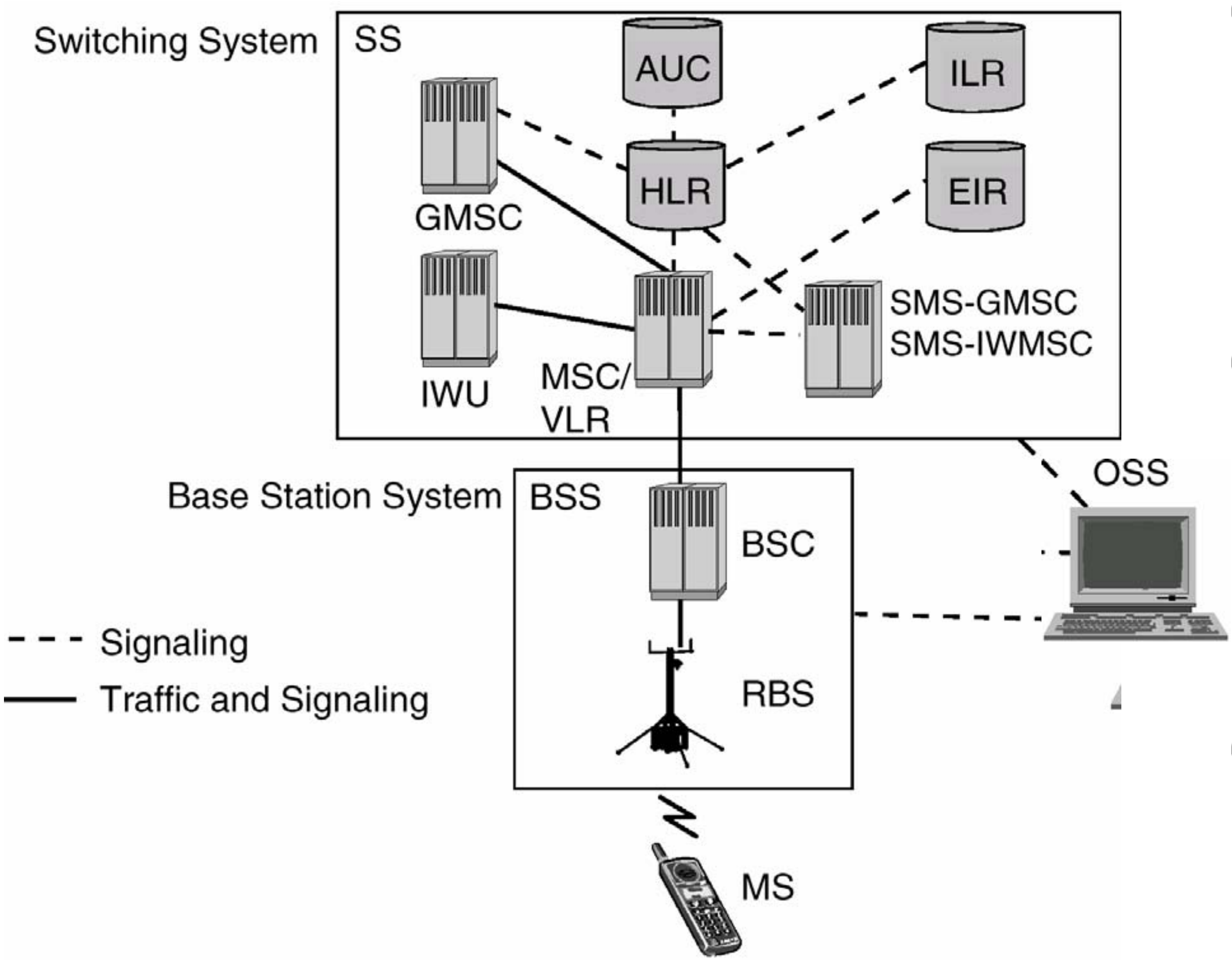
# 1. INTRODUCTION

## Architecture of a GSM system.



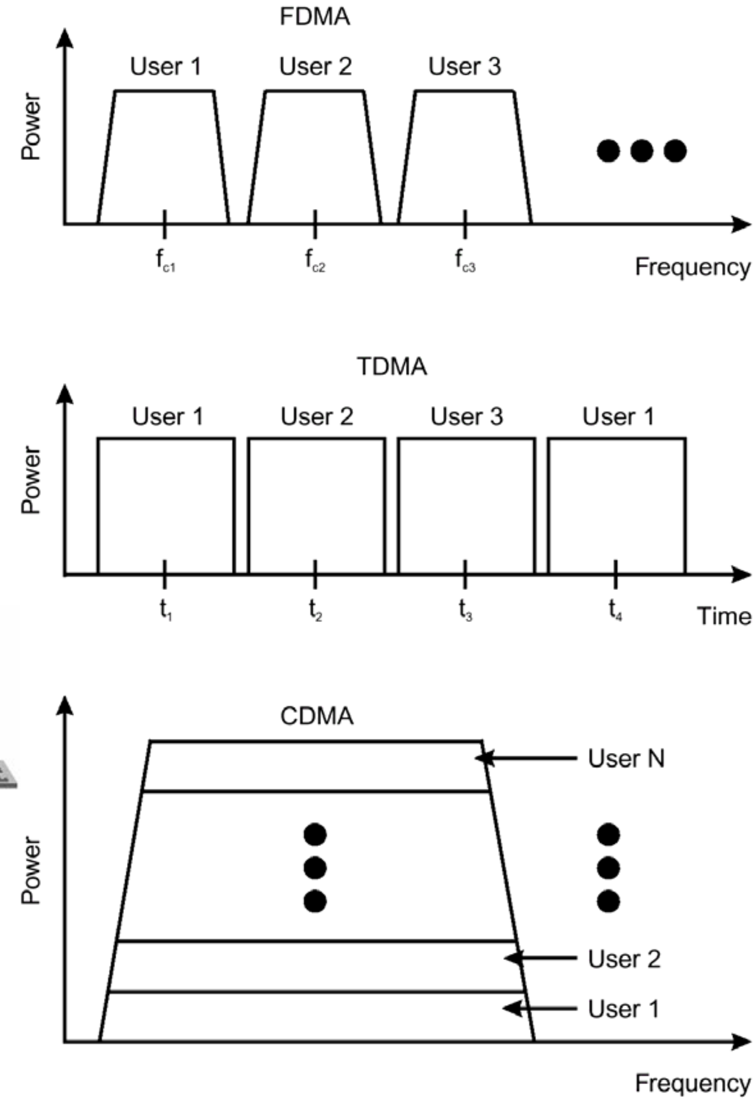




**Figure 3.9** Different multiple-access schemes.

# CDMA One - *Summer Students Course*

## 1 INTRODUCTION

**History of CDMA** (Code Division Multiple Access)

•***Qualcomm*** Company, throught Jacobs and Viterbi, suddenly announced to the world in 1991 that it had invented a new cellular system based on CDMA and that the capacity of this system was 20 or so times greater than any other cellular system in existence.

•GSM manufacturers became concerned that they would start to lose market share to this new system.

•CDMAone is the new name for a radio system that was previously known as IS-95, or Qualcomm CDMA.

•Much of CDMAone is the same as GSM:

The use of paging, location updating, random access, and security, is all the same as it is for GSM.

The only real difference lies in the detailed parameters of the radio signal sent between cell and mobile.

The biggest difference is that CDMAone uses the CDMA multiple access method, whereas GSM uses the TDMA multiple access method.

•This presentation primarily deals with a type of spread spectrum that is employed in the IS-95 standard called **Direct-Sequence Spread Spectrum** (DS-SS).

•Another form of spread spectrum is called **frequency-hopping spread spectrum** (FH-SS) where the carrier frequency of the signal is moved (hopped) around in the band in a pseudorandom fashion. The result is an increase in effective bandwidth over time.

**Principle of a DS SS multiple access scheme:**

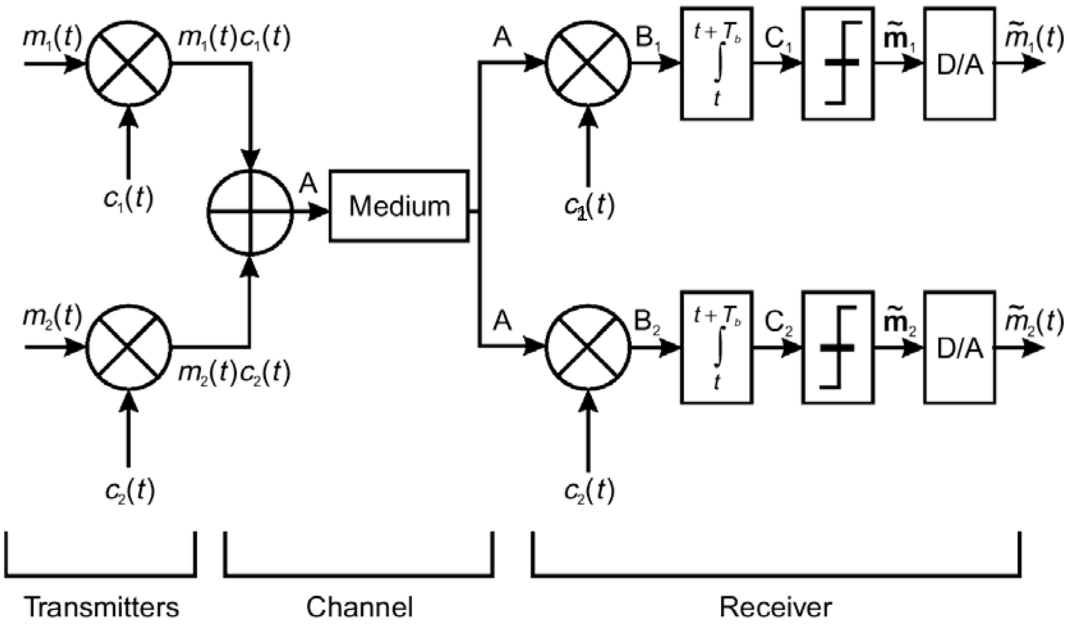



**Figure 1.1** An example showing the operating principle of DS-SS multiple access. Two users are sending two separate messages, $m_1(t)$ and $m_2(t)$, simultaneously through the same channel in the same frequency band and at the same time. Through the use of orthogonal codes $c_1(t)$ and $c_2(t)$, the receiver recovers the two messages perfectly.

**There are two problems:**
1) the **near-far** problem – required power control,
2) the **partial correlation** problem – required synchronize codes.

***The properties of the set of orthogonal codes:***

1. The cross-correlation should be zero or very small.

2. Each sequence in the set has an equal number of 1s and –1s, or the number of 1s differs from the number of –1s by at most 1.

3. The scaled dot product of each code should be equal to 1.

**Applications of DS-SS in Mobile Communication**

1) CDMA system can readily take advantage of the ***voice activity*** of normal human speech - reduction in interference - capacity gain for the system.

2) ***Frequency reuse factor of close to 1*** - there is no need to frequency plan in CDMA.

3) The third advantage is ***CDMA's ability to mitigate multipath distortion***.

# 2 RADIO PROPAGATION

## Link Analysis

*Carrier-to-noise ratio* at the receiver (C/N) as an indicator of link quality:

$$\frac{C}{N} = \frac{(\mathrm{ERP})L_p G_r}{N} \qquad \mathrm{ERP} = P_t L_c G_t \qquad N = kTW$$

## Propagation Loss

We will present here only three models:

1) ***Free Space:***

$$L_p = -32.4 - 20\log(f) - 20\log(d) \tag{2.5}$$

2) ***Lee model:***
- at the cellular frequency we have

$$L_p = -129.45 - 38.4\log(d) + 20\log(h) \tag{2.7}$$

3) ***Hata model:***
- is based on extensive empirical measurements taken in urban environments

$$L_p = -K_1 - K_2\log(f) + 13.82\log(h_b) + a(h_m) - [44.9 - 6.55\log(h_b)]\log(d) - K_0 \tag{2.8}$$

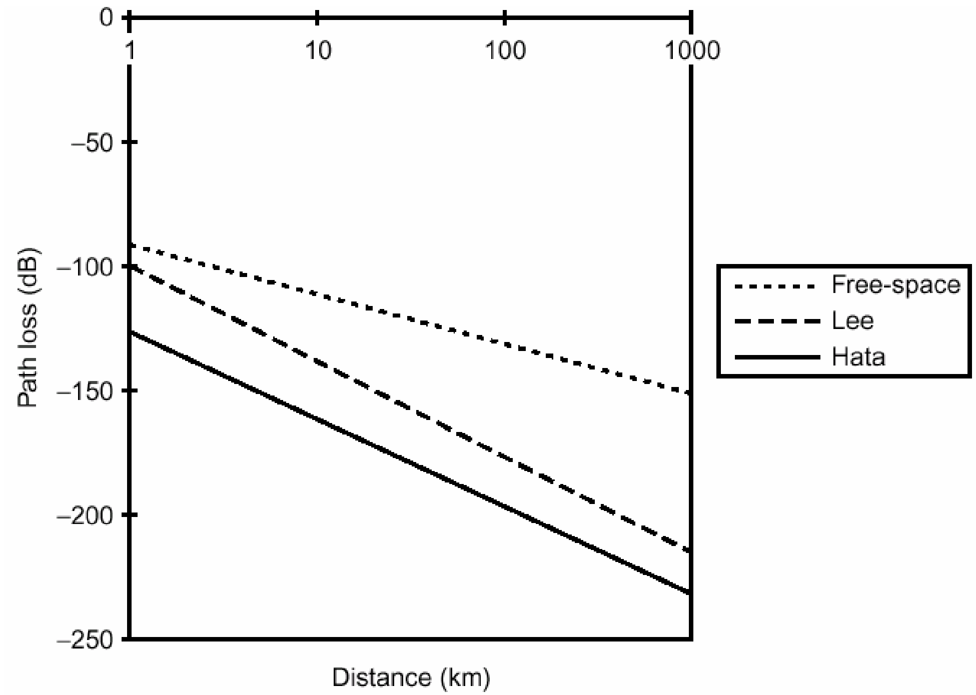



**Figure 2.1** As an illustration, the graph shows the path loss vs. distance for three different propagation models: free space, Lee, and Hata. The antenna height and carrier frequency are 30m and 881.5 MHz, respectively. For the Hata prediction, we use a mobile antenna height of 1.5m and an urban scenario.

## 2 RADIO PROPAGATION

### Shadowing

• A receiver traverses away, obstacles that partially block the signal path (such as trees, building, and moving trucks) cause occasional drops in received power. This decrease in power occurs over many wavelengths of the carrier and is thus called ***slow fading***. Slow fading is usually modeled by a *log-normal distribution* with mean power and standard deviation.

### Multipath Rayleigh Fading

• When a mobile receiver is completely out of sight of the base station transmitter the received signals are made up of a group of reflections from objects, and none of the reflected paths is any more dominant than the other ones. The envelope of a received carrier signal for a moving mobile is Rayleigh distributed and this type of fading is called ***Rayleigh fading*** or ***fast fading***.

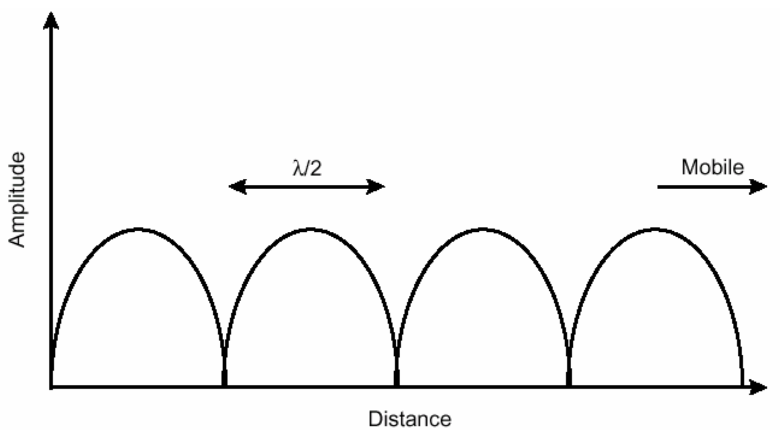



**Figure 2.2** For illustration, as it travels through the standing wave pattern, the mobile will experience fades once every half wavelength. Note that the standing wave pattern shown is a simple example resulting from the addition of two equally strong waves that are 180 degrees out of phase.

### Multipath Delay Spread

• Multipath occurs when signals arrive at the receiver directly from the transmitter and, indirectly, due to transmission through objects or reflection. ***Intersymbol interference*** (ISI) can occur.

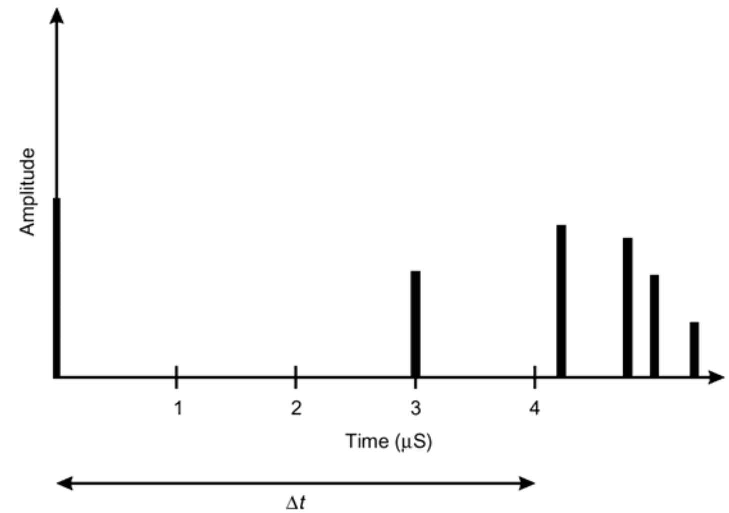



**Figure 2.3** An example of delay spread.

# 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

## Introduction

• There are many advantages for migrating from analog AM or FM to digital such as TDMA and CDMA, but there are at least four reasons for the recent trend in the industry, as follows:
1) ***Quality of service*** - ability to regenerate the signal
2) ***Increased capacity*** - convert A/D and speech compression (Vocoder in CDMA)
3) ***Privacy*** - encyption tehniques
4) ***Enabling technology and economics*** - new twhnologies such as *digital signal processing* (DSP) techniques and their implementation on *application-specific integrated circuits* (ASICs)

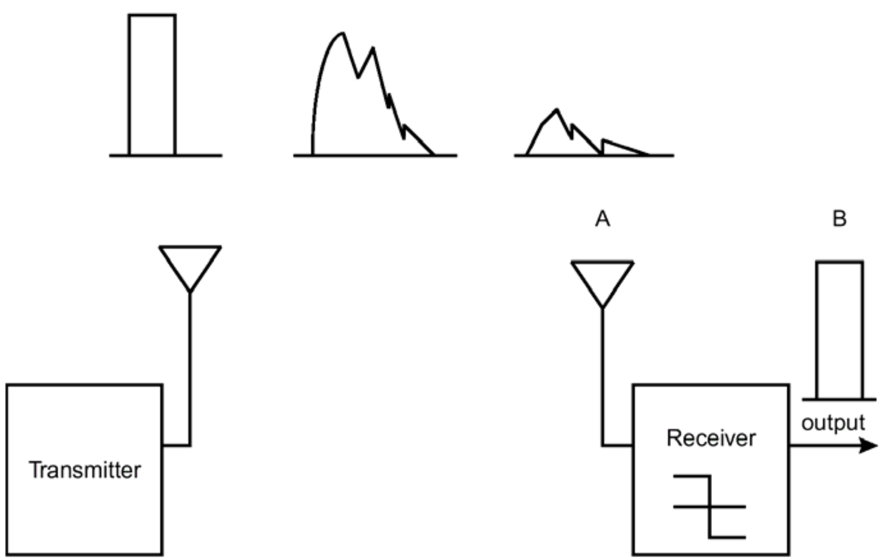



**Figure 3.1** A simplified digital communication system showing the concept of signal regeneration.

**System Components** - Functional block diagram of a typical digital communication system.

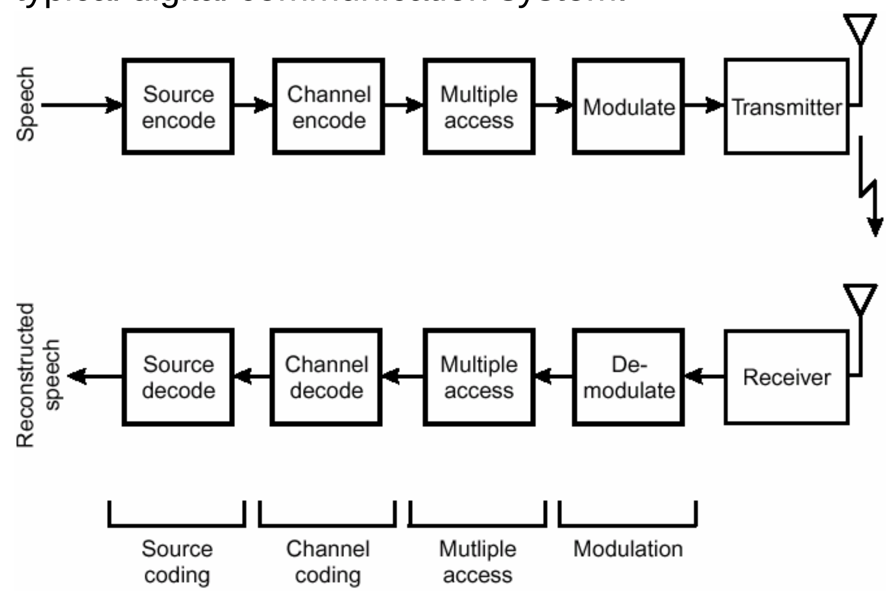



**Figure 3.2** Principal components of a digital communication system.

# 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

## Source Coding

• ***Pulse Code Modulation*** (PCM), where the analog voice is converted into a 64-Kbps bit stream. Other wireline techniques, such as ***adaptive pulse code modulation*** (ADPCM) and ***delta modulation*** (DM), are also used.

• In wireless applications an attractive solution is offered by the ***vocoders*** (see Figure 3.3).

## Vocoders

• IS-95 vocoder produces frames that are 20 ms.

• *Linear-predictive coding* (LPC) is widely used to estimate filter coefficients for *T(Z)*

***1/T(z)*** *- filter modelling the vocal tract*

***E(z)*** *- excitation signal*

• *In IS-95 CDMA system above parameters and coefficients are the information that is communicated between the transmitter and receiver.*

*S(z) - speech signal*

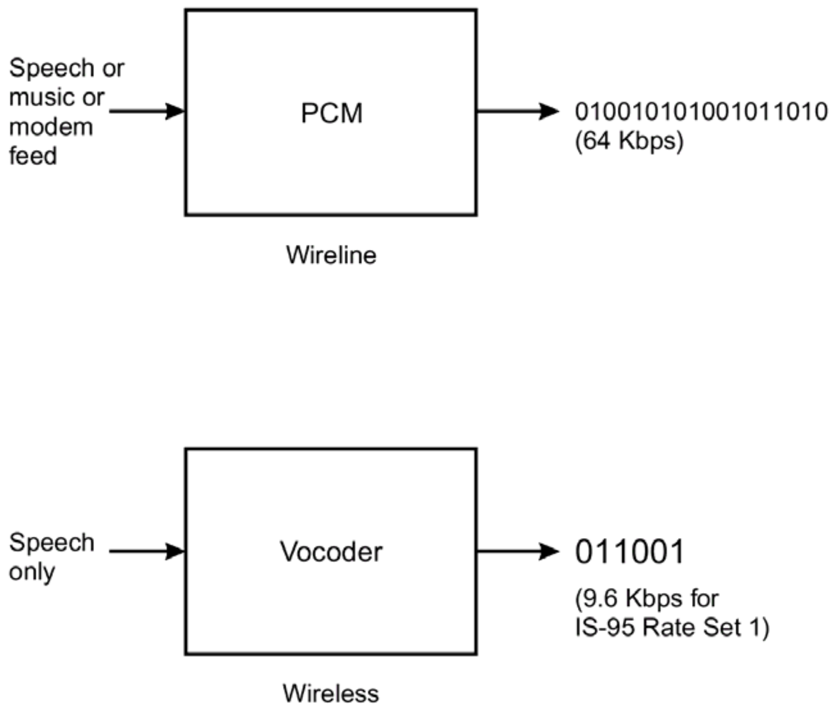



**Figure 3.3** Motivation for using vocoders in wireless applications.

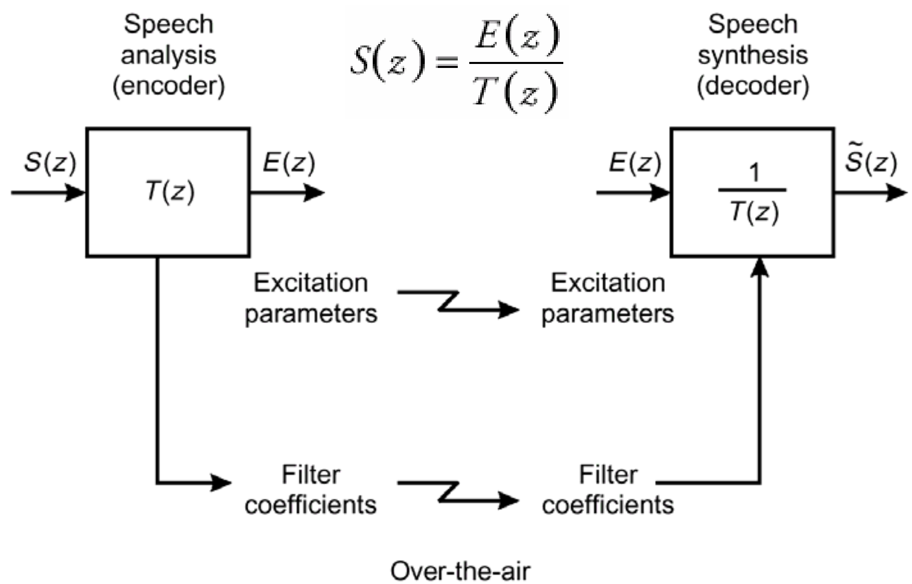



**Figure 3.5** Process of replicating human speech.

## 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

### Channel Coding

• The goal of channel coding is, given a desired probability of error, to reduce the required $E_b/N_0$, or alternatively, given an achievable $E_b/N_0$, to reduce the probability of error. The cost of this goal is more bandwidth, or more redundant bits that the system has to transmit.

• There are two major classes of error-correcting codes:
1) ***block codes*** - code an information sequence one block at a time,
2) ***convolutional codes*** - have a memory property.

### Linear Block Codes

• A linear block code can be characterized by the (n, k) notation, and for a given code, the encoder transforms a block of ***k*** information bits into a longer block of ***n*** code bits.

• *IS-95 CDMA uses block coding to indicate the quality of each transmitted frame* (which contains a block of information bits). The IS-95 system uses *cyclic redundancy check* (CRC), which is one of the most common block codes.

### Convolutional Codes

• The convolutional codes do have memory and in addition to using CRC, IS-95 CDMA uses *convolutional* coding to further improve the error performance. For convolutional codes, the encoded bits are functions of information bits and functions of the constraint length. ***Specifically, every encoded bit (at the output of the convolutional encoder) is a linear combination of some previous information bits***.

### Interleaving

• Most error-correcting codes perform well in correcting random errors.

• *Interleaving is a technique for randomizing the bits in a message stream so that burst errors introduced by the channel can be converted to random errors*.

## 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

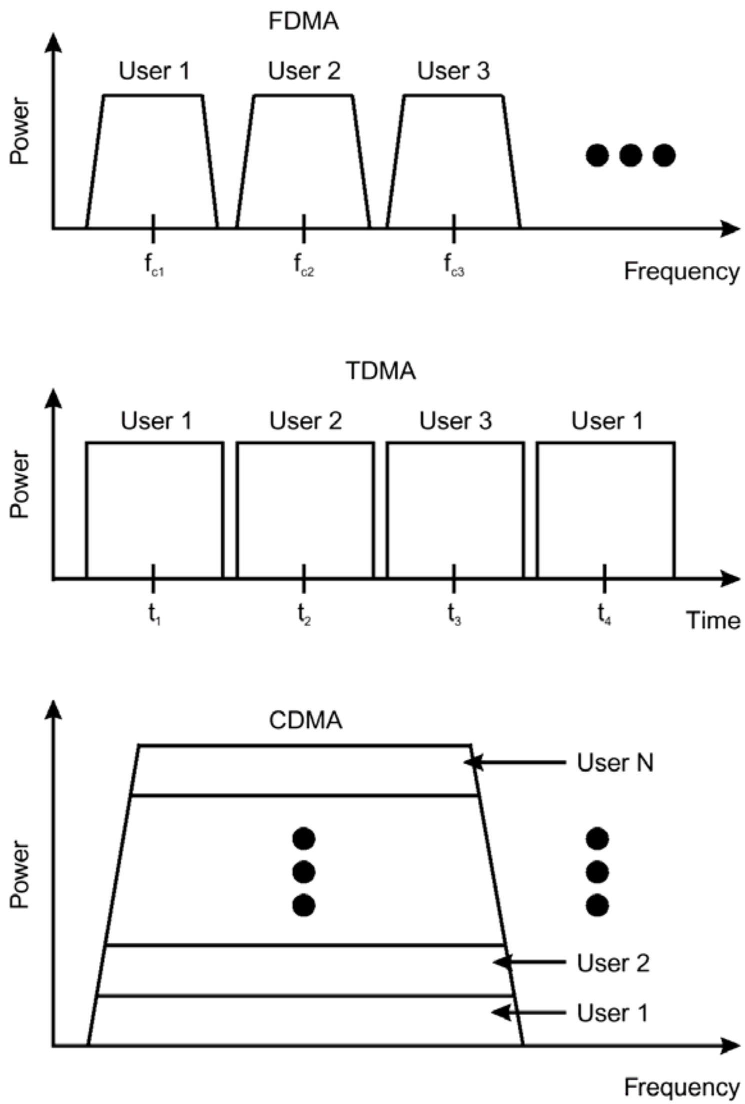



**Figure 3.9** Different multiple-access schemes.

### Multiple Access

• *Multiple access refers to the sharing of a common resource in order to allow simultaneous communications by multiple users, and this common resource is the RF spectrum*.

**The IS-95 CDMA system has asymmetric links:**

• ***the forward link uses Walsh codes***,

• ***the reverse link uses pseudorandom noise (PN) codes***

(for channelization).

# 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

## Walsh Codes

• Walsh codes as used in IS-95 are a set of 64 binary orthogonal sequences and they are generated by using the *Hadamard matrix*.

$$H_{2N} = \begin{bmatrix} H_N & H_N \\ H_N & \overline{H}_N \end{bmatrix}$$

$$H_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

$$H_4 = \begin{bmatrix} H_2 & H_2 \\ H_2 & \overline{H}_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

• $\overline{H}_N$ (complex) contains the same but inverted elements of $H_N$.

• The IS-95 forward link uses a set of 64 orthogonal Walsh sequences.

## PN Codes

• The incoherent nature of the reverse link calls for the use of another class of codes, ***PN codes***, for channelization having a length of *$2^{42}$ – 1 chips* and is generated using a 42-stage register.

• *The forward link uses also the short PN code (having a length of $2^{15}$ – 1 chips) that is superimposed on top of the Walsh code to provide isolation among the different base stations (or sectors).*

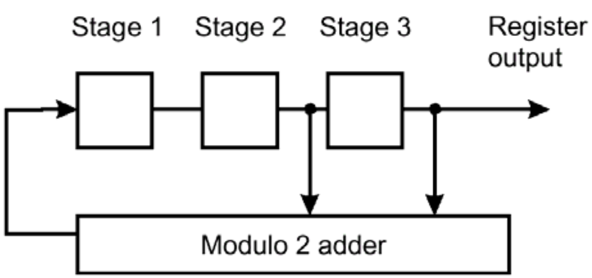



**Figure 3.10** An example of linear feedback shift register for PN code generation.

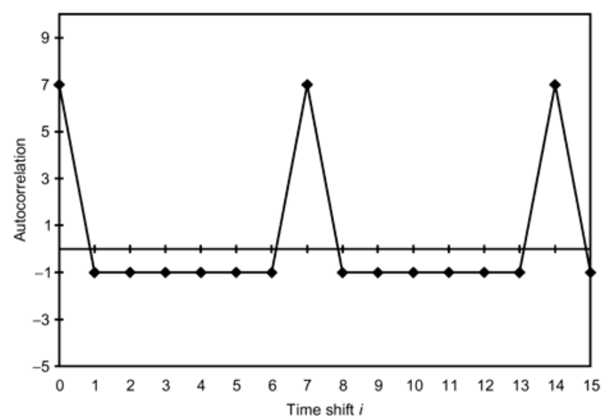



**Figure 3.11** Autocorrelation function of PN sequence $\mathbf{p}_0$.

The **discrette time Autocorrelation** help the mobile to aquire unmodulated pilot channel !

## 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

### Modulation

• Why modulation? - If one wishes to transmit a baseband signal at 9.6 kHz, the antenna size would be 31.25 km!

### Binary Phase-Shift Keying (BPSK)

*Modulator*

• Whenever the transmitter wants to send a +1, it will transmit a positive cosinusoid; whenever the transmitter wants to send a -1, it will transmit a negative cosinusoid.

$$+1: s_{+1}(t) = \sqrt{\frac{2E}{T}}\cos(2\pi f t) \qquad 0 < t < T \qquad (3.10)$$

$$-1: s_{-1}(t) = \sqrt{\frac{2E}{T}}\cos(2\pi f t + \pi) = -\sqrt{\frac{2E}{T}}\cos(2\pi f t) \qquad 0 < t < T \qquad (3.11)$$

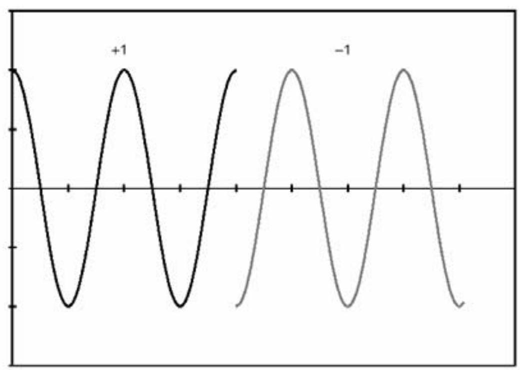



**Figure 3.12** Modulated signal in the time domain using BPSK.

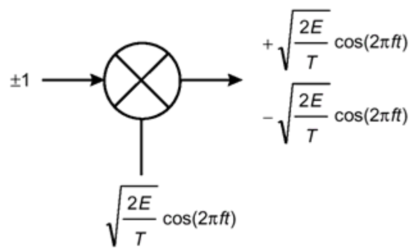



**Figure 3.13** BPSK modulator.

*Demodulator*

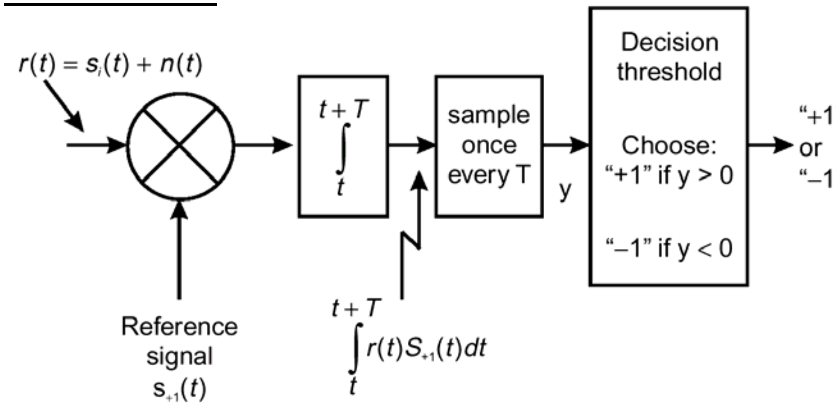



**Figure 3.14** Correlator demodulator for BPSK.

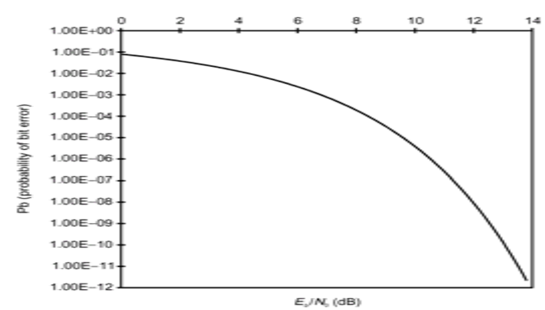



**Figure 3.17** Bit error performance of a coherent BPSK system.

Probability of bit error versus $E_b/N_0$

# 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

## Quadrature Phase-Shift Keying (QPSK)

• QPSK makes use of the quadrature component in addition to the in-phase component transmit two bits of information per symbol period.

*Modulator*

• In order to send two bits of information, the QPSK system needs to use four symbols: symbols 0, 1, 2, and 3.

**Table 3.4**
Mapping Between Transmitted Symbols and Represented Bits

| Transmitted Symbol | Represented Bits |
|---|---|
| 0 | +1, +1 |
| 1 | −1, +1 |
| 2 | −1, −1 |
| 3 | +1, −1 |

*• The even bit stream is multiplied by the in-phase carrier, and the odd bit stream is multiplied by the quadrature carrier*

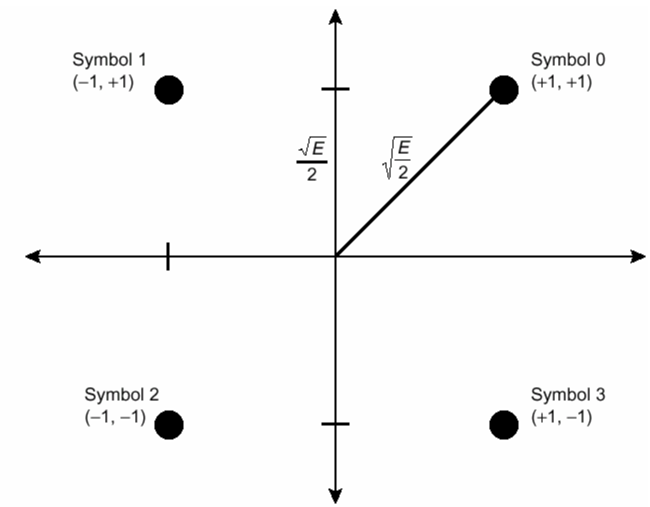



**Figure 3.18** Signal-space representation of a QPSK constellation.

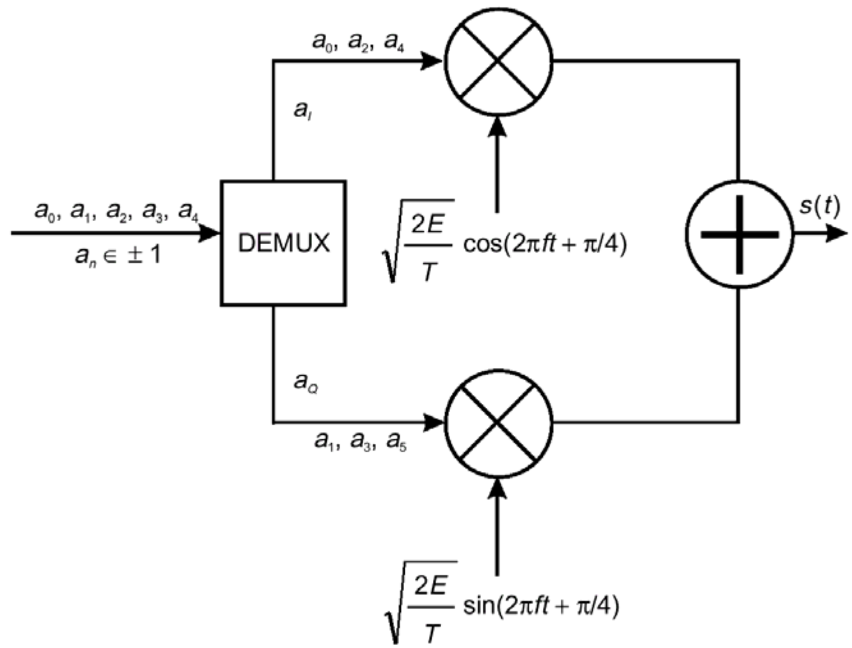



**Figure 3.19** QPSK modulator.

# 3 FUNDAMENTALS OF DIGITAL RF COMMUNICATION

## Quadrature Phase-Shift Keying (QPSK)

• *Note that BPSK and QPSK have the same probability of bit error as a function of $E_b/N_0$* (!)

• The IS-95 CDMA system uses ***offset quadrature phase-shift keying (OQPSK) for reverse link*** to avoid a 180-degree phase transition that occurs in conventional QPSK systems.

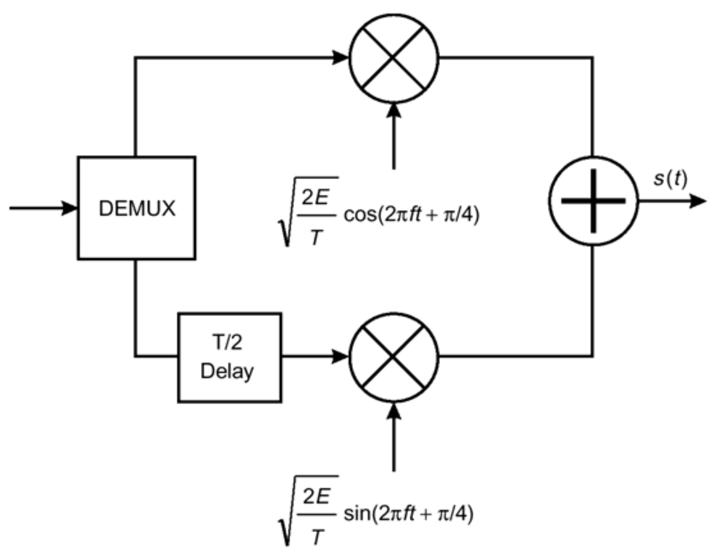



**Figure 3.22** OQPSK modulator.

*Demodulator*

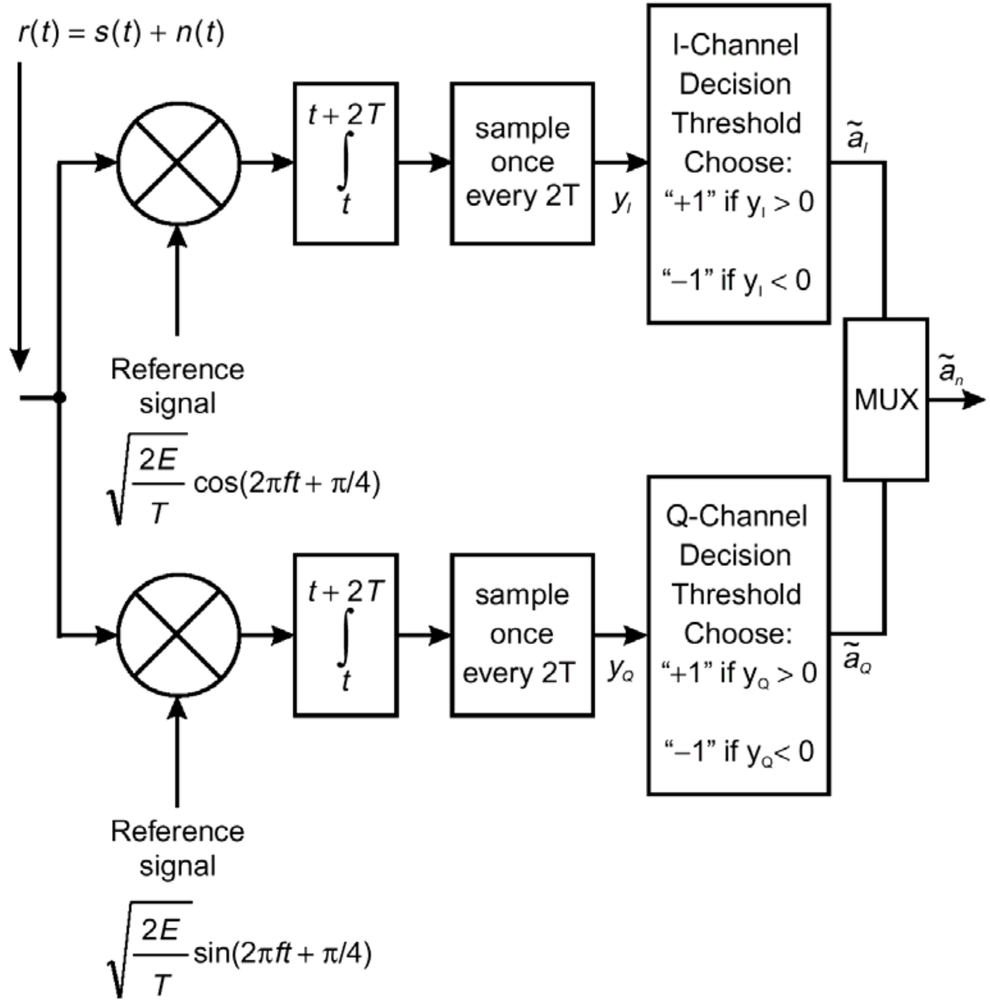



**Figure 3.20** Correlator demodulator for QPSK.

# 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

## Introduction

***Capacity*** is defined as the total number of simultaneous users the system can support
***Quality*** is defined as the perceived condition of a radio link assigned to a particular user ~ bit error rate (BER).

- *CDMA system that need to be optimized in order to reduce interference and increase quality.*

## Capacity

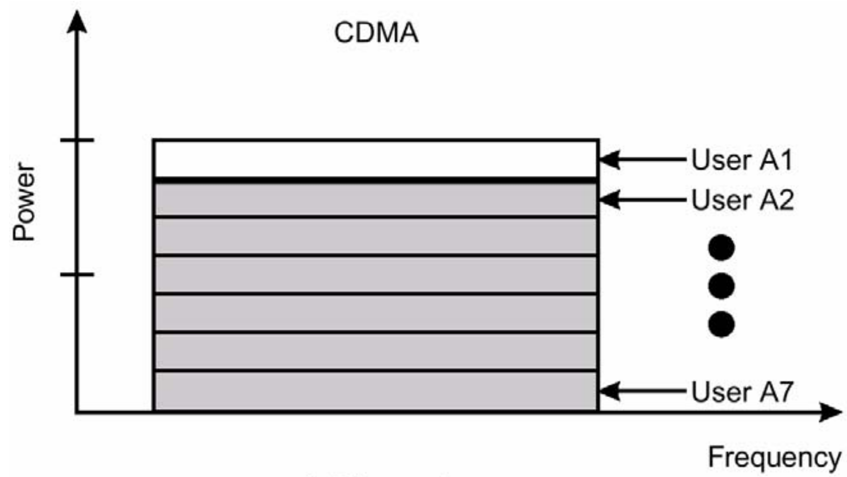
- CDMA system capacity is presented using the amount of user interference in the band.
- We are primarily interested in a link metric called $E_b/N_0$, or ***energy per bit per noise power density***.

$$E_b = ST$$

$$\frac{E_b}{N_0} = \frac{S}{N}\frac{W}{R}$$

S - average modulating signal power
R- bit rate
W – bandwidth of signal
N – total power noise

$$\frac{S}{N} = \frac{1}{M-1}$$




***The capacity M is:***

$$\frac{E_b}{N_0} = \frac{1}{(M-1)}\frac{W}{R}$$

$$M - 1 = \frac{(W/R)}{(E_b/N_0)}$$

Note that the ratio **W/R** is also known as the ***processing gain of the system***.

$$\left(\frac{S}{N}\right)_{A1} = \frac{1}{6}$$

**4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS**

**Effects of Loading**

• *Cell A is said to be loaded by users from other cells.*

$$\frac{E_b}{N_0} = \frac{1}{(M-1)} \frac{W}{R} \left( \frac{1}{1+\eta} \right)$$

Where $\eta$ is the loading factor (between 0% and 100%)

• Frequency reuse factor F is defined as:

$$F = \frac{1}{(1+\eta)}$$

(ideally F = 1)

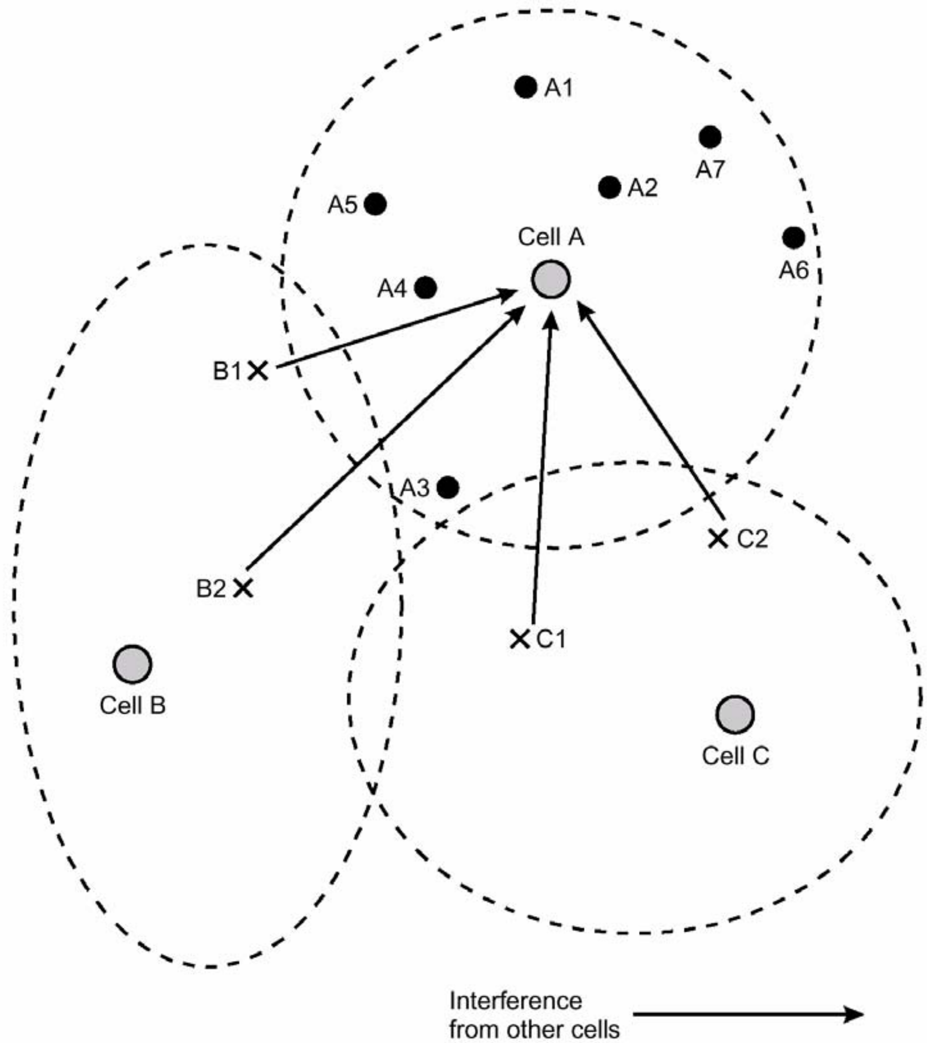



**Figure 4.2** Interference introduced by users in the neighboring cell.

## 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

### Effects of Sectorization

• *A sectorized antenna rejects interference from users that are not within its antenna pattern.*

$$\frac{E_b}{N_0} = \frac{1}{(M-1)}\frac{W}{R}\left(\frac{1}{1+\eta}\right)\lambda$$

where $\lambda$ is the sectorisation gain:

$$\lambda = \frac{\int_0^{2\pi} I(\theta)d\theta}{\int_0^{2\pi}\left(\frac{G(\theta)}{G(0)}\right)I(\theta)d\theta}$$

where:

• $G(\theta)$ is the horizontal antenna pattern of the sector antenna;

• $G(0)$ is the peak antenna gain,

• $I(\theta)$ is the received interference power from users of other cells as a function of $\theta$.

*Typically:*

$\lambda$ = 2.5 for three-sector configured systems,

$\lambda$ = 5 for six-sector configured systems.

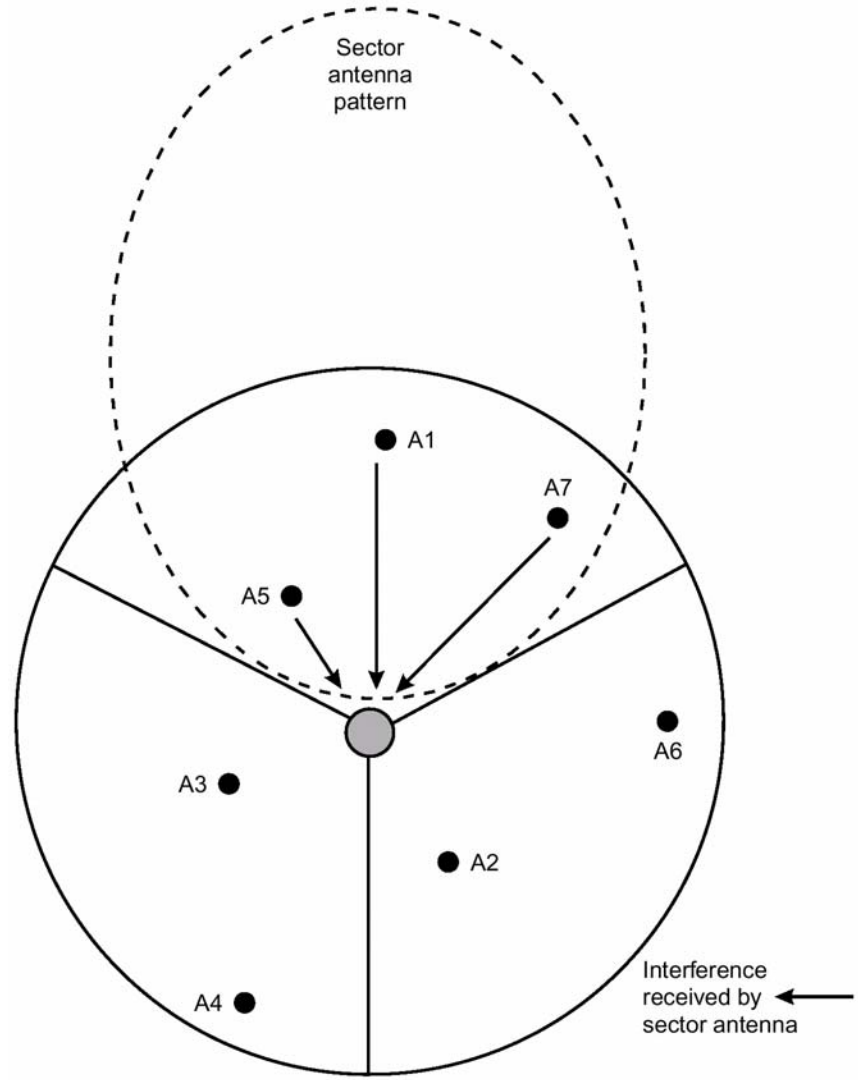



**Figure 4.4** A sectorized antenna rejects interference from users not in its antenna pattern.

**4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS**

## Effects of Voice Activity

• Speech statistics shows that a user in a conversation typically speaks between 40% and 50% of the time. By employing variable-rate vocoding, the system reduces the total interference power by this *voice activity factor v*.

$$\frac{E_b}{N_0} = \frac{1}{(M-1)}\frac{W}{R}\left(\frac{1}{1+\eta}\right)\lambda\left(\frac{1}{v}\right)$$

*where v is voice activity factor*.

The capacity M is:

$$M = 1 + \frac{(W/R)}{(E_b/N_0)}\left(\frac{1}{1+\eta}\right)\lambda\left(\frac{1}{v}\right)$$

***Several conclusions regarding CDMA capacity:***

**1.** Capacity, or number of simultaneous users M, is directly proportional to the processing gain of the system.

**2.** The link requires a particular $E_{b/}N_0$ to attain an acceptable BER and ultimately an acceptable frame error rate (FER). Capacity is inversely proportional to the required $E_b/N_0$ of the link. The lower the required threshold $E_b/N_0$, the higher the system capacity.

**3.** Capacity can be increased if one can decrease the amount of loading from users in adjacent cells.

**4.** Spatial filtering, such as sectorization, increases system capacity. For example, a six-sector cell would have more capacity than a three-sector cell.

# 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

## Power Control

Why Power Control?

• *Power control* is implemented to overcome the near-far problem and to maximize capacity.

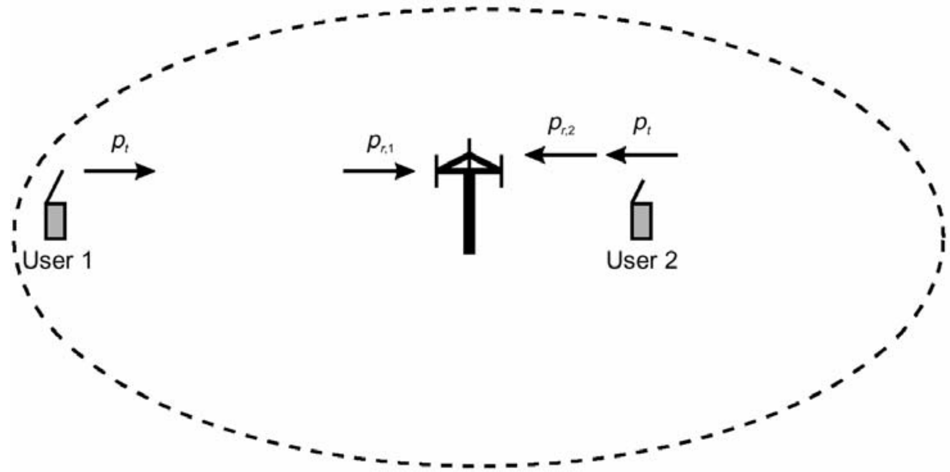



**Figure 4.5** A base station with two hypothetical users. Each user is transmitting to the base station a fixed amount of power $p_t$.

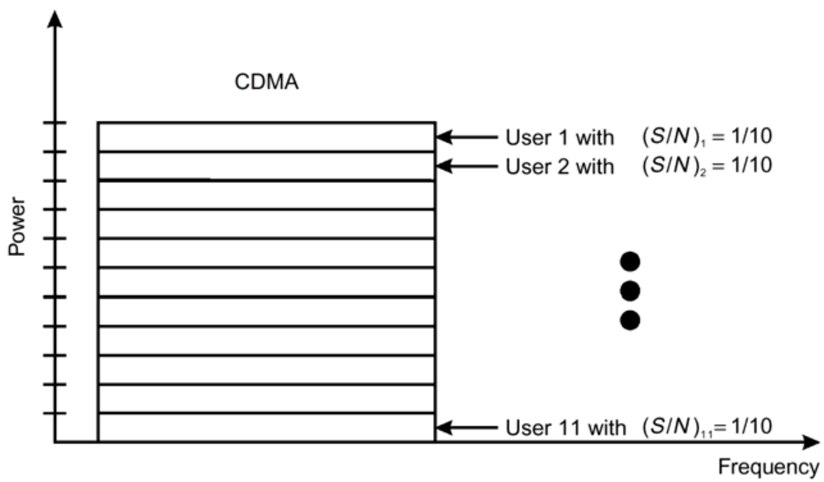



**Figure 4.8** Capacity is maximized when the received powers of all users are equal at the base station.

***Near-far*** problem

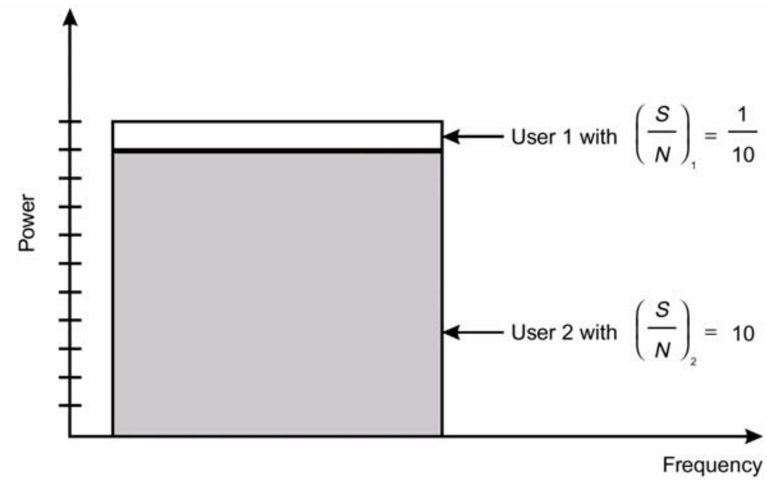



**Figure 4.6** Received power from the two users at the base station. User 2 has a much higher SNR than user 1 does.

# 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

## Reverse link

$$p_{t,\text{initial}} = -p_r - 73 + NOM\_PWR + INIT\_PWR$$

- ***Open Loop*** - only mobile controlled operation

$$p_t = -p_r - 73 + NOM\_PWR + INIT\_PWR + (\text{sum of all access probe corrections})$$

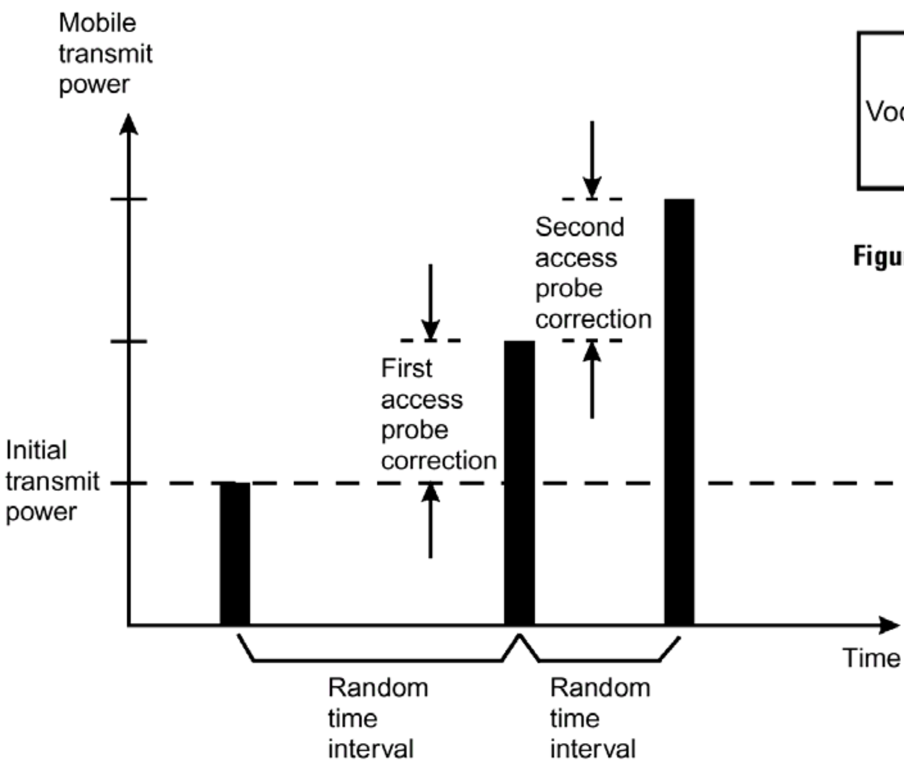



**Figure 4.9** A series of access probes by the mobile to access the system.

- ***Closed Loop*** - to compensate for power fluctuations due to fast Rayleigh fading and involved both mobile and base station

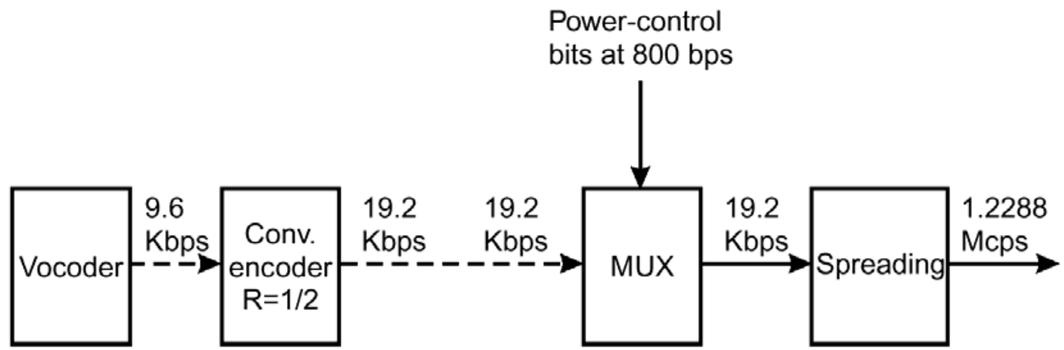
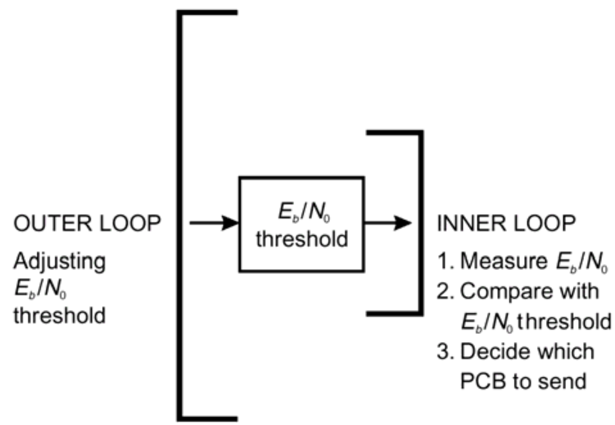



**Figure 4.10** In the forward traffic channel, the PCBs at 800 bps are multiplexed directly onto the baseband information stream at 19.2 Kbps.




***To maintain an acceptable FER means evaluate continuously $E_b/N_0$***

**Figure 4.13** Inner and outer loops of the closed-loop power control.

## 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

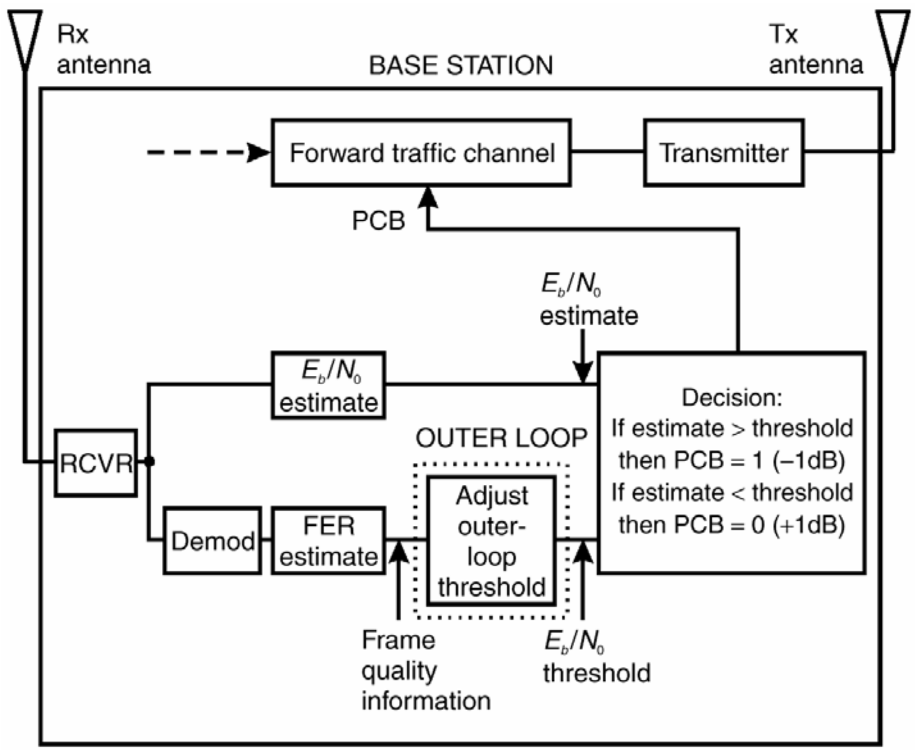
**Power Control - *Forward link***

• The mobile continuously monitors the FER of the forward link, and it reports this FER back to the base station in a message called the ***power measurement report message*** (PMRM).

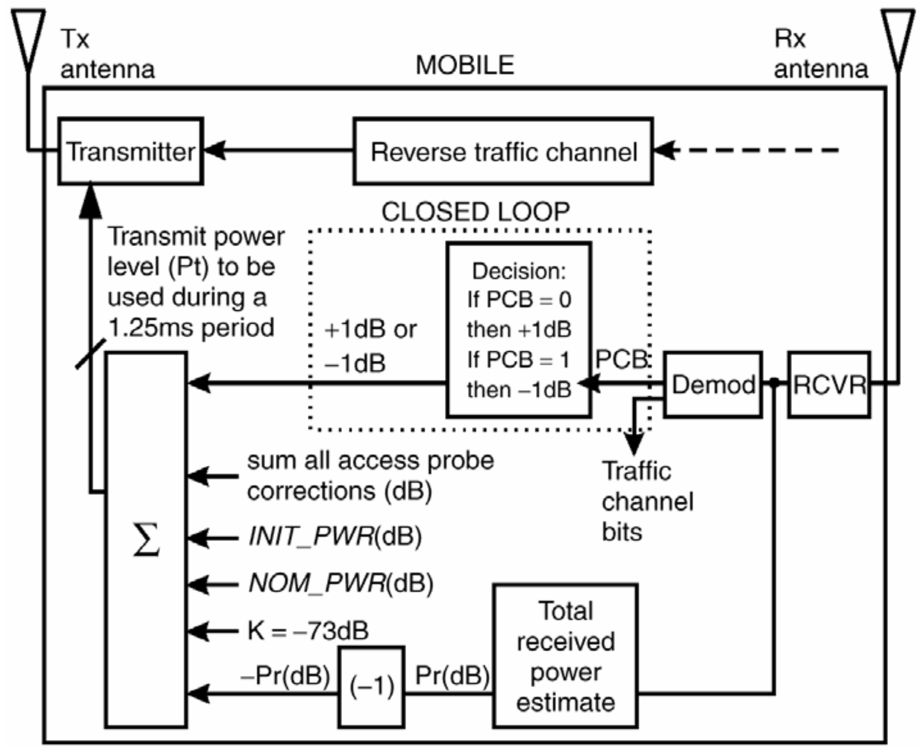
• The base station, knowing the quality of the forward link, may then adjust its transmit power to that particular mobile.

***Open Loop*** -and ***Closed Loop Implementation***

$$p_t = -p_r - 73 + NOM\_PWR + INIT\_PWR + (\text{sum of all access probe corrections}) + (\text{closed - loop correction})$$




(a) Reverse-link power-control functions carried out by the base station.




(b) Reverse-link power-control functions carried out by the mobile.

## 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

### Handoff

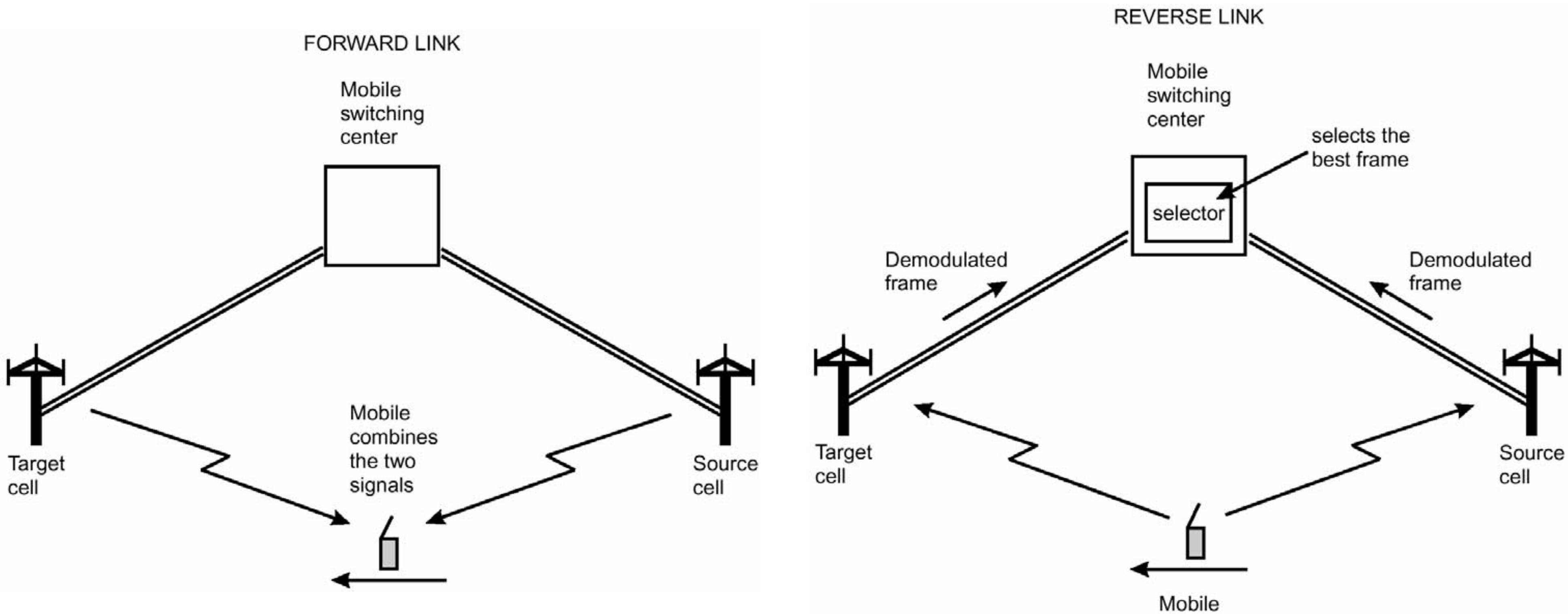
***1) Soft Handoff*** - CDMA uses soft handoff where, during handoff, ***a mobile simultaneously maintains connection with two or three base stations***. As the mobile moves from its current cell (source cell) to the next cell (target cell), *a traffic channel connection is simultaneously maintained with both cells* (for ex. see figures below).

***2) Softer Handoff*** - This type occurs when a mobile transitions between two different sectors of the same cell.

***3) Hard Handoff*** - two types:

a) ***CDMA-to-CDMA*** handoff (D-to-D handoff ) occurs when the mobile is transitioning between two CDMA carriers (i.e., two spread-spectrum channels that are centered at different frequencies).

b) ***CDMA-to-analog*** handoff (D-to-A handoff) occurs when a CDMA call is handed down to an analog network.



## 4 PRINCIPLES OF CODE DIVISION MULTIPLE ACCESS

### Handoff Process

• In managing the handoff process, the mobile maintains in its memory ***four exclusive lists*** of base station sectors. The sectors are stored in the form of pilot PN offsets of those sectors.

1) ***Active (A) set*** contains the pilots of those sectors that are actively communicating with the mobile on traffic channels.

2) ***Candidate set*** set contains those pilots whose $E_c/I_0$ are sufficient to make them handoff candidates.

3) ***Neighbor (N) set*** contains those pilots that are in the *neighbor list* of the mobile's current serving sector.

4) ***Remaining (R) set*** contains all possible pilots in the system for this CDMA carrier frequency, excluding pilots that are in active, candidate, and neighbor sets.

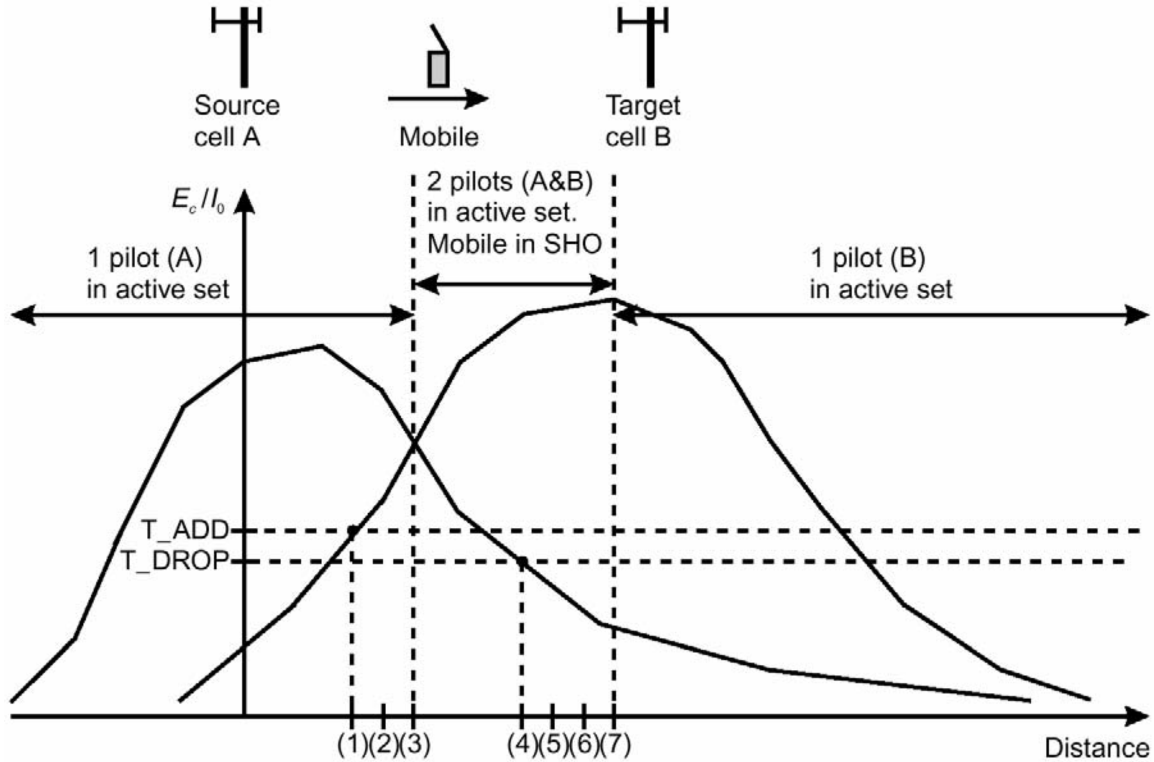



**Figure 4.18** The handoff process.

**Note:**

• To avoid limitation causing by multipaths components, **search windows** are provided to search for pilots that are in the active, candidate, neighbor, and remaining windows (parameters **SRCH_WIN_A**, **SRCH_WIN_N** and **SRCH_WIN_R** that defines the search-window width used to search for pilots in the corresponding sets).

# 5 LINK STRUCTURE

## Asymmetric Links

• The ***forward link*** consists of four types of logical channels: **pilot**, **sync**, **paging**, and **traffic** channels.

• The ***reverse link*** consists of two types of logical channels: **access** and **traffic** channels

## Forward link

### Pilot Channel

• The pilot channel is effectively the PN sequence itself.

• The PN sequence with a specified offset uniquely identifies the particular sector that is transmitting the pilot signal.

• The pilot channel is transmitted continuously by the base station sector. The pilot channel provides the mobile with timing and phase reference.

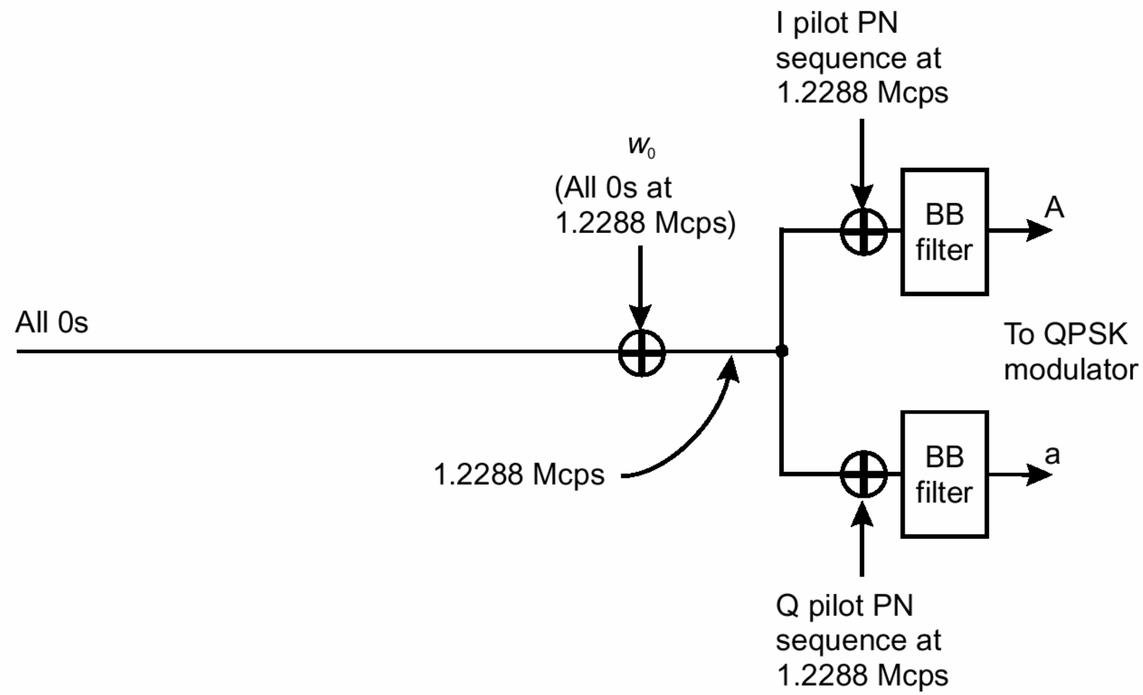


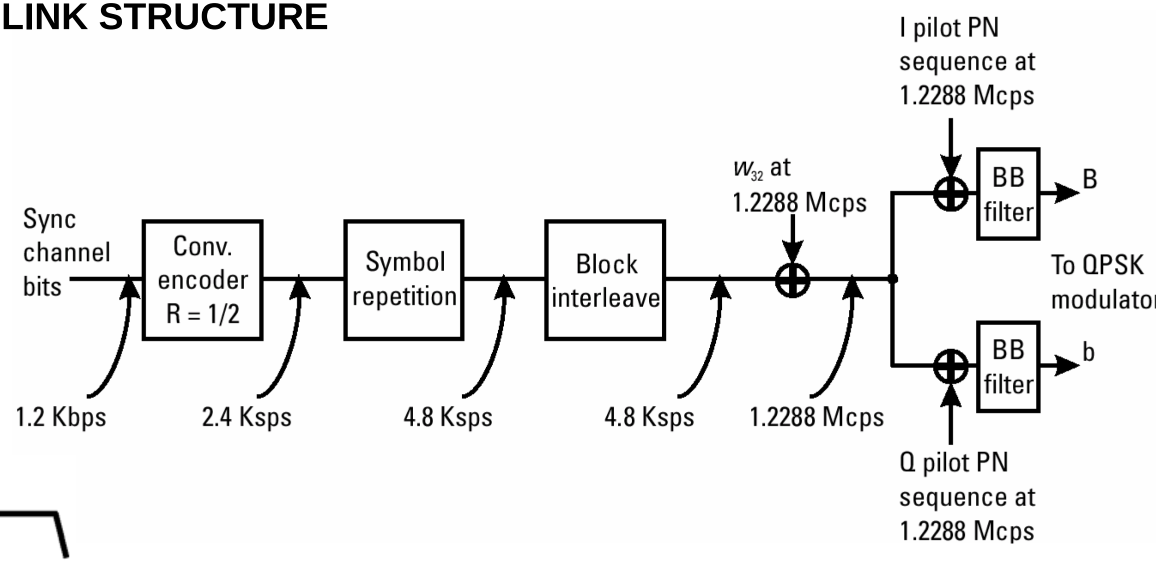

**Figure 5.1** Pilot channel.

# 5 LINK STRUCTURE

## Forward Link

**Sync Channel** - carries baseband information.

- The information is contained in the ***sync channel message*** that notifies the mobile of important information about system synchronization and parameters (offset PILOT_PN, + information that help mobile to syncronize with long PN sequence)



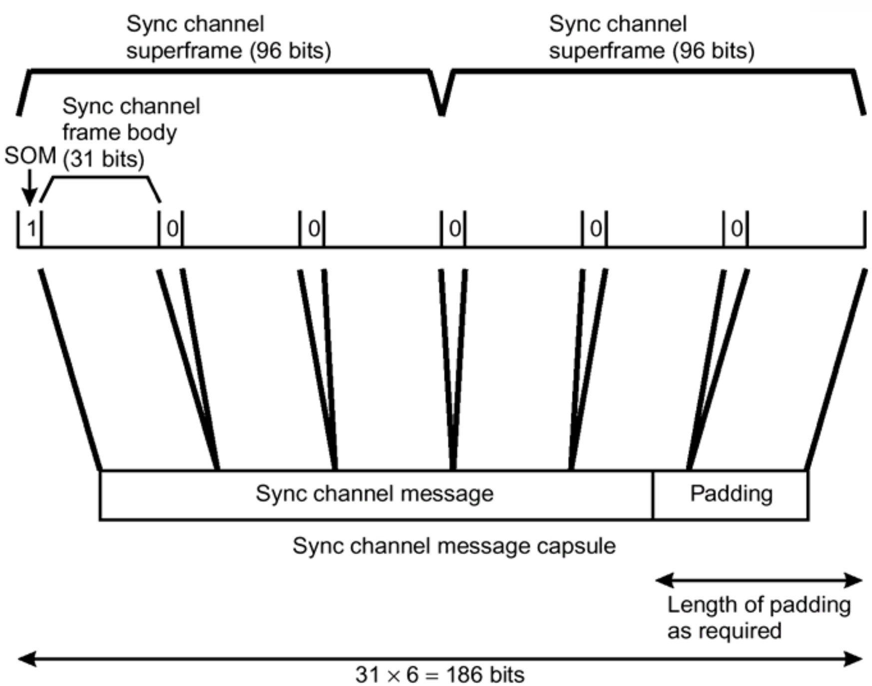




**Figure 5.4** Sync channel message structure for a hypothetical message that occupies two consecutive superframes.

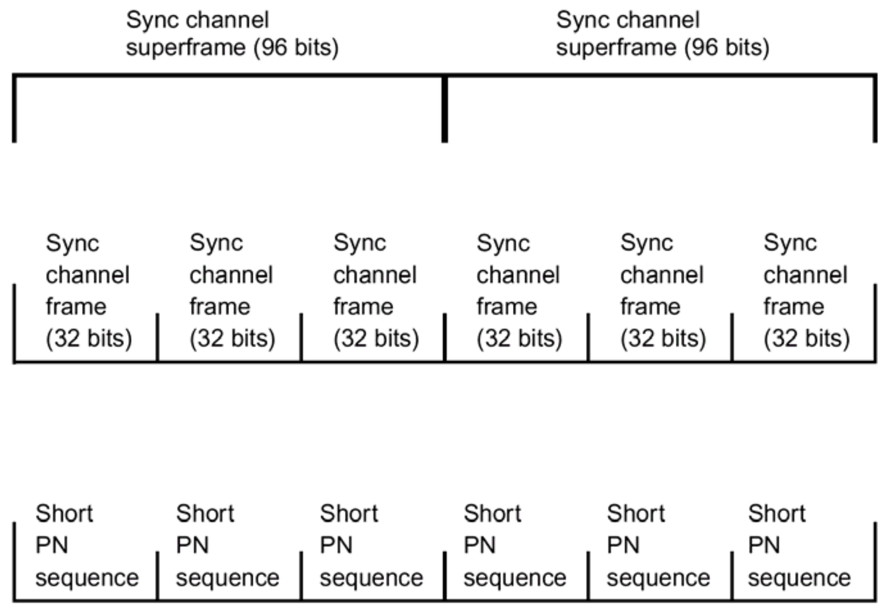



**Figure 5.3** Sync channel frame structure.

# 5 LINK STRUCTURE

## Forward Link

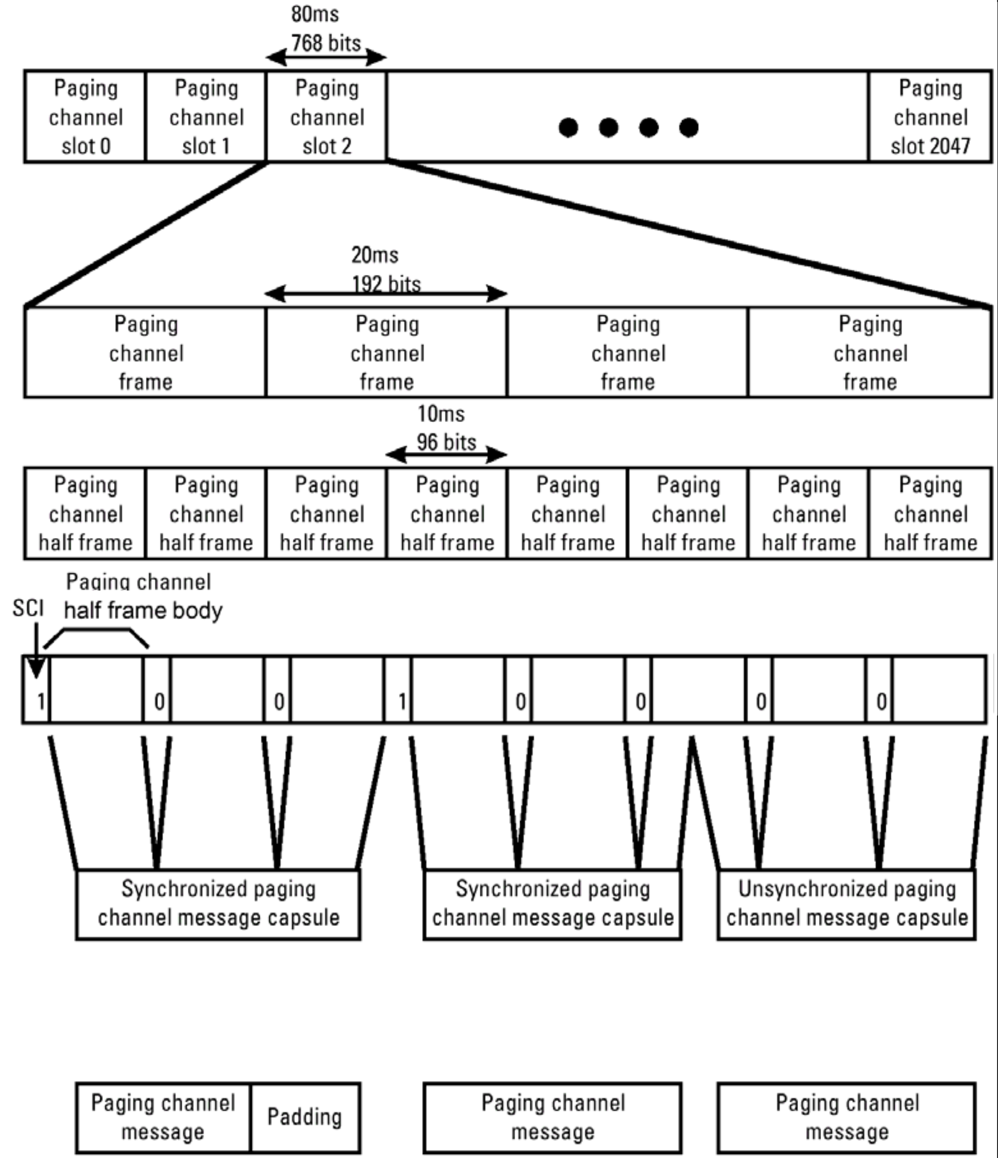
**Paging Channel** - carries baseband information.

• *Although there can be up to seven paging channels per sector, each mobile only monitors one paging channel*

• *Messages over paging channel:*

1) ***overhead*** - notify to mobile the system configuration

2) ***paging*** - may contain a page to one or group of mobiles



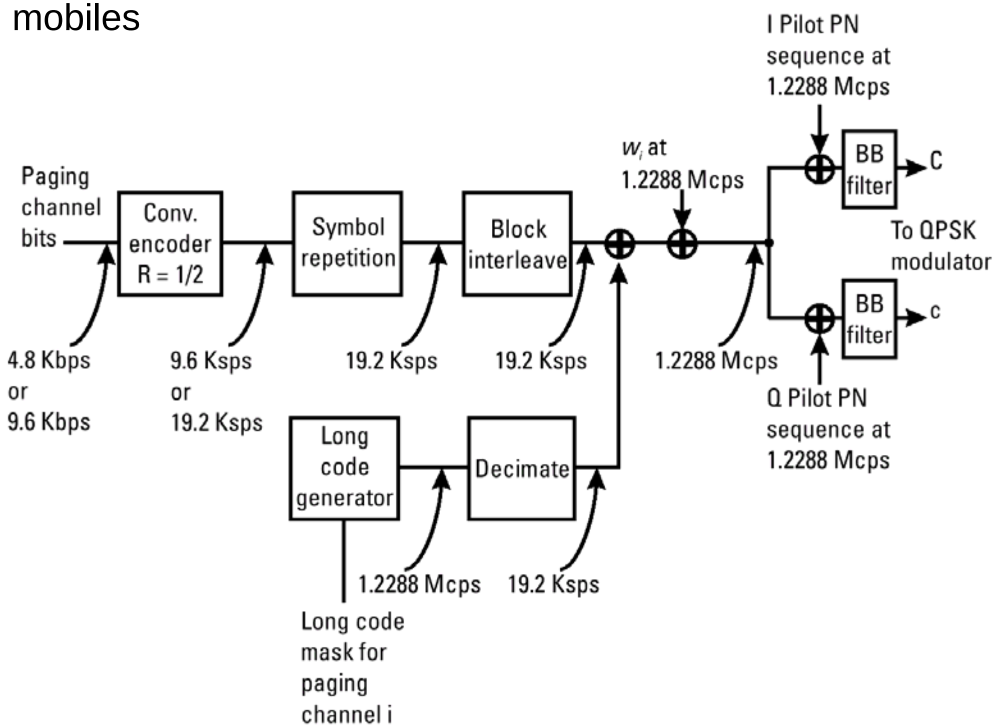




**Figure 5.5** Paging channel.

## 5 LINK STRUCTURE

### Forward Link - Traffic Channel

- Is used to transmit user and data voice; signaling messages are also sent over the traffic channel.
- There are four data rates output of the vocoder: 1.2, 2.4, 4.8 and 9.6Kbps
- The reason for repeating symbols is to reduce overall interference power at a given time when lower rate data are transmitted
- The mask used to produce long PN is a function of the mobile's ESN,

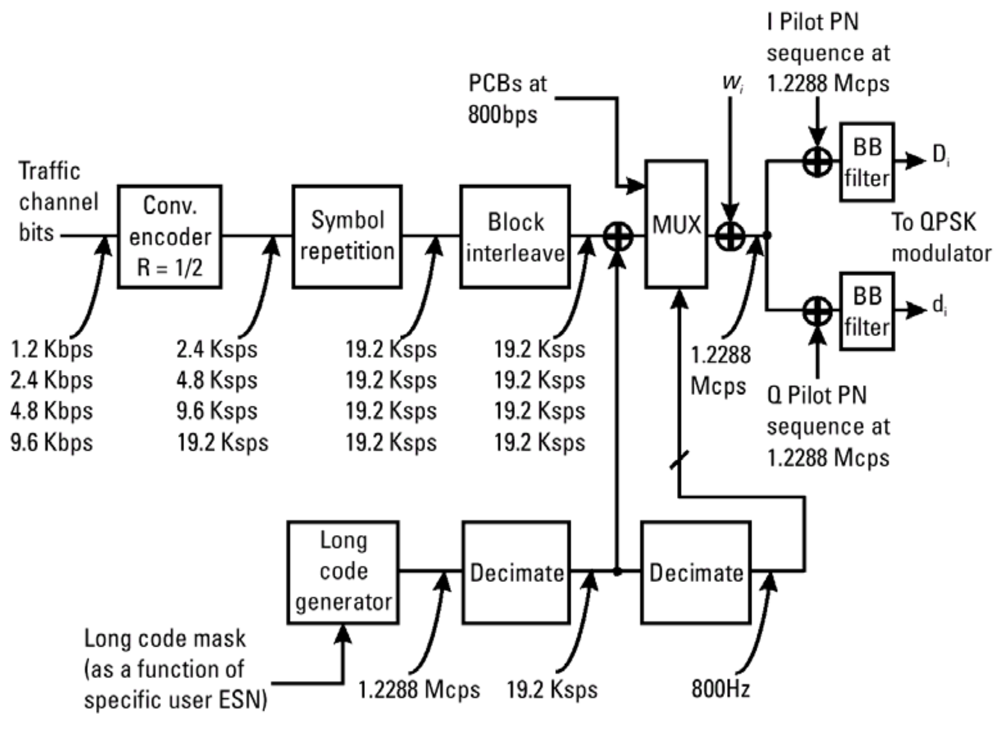



**Figure 5.8** Forward traffic channel for Rate Set 1.

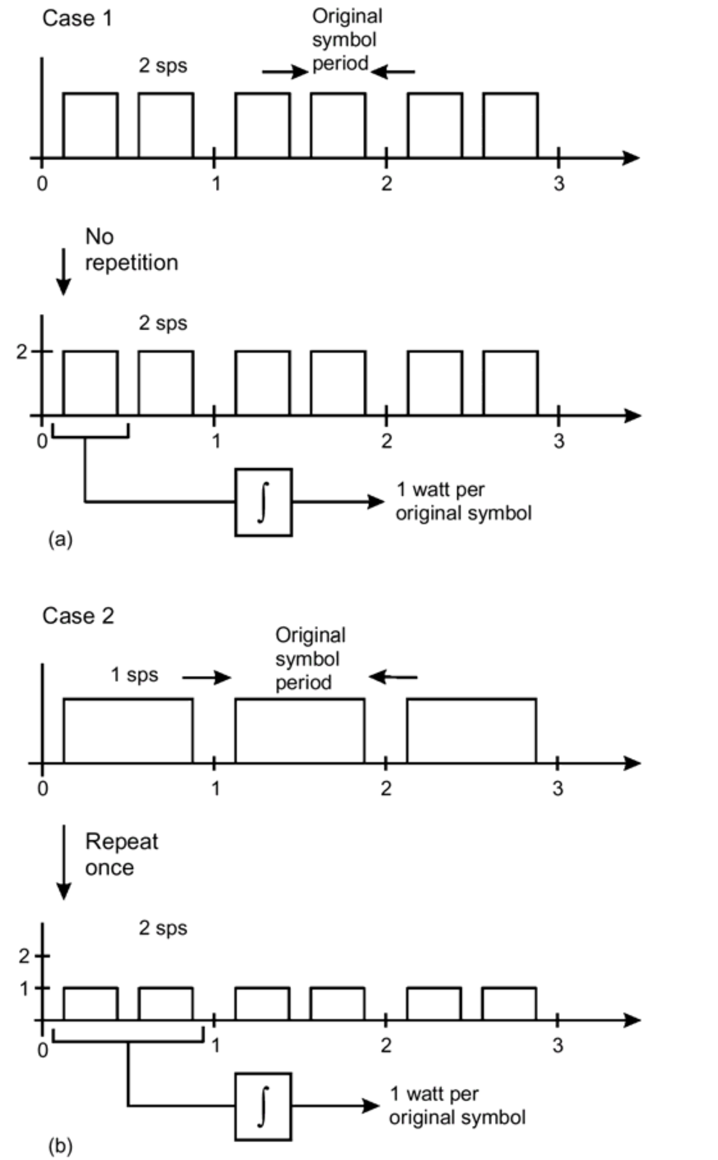



**Figure 5.9** (a) Reduction of power as a result of symbol repetition—Case 1; (b) reduction of power as a result of symbol repetition—Case 2.

# 5 LINK STRUCTURE

## Reverse Link

### Acsess Channel

• Is used by the mobile to communicate with the base station when the mobile doesn't have a traffic channel assigned. The mobile uses this channel ***to make call originations and respond to pages and orders***.

• The set of 64 Walsh functions is used, to modulate, or represent, groups of six symbols (*a group of six binary symbols corresponds to a decimal value between 0 and 63 and the corresponding Walsh is transmitted*)

• Information is transmitted on the access channel in *access channel slots* and *access channel frames*.

• *Messages over access channel:*

1) ***response*** message - in response to a base station message

2) ***request*** message - sent by the mobile station

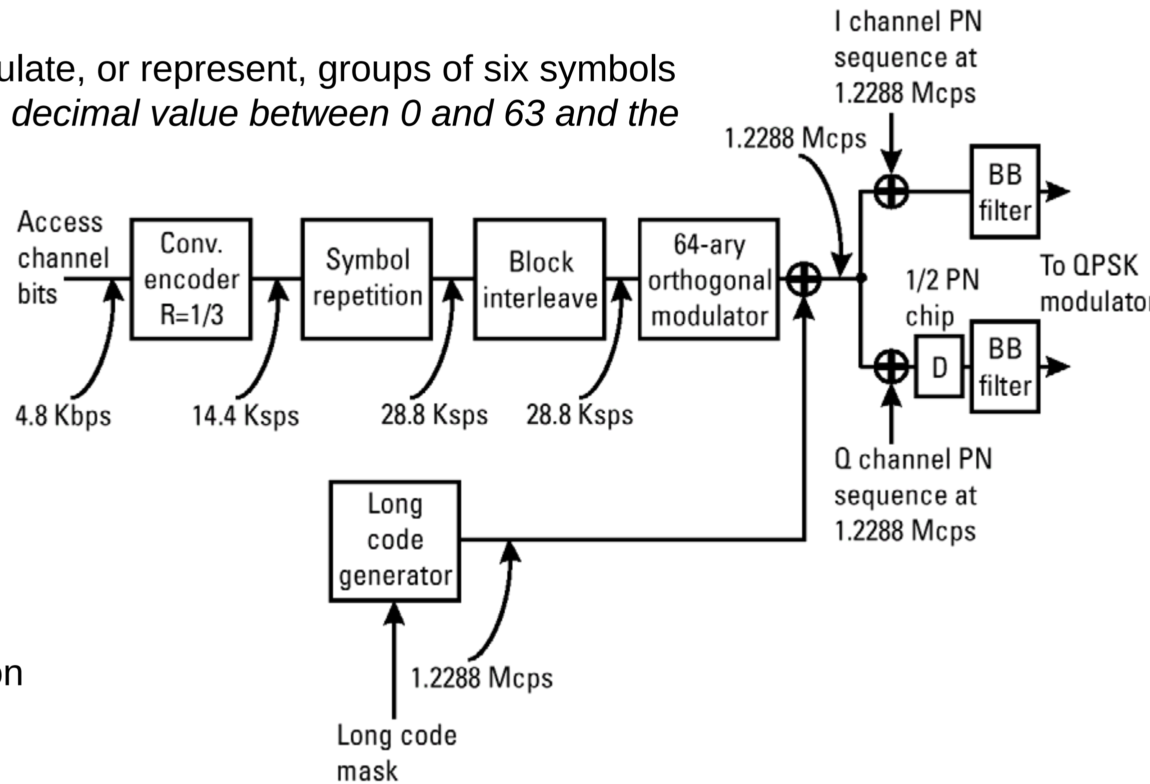



**Figure 5.12** Access channel.

## 5 LINK STRUCTURE

### Reverse Link

### Traffic Channel

• *Is used to transmit user data and voice; signaling messages are also sent over the traffic channel.*

• *The structure of the reverse traffic channel is similar to that of the access channel. The major difference is that the reverse traffic channel contains a data burst randomizer*

• *The function of the data burst randomizer is to take advantage of the voice activity factor on the reverse link*

***Remember!***

1) The reverse link use OQPSK where the data in the Q path is delayed by one half a PN chip (to avoid QPSK signal envelope to colapse to zero.

2) The IS-95 CDMA system uses **Multiplex Option 1** to transmit primary (i.e., voice) and secondary (i.e., data) traffic - but only at full rate.

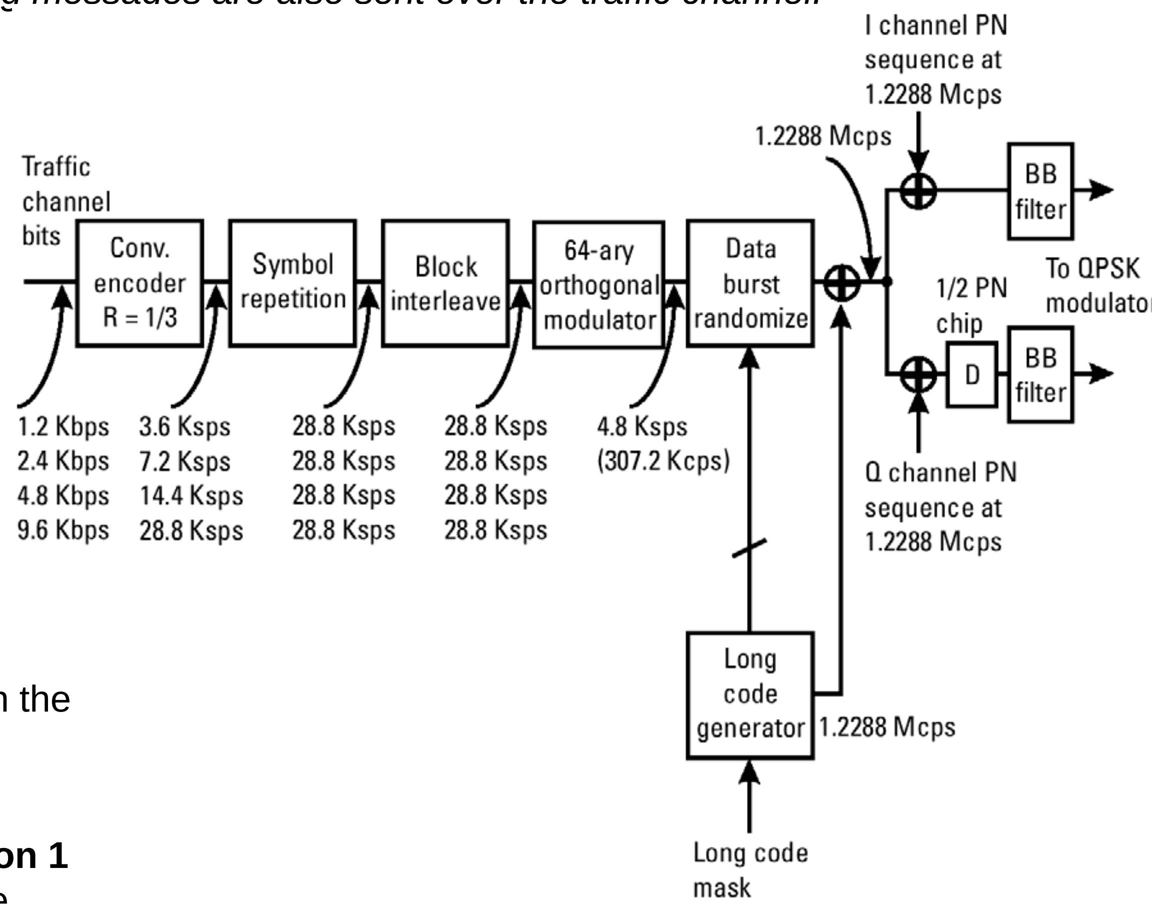



**Figure 5.15** Reverse traffic channel for Rate Set 1.

# 6 CALL PROCESSING

## Call Processing States

### 1. Initialization State

After power-up, the mobile enters the initialization state. This state contains four substates, which the mobile sequentially goes through:

*a. System determination substate;*

*b. Pilot channel acquisition substate;*

*c. Sync channel acquisition substate;*

*d. Timing change substate.*

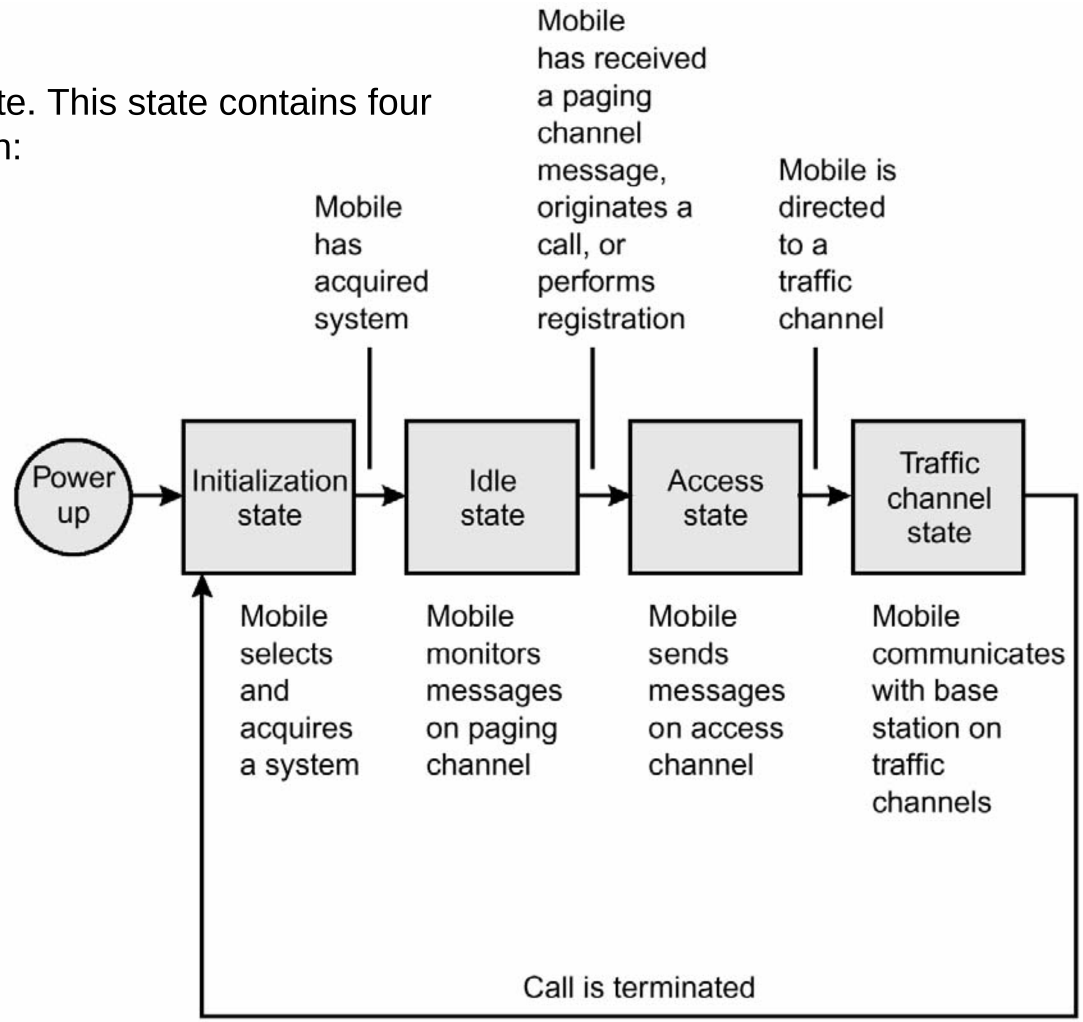



**Figure 6.1** Call processing states of the mobile station.

### 2. Idle State

*<u>a. Paging Channel Monitoring</u>*

In the idle state, the mobile monitors the paging channel on the forward link.

*<u>b. Idle Handoff</u>*

If the mobile detects that the pilot strength from another base station is sufficiently stronger than that of the current base station, then the mobile proceeds to perform an idle handoff.

*<u>c. Paging Channel Messages</u>*

There is a total of six overhead messages that are sent to the mobile on the paging channel.

# 6 CALL PROCESSING

**3. Access State**

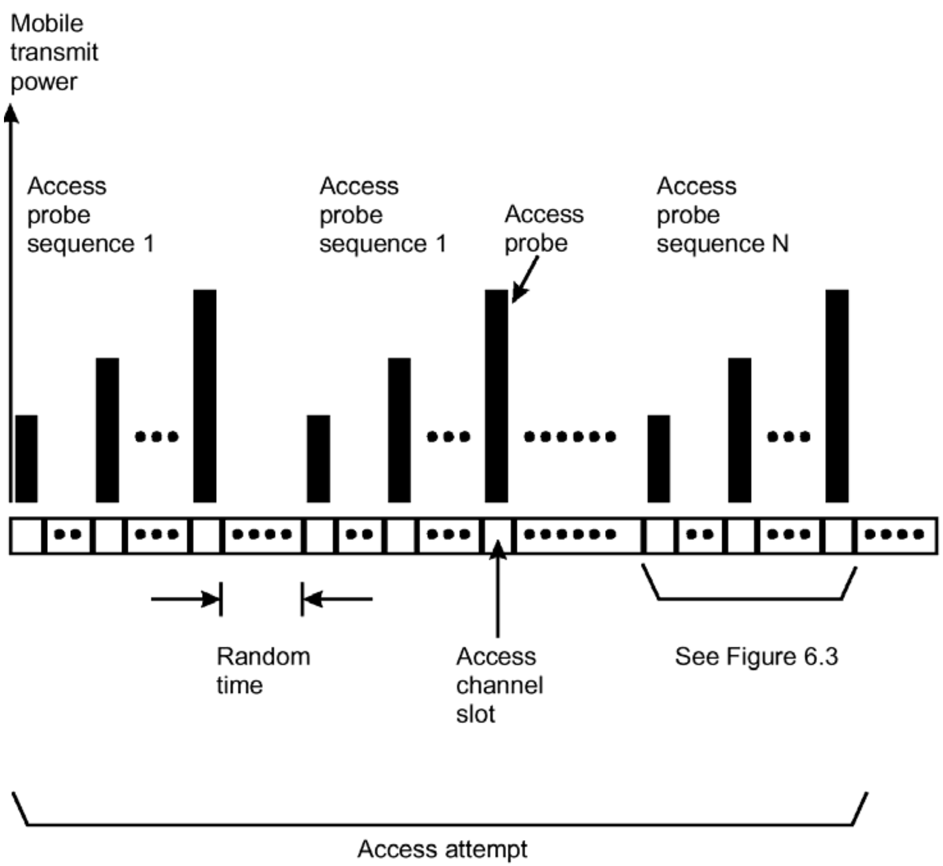
• The mobile transmits messages to the base station using the access channel and in addition, the mobile also receives messages from the base station on the paging channel.

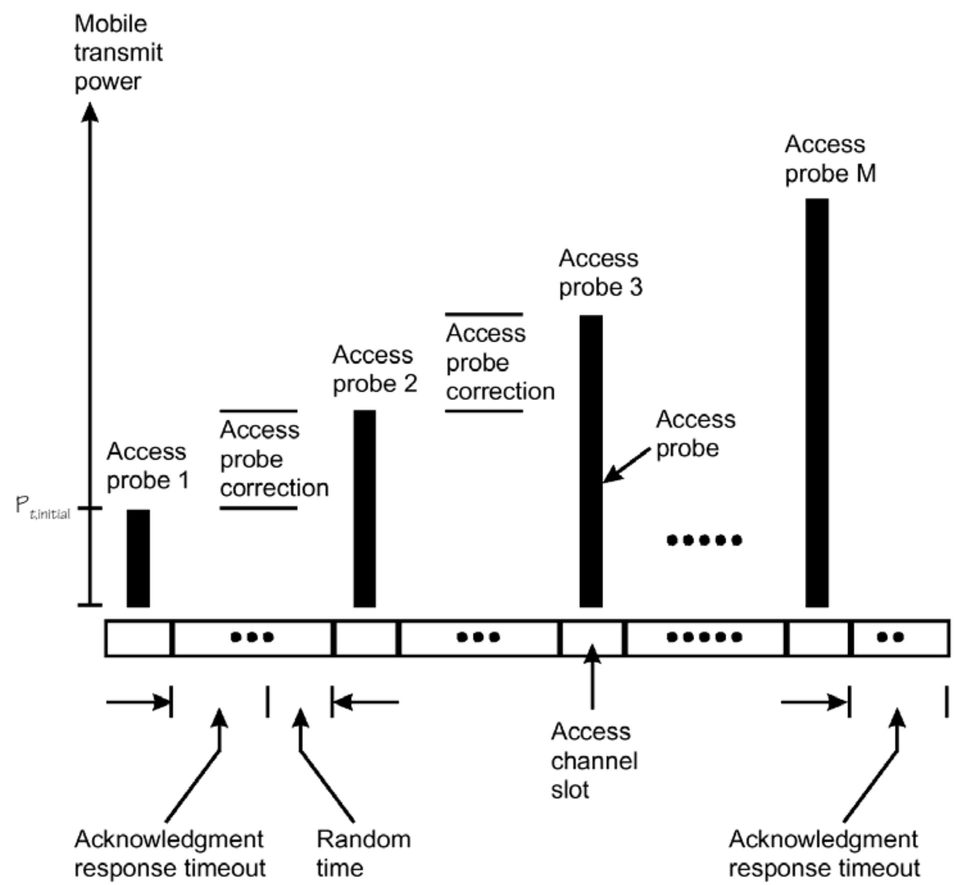
• *Access Procedures* - see figures below

• There are *two types of messages sent on the access channel*: ***a response message*** and ***a request message***.

**4. Traffic Channel State**

• The mobile communicates with the base station using the forward and reverse traffic channels



## 7 CDMA DESIGN ENGINEERING

• Are all the radio parameters adequate to maintain a high-quality radio link between the base station and the mobile?

### Forward Link Analysis: Pilot Channel + Traffic Channel

• The $E_c/I_0$ is the energy per chip per interference density measured on the pilot channel; it is effectively the signal strength of the pilot channel.

• The $E_b/N_0$ translates directly into BER, which has implications on forward-link voice quality

$$\frac{E_c}{I_0} = \frac{\alpha_0 P_0(\theta_0) L_0(\theta_0, d_0) G}{I_h + I_n + I_o + I_m + I_t + N} \qquad \frac{E_b}{N_0} = \frac{T_0(\theta_0) L_0(\theta_0, d_0) G}{I_h + I_n + I_o + I_{m'} + I_t + N}\left(\frac{W}{R}\right)$$

· $P_0(\theta_0)$ = home base station (sector 0) overhead ERP including pilot, paging, and sync powers in the direction $\theta_0$ to the probe mobile.
· $T_0(\theta_0)$ = home base station (sector 0) traffic channel ERP in the direction $\theta_0$ to the probe mobile.
$\alpha_0$ = fraction of home base station overhead ERP allocated to pilot power.
· $L_0(\theta_0,d_0)$ = path loss from home base station in the direction $\theta_0$ to the probe mobile a distance $d_0$ away.
· $G$ = receive antenna gain of probe mobile.
· $I_h$ = power received at the probe mobile from overhead power emitted by home base station.
· $I_n$ = power received at the probe mobile from other interference of non-CDMA origins.
· $N$ = thermal noise power.
· $I_0$ = is the sum of overhead powers from other base stations.
· $I_m$ = power received at the probe mobile from total trafic channel power (from the home base station); $I_{m'}$ = power received from total trafic channel interference.
· $I_t$ = power received at the probe mobile from total trafic channel power (from all other base stations).
· $(W/R)$ = processing gain.

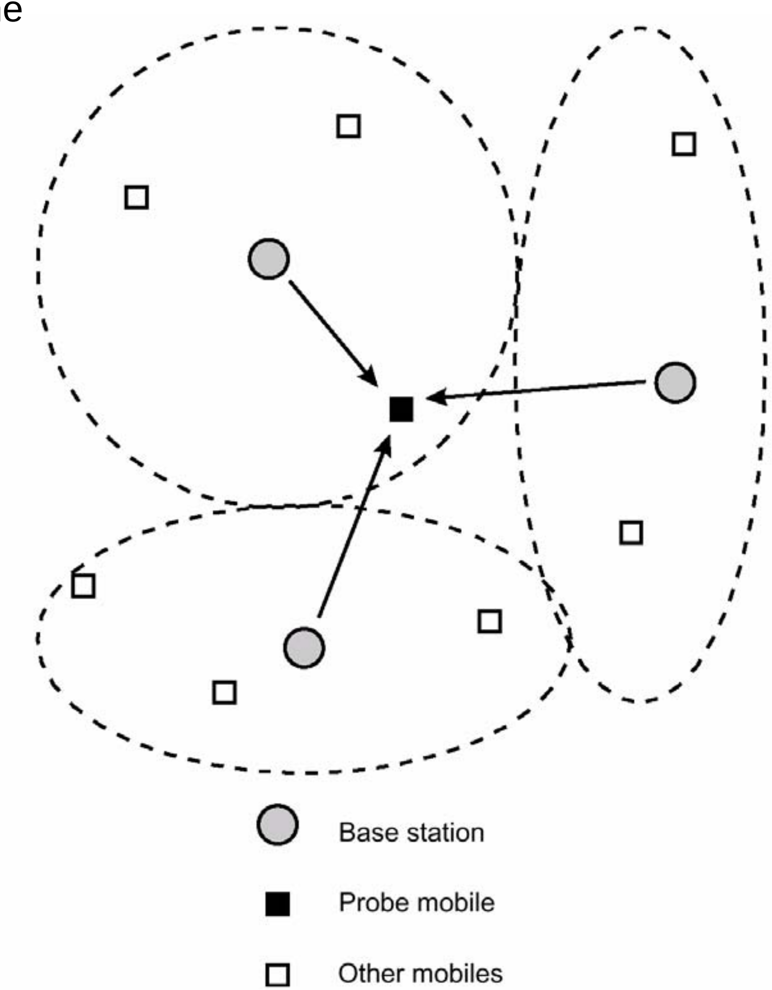



**Figure 7.4** Many cells serving many mobiles—forward-link characterization.

## 7 CDMA DESIGN ENGINEERING

### Reverse Link - Traffic Channel

•The link $E_b/N_0$ translates directly into BER, which has implications on reverse-link voice quality.

$$\frac{E_b}{N_0}=\frac{T'L'_0(\theta_0,d_0)G_0(\theta_0)}{I'_m+I'_t+I'_n+N}\left(\frac{W}{R}\right)$$

· $T'$ = reverse traffic channel ERP of the probe mobile; the transmit pattern is assumed to be omnidirectional.
· $L'_0(\theta_0,d_0)$ = reverse path loss from the probe mobile in the direction $\theta_0$ to the home base station a distance $d_0$ away.
· $G_0(\theta_0)$ = receive antenna gain of home base station in the direction $\theta_0$ to the probe mobile.
· $I'_m$ = power received at the home base station from total interference introduced by the reverse traffic channel transmissions of all the mobiles that are served by home base station,
· $I'_t$ = power received at the home base station from total interference introduced by the reverse traffic channel transmissions of all the mobiles that are not served by home base station,
· $I'_n$ = power received at the home base station from other interference of non-CDMA origins.
· $N$ = thermal noise power, and ($W/R$) = processing gain.

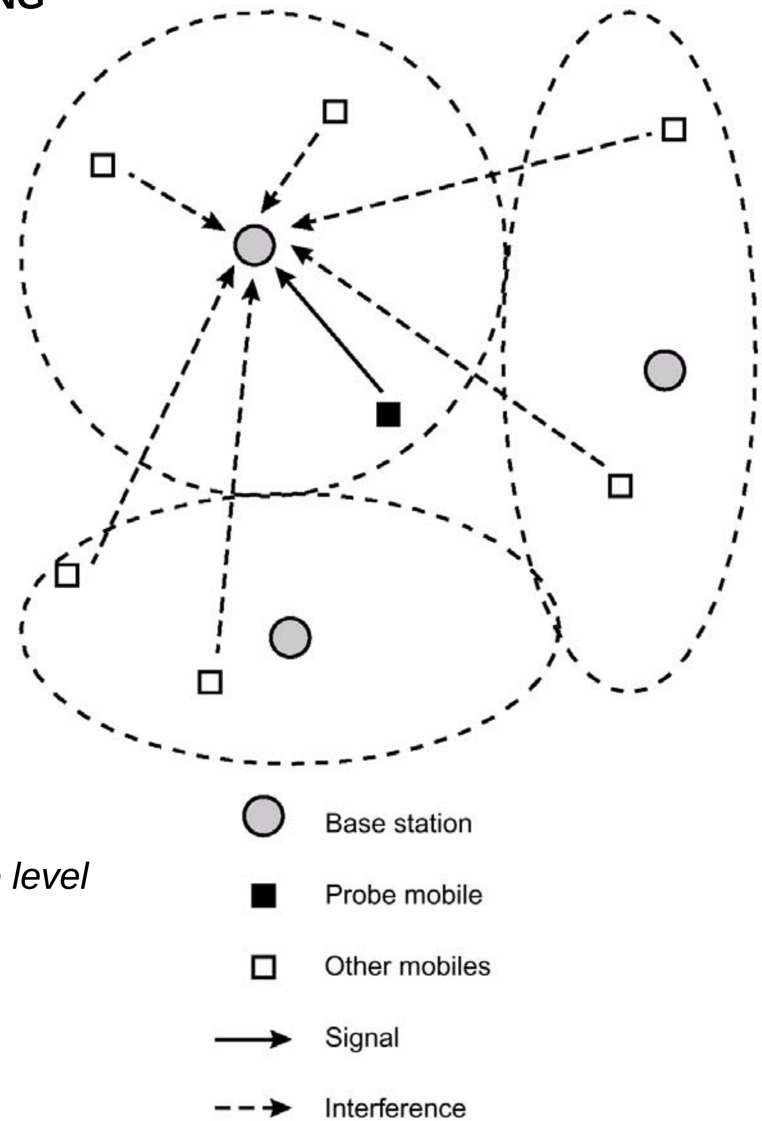



**Figure 7.7** Many cells serving many mobiles—reverse-link characterization.

Important ! ***R** is the rise of the interference level above the thermal noise level*

***Reverse - Link Rise*** ***Frequency Reuse Factor*** ***Loading factor***

$$R=\frac{I'_m+I'_t+I'_n+N}{N} \qquad F=\frac{1}{1+\eta} \qquad \eta=\frac{I'_t}{I'_m}$$

• **R** is a very good indicator of whether or not the base station is heavily loaded on the reverse link.

## 7 CDMA DESIGN ENGINEERING

### PN Offset Planning

• To realize separation between the logical channels from different base stations, each base station (or sector) is assigned a different short PN sequence

### Short PN Sequences

• Each short PN sequence is generated using a shift register with 15 delay elements and the length of such a PN sequence is about $2^{15}$ ,or 32,768 chips that means theoretically about 32,768 different PN sequences to assign to different base stations!

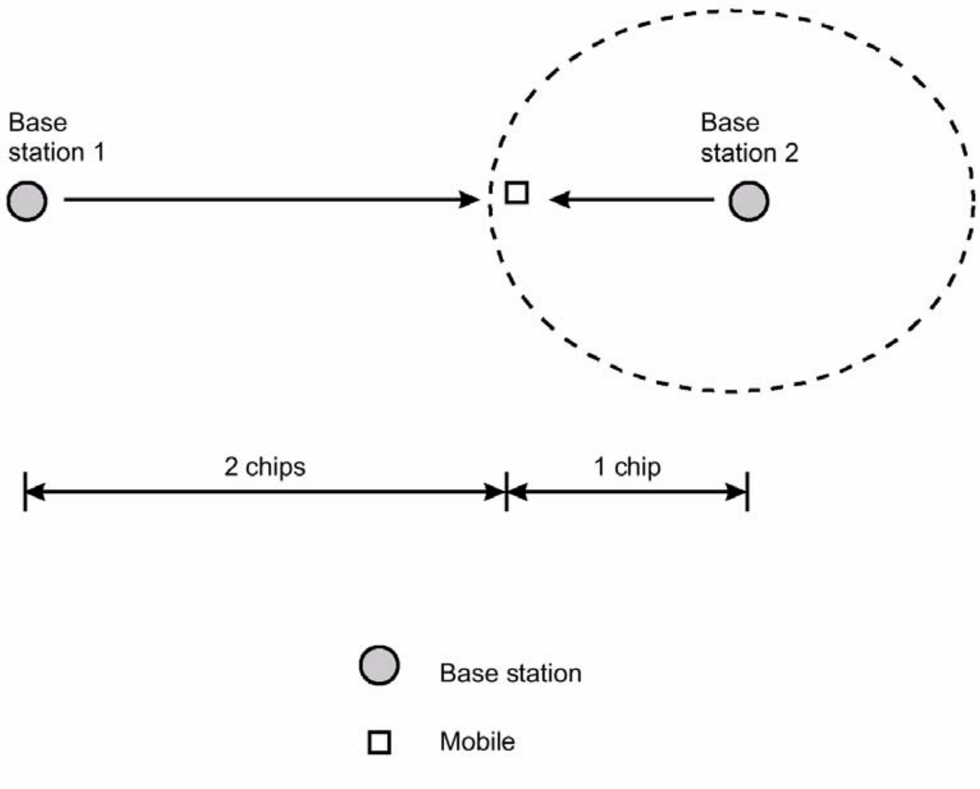



**Figure 7.8** A situation where a mobile cannot distinguish the received PN sequences of two base stations.

• Given that the transmission rate is 1.2288 Mcps, ***the duration of each chip*** is:

$$\frac{1 \text{ sec}}{1.2288 \times 10^6 \text{chips}} = 0.81380 \times 10^{-6} \text{ sec} = 0.81380\, \mu \text{ sec}$$

• A time duration of 0.81380 μsec corresponds to ***a propagation distance of 244.14m***; that is,

$$\left(0.81380 \times 10^{-6} \text{ sec}\right)\left(3 \times 10^8 \frac{\text{meters}}{\text{sec}}\right) = 244.14 \text{ meters}$$

• ***Is required mimimum separatiom (chips) between usable PN sequences!***

# 7 CDMA DESIGN ENGINEERING

## PN Offset Planning

### Short PN Sequences

- *To provide more isolation among PN sequences that can be assigned (used), the IS-95 standard specifies that usable PN sequences need to have a **minimum separation of 64 chips** between each other.*

- *Each usable PN sequence is defined by its **PN offset**.*

- The separation can be increased further by using the **PILOT_INC** parameter.

- The total number of usable PN sequences is:

$$\frac{32{,}768 \text{ chips}}{\text{PILOT\_INC} \times (64 \text{ chips})}$$

- For PILOT_INC=1 then result 512 PN sequences!

- If PILOT_INC=4 then there are only 128 usable PN sequences available for assignment and PN sequence planning now becomes analogous to AMPS or GSM frequency planning.

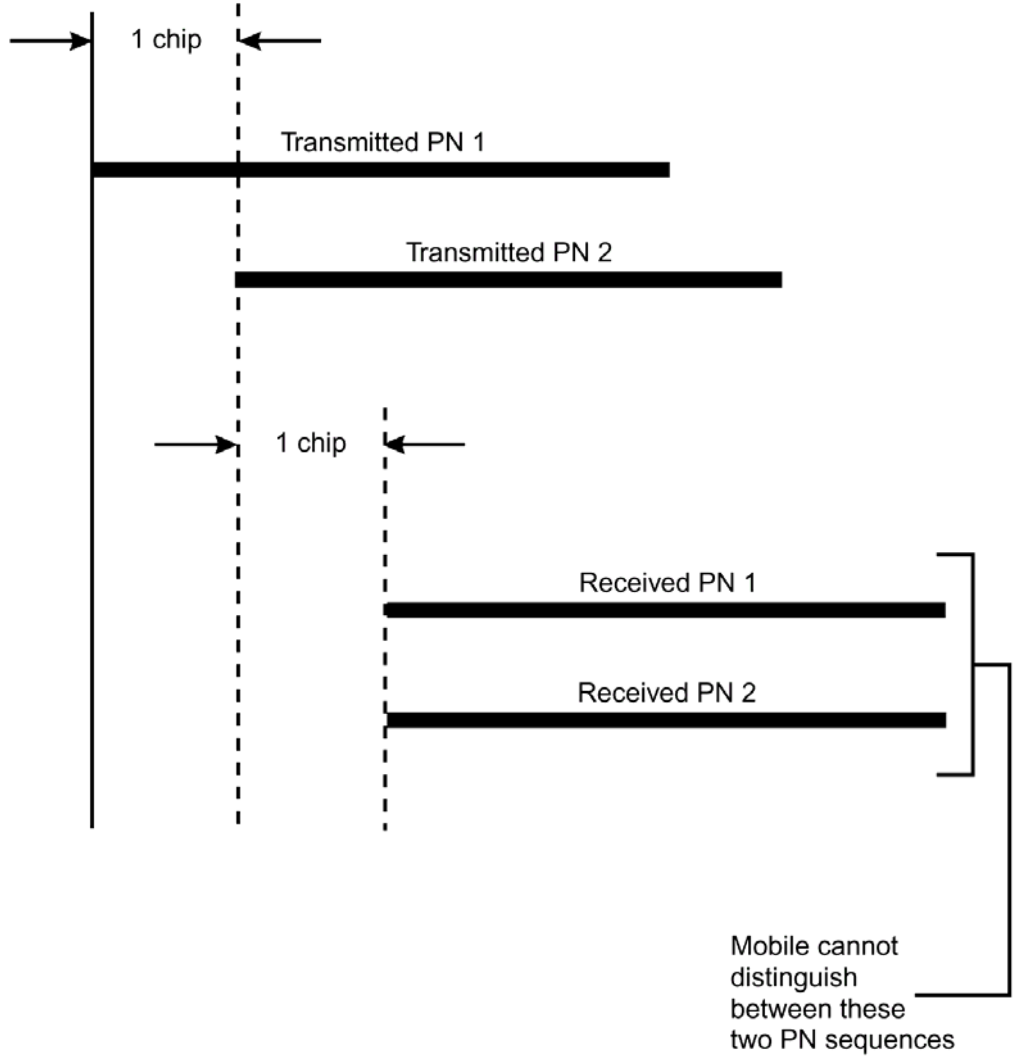



**Figure 7.9** PN sequences in the time domain. The illustration corresponds to the situation shown in Figure 7.8.

# 7 CDMA DESIGN ENGINEERING

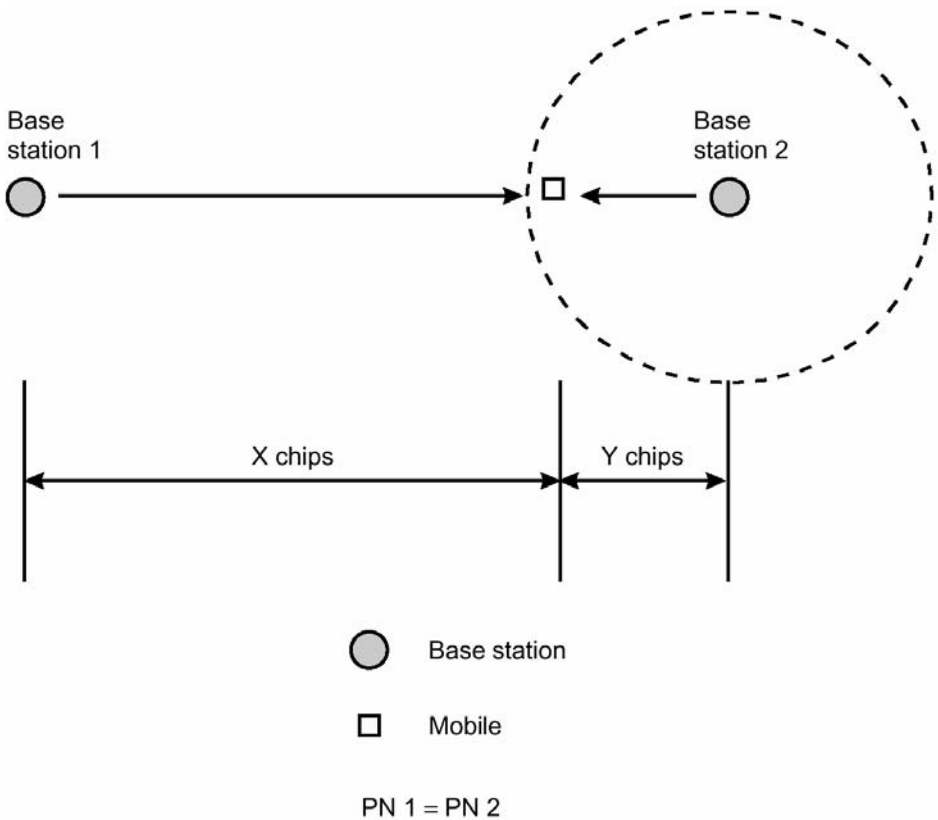
## Co-PN Offset

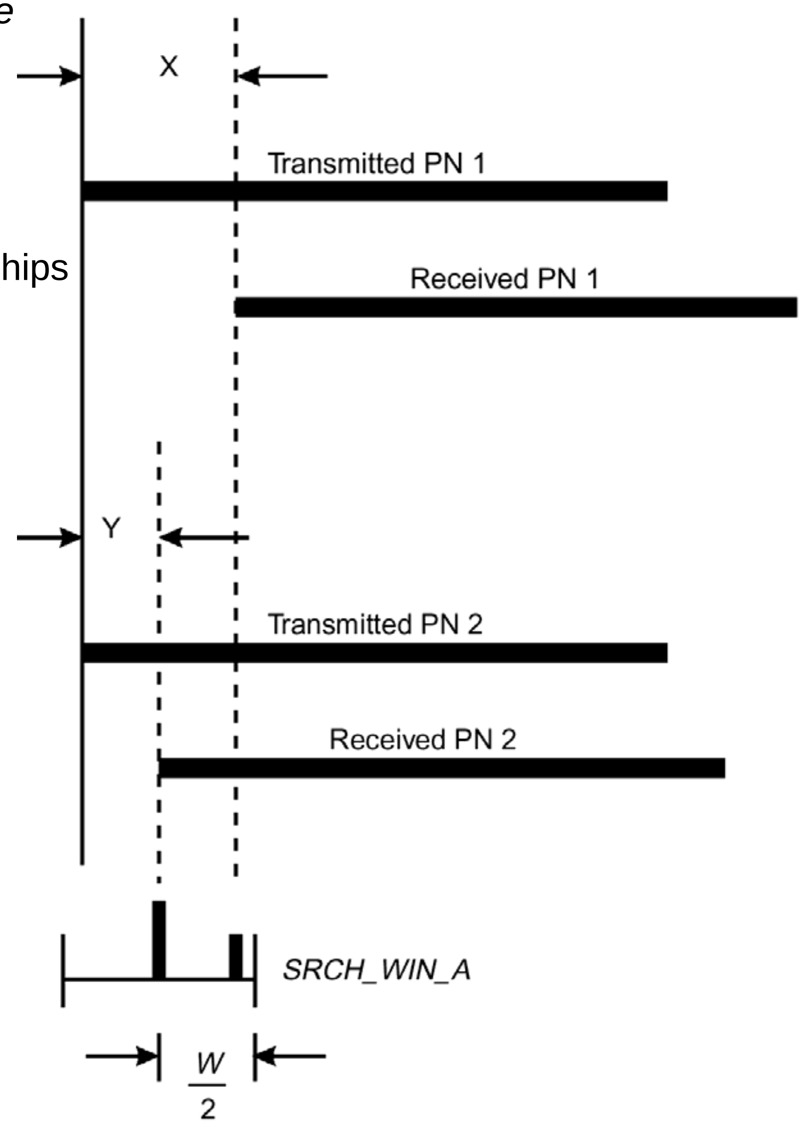
- *If two base stations are using the same PN sequence what is the minimum required distance between the two base stations?*

$$d > 122W + 2r$$

$$X > Y + \frac{W}{2} \quad \text{(in chips)}$$

where **d** is in meters, **r** is the coverage radius of base station 2 (home base station) in meters, and **W** is the size of SRCH_WIN_A in chips



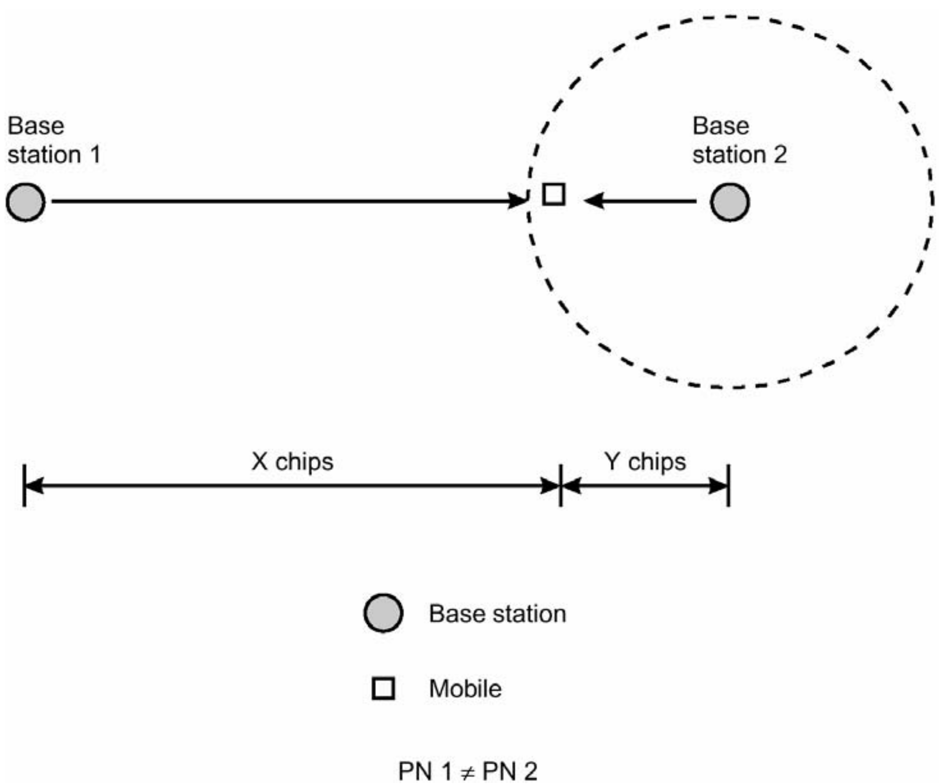



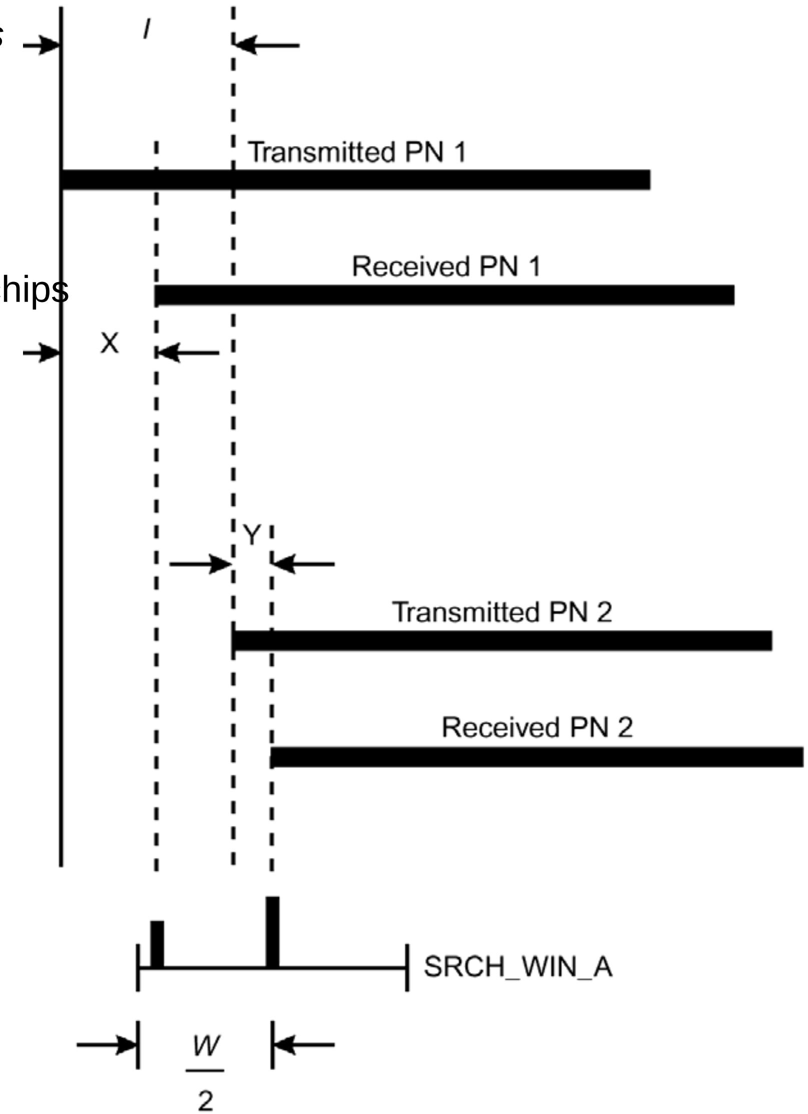
## Adjacent PN Offset

• *If two base stations are using adjacent PN sequences (i.e., PN sequences that are separated by (**I=PILOT_INC x 64**) chips), what is the necessary condition for no PN offset aliasing?*

$$d < 244I - 122W + 2r \qquad X < I + Y - \frac{W}{2} \quad \textit{(in chips)}$$

where **d** is in meters, **r** is the coverage radius of base station 2 (home base station) in meters, and **W** is the size of SRCH_WIN_A in chips



## 9.6-Kbps and 14.4-Kbps Systems

### Voice Quality

• For the two vocoders, is illustrated an approximate relationship between ***mean opinion score*** (MOS) and FER.

• *Taking into account the level of $E_b/N_0$ versus FER result that a **higher voice quality** demands that the system have **less coverage** and/or **less capacity**.*

### Power Control - Forward Link

• In the 14.4-Kbps system, this ***fast power control*** enables the mobile to report the forward-link condition more frequently (50 times a second against 4 times a second as it is at 9.6-Kbps system) and the benefit of this enhanced tracking performance ***is reducing the required $E_b/N_0$ on the forward link***.

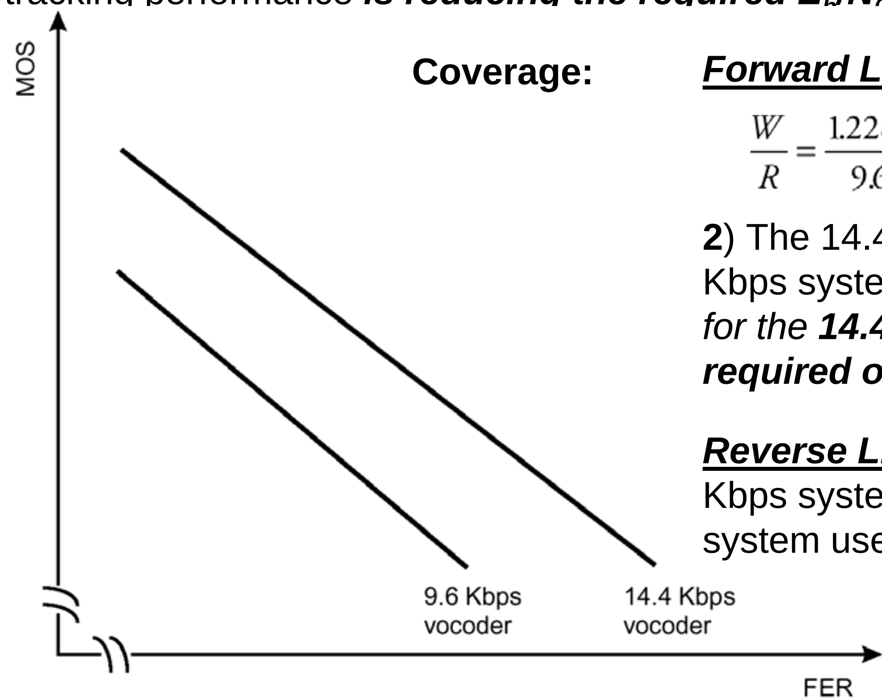



**Figure 7.14** An approximate relationship between MOS and FER. The curves are for illustrative purposes only.

**Coverage:**

***<u>Forward Link</u>*** - **1**) Differences in processing gain of 1.76dB:

$$\frac{W}{R} = \frac{1.2288\times 10^6}{9.6\times 10^3} = 128.00 = 21.072\,\text{dB} \qquad \frac{W}{R} = \frac{1.2288\times 10^6}{14.4\times 10^3} = 85.333 = 19.311\,\text{dB}$$

**2**) The 14.4-Kbps system uses a convolutional code of $R$ = 3/4, while the 9.6-Kbps system uses a more powerful convolutional code of $R$ = 1/2 *that means for the **14.4-Kbps system less error protection** and thus, a **higher $E_b/N_0$ is required on the forward link to achieve a specified FER***.

***<u>Reverse Link</u>*** - **1**) Differences in processing gain of 1.76dB; **2**) The 14.4-Kbps system uses a convolutional code of $R$ = 1/2, while the 9.6-Kbps system uses a more powerful convolutional code of $R$ = 1/3.

**Capacity:**

$$\frac{M_{14.4}}{M_{9.6}} = \frac{\left(\dfrac{W/R_{14.4}}{(E_b/N_0)_{\text{required},14.4}}\right)}{\left(\dfrac{W/R_{9.6}}{(E_b/N_0)_{\text{required},9.6}}\right)} = \left(\frac{W/R_{14.4}}{W/R_{9.6}}\right)\left(\frac{(E_b/N_0)_{\text{required},9.6}}{(E_b/N_0)_{\text{required},14.4}}\right) \qquad (7.31)$$

# 8 CDMA PERFORMANCE ENGINEERING

• *Performance engineering means process of optimizing the RF performance of a cell, a cluster of cells, or a system.*

***Channel Supervision*** - On Forward and Reverse link CRC is monitoring representing frame quality indicator.

***Power-Control Parameters*** - The mobile reports in two ways to the base station the condition of the forward link (*periodic* and *threshold*).

***Search-Window Sizes - SRCH_WIN_A***

• *The size of this window needs to be set according to the anticipated propagation environment.*

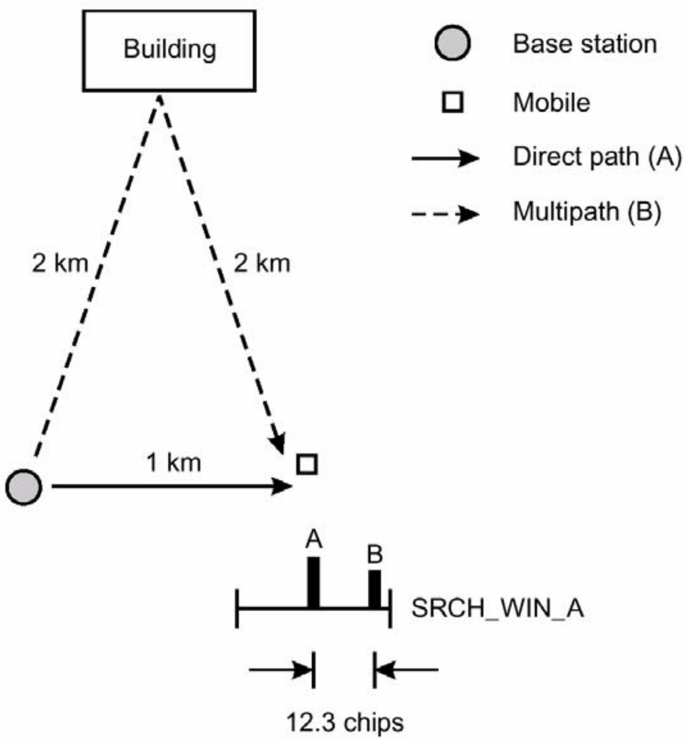



**Figure 8.1** SRCH_WIN_A is used to capture the two paths A and B.

***Direct Path:***

$$\frac{1{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 4.1 \text{ chips}$$

***Multipath***

$$\frac{4{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 16.4 \text{ chips}$$

• The difference in distance traveled between the two paths is:

$$16.4 \text{ chips} - 4.1 \text{ chips} = 12.3 \text{ chips}$$

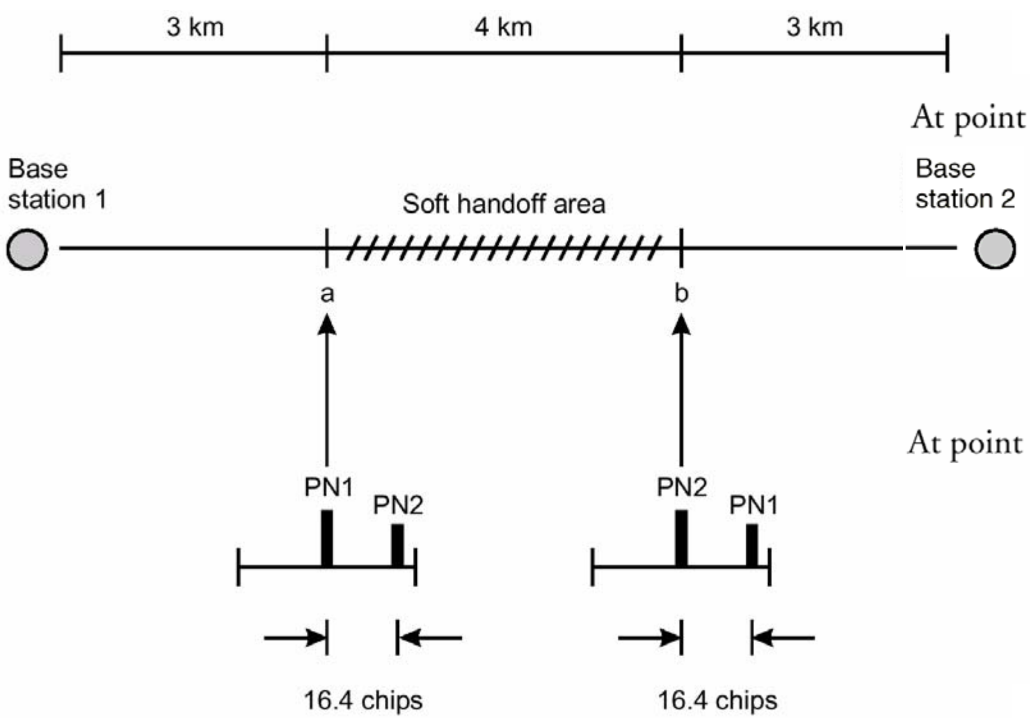
• ***A smaller SRCH_WIN_A can be used to limit the number of multipaths allowed!***

# 8 CDMA PERFORMANCE ENGINEERING

## *Search-Window Sizes - SRCH_WIN_A*

• *SRCH_WIN_A can be used to reduce the area where the mobile can conduct soft handoff*.

• If the RF engineer wishes to contain the soft handoff area to a smaller area between points a and b, he or she should set SRCH_WIN_A to at least twice the *maximum* of the path differences (i.e., at least (2 x 16.4) chips, or 32.8 chips wide).




At point a, the mobile is

$$\frac{3{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 12.3 \text{ chips from base station 1}$$

$$\frac{7{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 28.7 \text{ chips from base station 2}$$

$$\text{Path difference} = 28.7 \text{ chips} - 12.3 \text{ chips} = 16.4 \text{ chips}$$

At point b, the mobile is

$$\frac{7{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 28.7 \text{ chips from base station 1}$$

$$\frac{3{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 12.3 \text{ chips from base station 2}$$

$$\text{Path difference} = 28.7 \text{ chips} - 12.3 \text{ chips} = 16.4 \text{ chips}$$

**Figure 8.2** SRCH_WIN_A and a larger soft handoff area.

## 8 CDMA PERFORMANCE ENGINEERING

### *Search-Window Sizes - SRCH_WIN_N and SRCH_WIN_R*

• ***SRCH_WIN_N*** *is the search window that the mobile uses to track the neighbor set pilots.* The size of this window is typically larger than that of SRCH_WIN_A.

• The maximum size of this search window is limited by the distance between two neighboring base stations.

$$\frac{5{,}000 \text{ meters}}{244.14 \text{ meters/chip}} = 20.5 \text{chips}$$

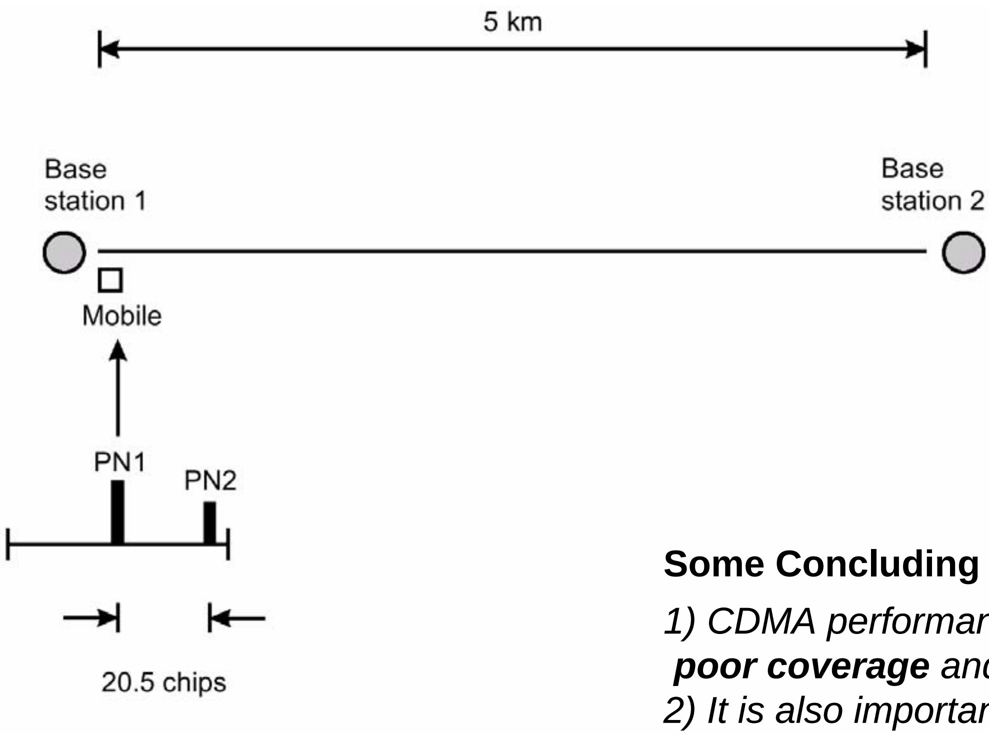



**Figure 8.4** An upper bound for SRCH_WIN_N.

• ***SRCH_WIN_R*** *is the search window that the mobile uses to track the remaining set pilots*

**Field Optimization**

• It is important to note that field conditions change due to loading.

**Pilot Strength**

• The mobile requires sufficient $E_c/I_0$ to lock on or to remain on the system.

**FER**

• *An area with high FER indicates that $E_c/I_0$ has decreased below a certain threshold.*

**Some Concluding Remarks**

*1) CDMA performance problems are divided into four causes*, which are: ***poor coverage*** *and* ***high interference*** *on forward and reverse links*.

*2) It is also important to keep in mind that* ***managing CDMA performance is effectively managing interference and noise****.*

# 9 SYSTEM NOISE MANAGEMENT

## *Introduction*

• *Contrary to the conventional FDMA and TDMA systems where noise rejection deals primarily with out-of-band noise, a CDMA system concerns mostly with in-band noise*.

• The goal of an RF system engineer is to design a network that ***minimizes the amount of unwanted noise introduced into the receiver on both forward and reverse links***.

**Thermal Noise** - remind that ***N = k·T·W*** (*K* = Boltzmann's constant, *T* = temperature in kelvin; *W* = bandwidth in hertz)

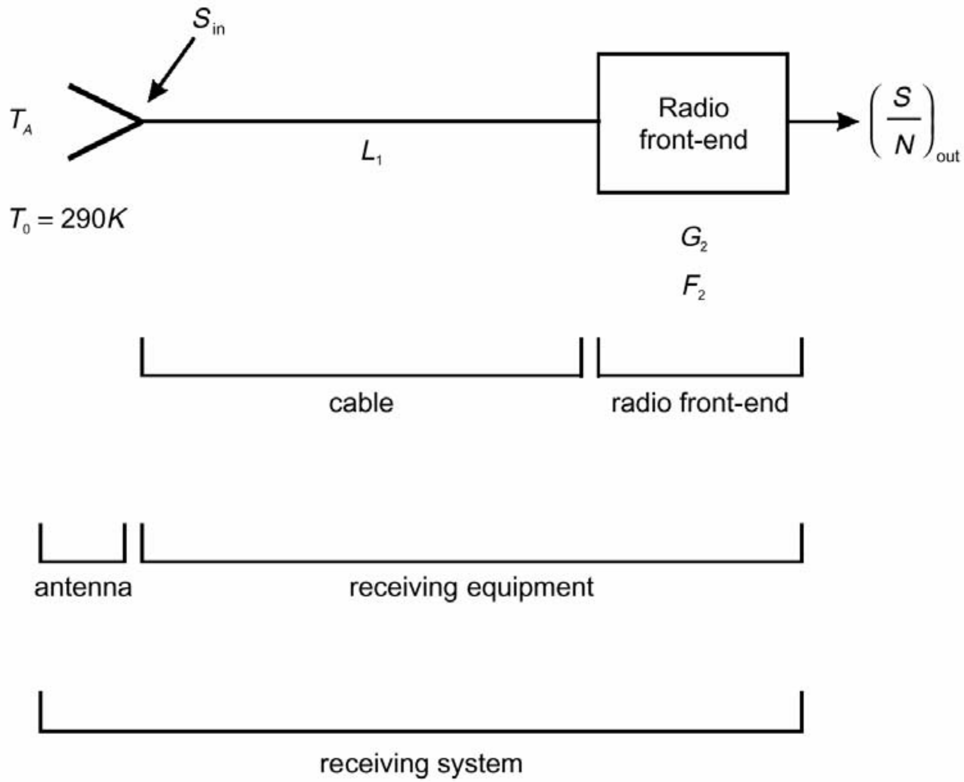


**Figure 9.2** A CDMA base station with no LNAs.

**Low-Noise Amplifier**

• *A technique to reduce the system noise figure on the reverse link is accomplished by installing low-noise amplifiers (LNAs) at a CDMA base station*

**System Without LNAs** - Figure 9.2 (left)

$$\left(\frac{S}{N}\right)_{out} = \frac{S_{in}}{k\sigma T_0 W}$$

$\sigma$ is the ***noise enhancement*** given by:

$$\sigma = R + (L_1 F_2 - 1)$$

$$R = \frac{I'_m + I'_t + I'_n + N}{N}$$

(R is the reverse link rise)

# 9 SYSTEM NOISE MANAGEMENT

## System With LNA

• *The low-noise amplifier is so called because its noise figure $F'_2$ is typically less than the noise figure $F'_4$ of the radio.*

$$\left(\frac{S}{N}\right)'_{\text{out}} = \frac{S_{\text{in}}}{k\sigma' T_0 W}$$

$\sigma'$ is the ***noise enhancement*** given by:

$$\sigma' = R + L'_1\, F'_2 + \frac{L'_1\left(L'_3 - 1\right)}{G'_2} + \frac{L'_1\, L'_3\left(F'_4 - 1\right)}{G'_2} - 1$$

If $G'_2$ is large then:

$$\sigma' \approx R + L'_1\, F'_2 - 1$$

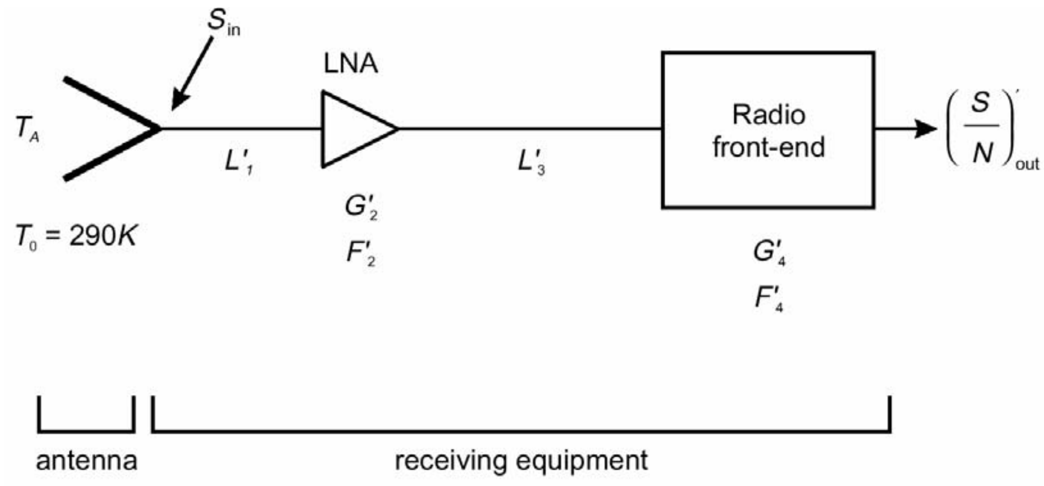



**Figure 9.3** A CDMA base station with LNA.

## Signal-to-Noise Ratio Improvement

• The SNR improvement quantifies how much the SNR has improved by adding an LNA between the antenna and the radio.
• The SNR improvement is defined as Q:

$$Q \equiv \frac{(S/N)'_{\text{out}}}{(S/N)_{\text{out}}}$$

If $G'_2$ is large then:

$$Q \approx \frac{(R-1) + L_1 F_2}{(R-1) + L'_1\, F'_2}$$

## Capacity Improvement

$$M \approx \frac{(W/R)}{(E_b/N_0)}\left(\frac{1}{1+\eta}\right)\lambda\left(\frac{1}{v}\right)$$

• *Since the required $E_b/N_0$ has not changed, the capacity of a base station with LNAs has not improved.*
• *However, the capacity of a neighboring base station (with no LNAs) may improve because the neighboring base station is lower loaded by the mobile which transmit now with lower power.*

# 9 SYSTEM NOISE MANAGEMENT

## Intermodulation

• *Intermodulation* (IM) is a nonlinear process that generates an output signal containing frequency components not present in the input signal.

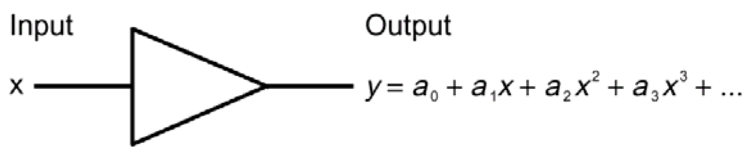
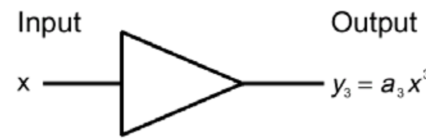



**Figure 9.8** A nonlinear device.




•If we model the input *x* as two sinusoids at two different frequencies $f_1$ and $f_2$ that is:

$$x = A\cos(2\pi f_1 t) + B\cos(2\pi f_2 t)$$

• By examining the ***output due to the third order term***, we can see that there are six new frequency components that were not present in the original input:

$(3f_1)$, $(3f_2)$, $(2f_1+f_2)$, $(2f_2+f_1)$, $(2f_1-f_2)$ and $(2f_2-f_1)$.

• However, the frequency components **$(2f_1-f_2)$** and **$(2f_2-f_1)$** can cause severe problem because these two components fall inside the operating band (see right).

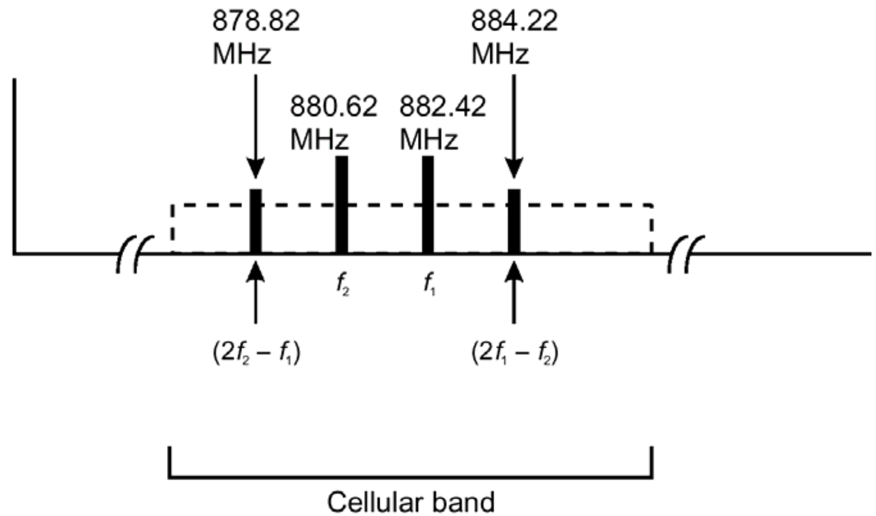



**Figure 9.10** Third-order IM components in the cellular band. Note that $a_3 = 1$, $A = 1$, and $B = 1$.

**Interference Due to Other Mobiles** - (at the reverse link expression $E_b/N_0$ contain the interference term $I'_t$)

• *Downtilting an base station antenna is an effective way of reducing the receive gain to those mobiles that are far away while maintaining an adequate gain to those mobiles that are close by. In essence, downtilting reduces $I'_t$.*

# 10 CDMA TRAFFIC ENGINEERING

## Introduction

• *For cellular and PCS systems, traffic engineering is the process of provisioning communication circuits for a given service area*

**Fundamental Concepts** - *Traffic Intensity*

• Traffic is measured in terms of *traffic intensity*. Traffic intensity is commonly measured in the unit of ***Erlang*****.**

An ***Erlang*** is defined as the ***average number of simultaneous calls*** or is the ***total usage during a time interval divided by the time interval*****.**

***Loads; Grade of Service***

• What we can directly measure is the ***carried load*** of a base station. The traffic demand, or ***offered load***, during the same time interval can be estimated by the following:

$$\text{carried load} = (\text{offered load}) \times (1 - \text{blocking rate})$$

$$\text{offered load} = (\text{carried load}) / (1 - \text{blocking rate})$$

• The ***blocking rate*** is defined as a measured quantity for a particular base station.

• The ***blocking probability*** *is the probability that a call is blocked due to no channel available*;

• The term ***blocking probability*** is often used interchangeably with ***grade of service***.

•*The blocking probability is typically evaluated for the offered load during the busy hour* (see right fig. for a base station).

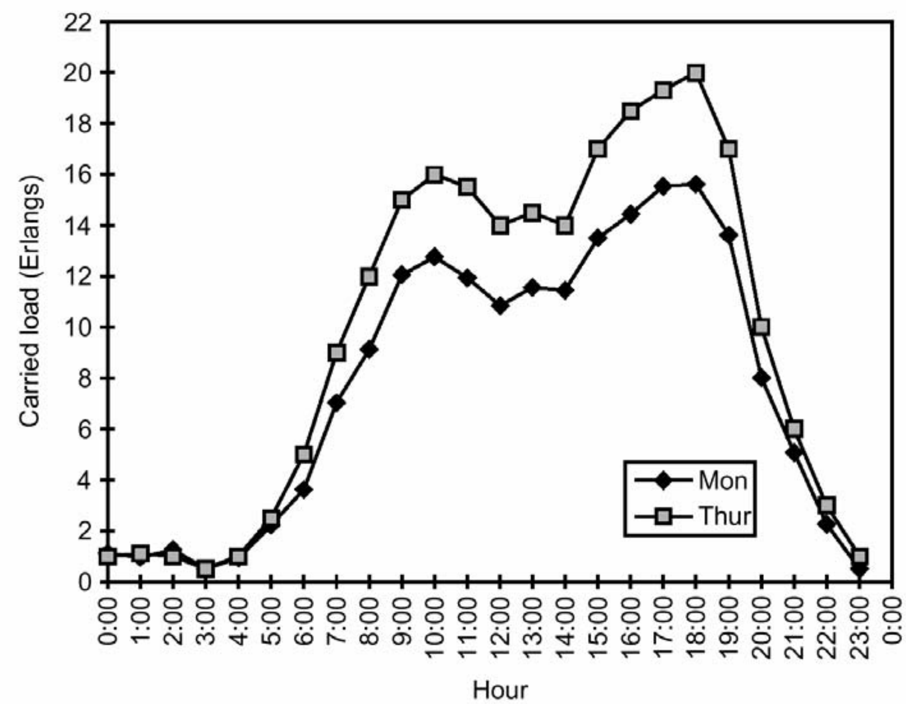



**Figure 10.2** A typical intraday traffic distribution.

## 10 CDMA TRAFFIC ENGINEERING

### Grade of Service

• ***Erlang-B*** and ***Erlang-C*** are two widely used mathematical models that describe the relationship among the blocking probability (grade of service), offered load (demand), and number of channels.

***Erlang-B*** *Erlang-B assumes that blocked calls are cleared and that the caller tries again later*.

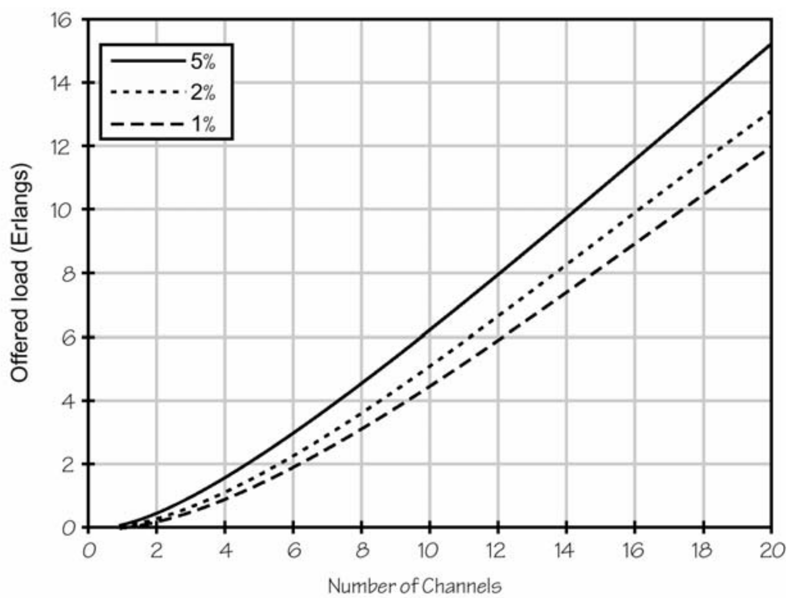



**Figure 10.3** Erlang-B.

***Erlang-C*** *Erlang-C assumes that blocked calls are* retried until the call is established

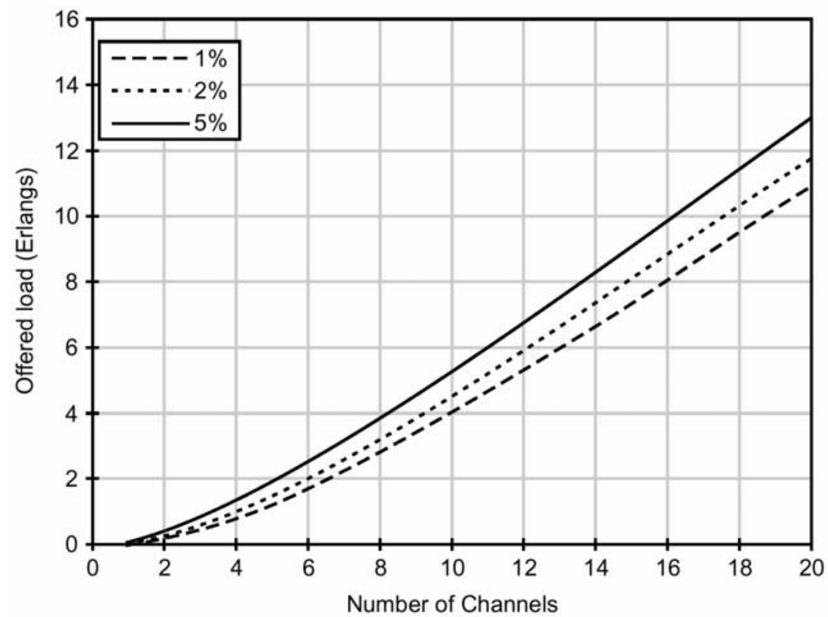



**Figure 10.4** Erlang-C.

### CDMA Applications (*Soft Blocking* + *Hard Blocking*)

• ***Soft Blocking*** - There may be **plenty of channels available** at a base station, but since there are many users in the same cell already, the interference level is such that adding an additional user would increase the interference above a predetermined threshold. The call is thus denied. This is the *soft-blocking* scenario.

• ***Hard Blocking*** - A call may have an excellent quality, but if there **is no channel available at the base station**, the call is still blocked. This is the *hard-blocking* scenario.

## 11 TDMA or CDMA - COMPARISON OF ADVANTAGES AND DISADVANTAGES

### Capacity

• The main debate between CDMA and TDMA concerned which provides the greatest capacity. It turns out that it is almost impossible to calculate the capacity of CDMA systems; the mathematics is just too complicated. As experience has subsequently shown, those who did try to calculate it generally got it wrong.

• There are actually TDMA systems and CDMA systems working and the easiest approach is simply to compare the capacity of each in real life. It turns out that ***CDMA systems currently provide a capacity probably around 30% greater than TDMA systems*** (as a gross simplification).

• This may change in the future as new CDMA and TDMA techniques are introduced, but it seems likely that CDMA systems will maintain a small but not insignificant capacity increase into the foreseeable future. In addition to capacity, a number of other advantages are claimed for CDMA systems. Each of these is examined in this section to assess whether the claims can be supported.

### Greater range

• It is claimed that CDMA systems have a greater range than equivalent TDMA systems. Range is related to the minimum signal level that the receiver can reliably decode, so the claim is basically one that CDMA can work with a lower received signal strength than TDMA.

### Sectorization

• In summary, the CDMAcapacity can be increased by a factor of 2 to 3 by sectorization with only a small increase in cost. This option is not available to TDMA and, hence, represents an advantage to CDMA.

## 11 TDMA or CDMA - COMPARISON OF ADVANTAGES AND DISADVANTAGES

*Discontinuous transmission*

***GSM*** use a circuit in the mobile known as a voice activity detector that detects when you are not speaking. That means:

· Clipping - that the first syllable that you say is often lost,
· Less interference with neighbors,
· The same capacity.

***CDMA*** use a gradually reduction of information transmitted at each speech stop, that means:

· Less interference,
· Increased capacity.

**No frequency planning**

• In general CDMA does not require frequency planning although it may require PN code assignment planning. However, this is not a major advantage. Frequency planning can be readily accomplished with today's planning tools and easily adjusted if problems occur.

**Macrocell/microcell**

• The concept of using small cells in high-density areas is well known and there are situations where smaller cells are deployed within the coverage area of larger cells. Subscriber units configured for the larger cell will be operating with much higher powers than those configured for the smaller cells.

• This is a problem for CDMA systems and in the worst case this is equivalent with reducing the CDMA capacity by a factor of two. This reduction does not occur in TDMA.

## 11 TDMA or CDMA - COMPARISON OF ADVANTAGES AND DISADVANTAGES

*Power control*

• Another factor that is used to improve the capacity of both TDMA and CDMA systems is power control (used to compensate attenuation causing by distance/obstruction/propagation between base station-mobile). So in GSM, accurate power control can increase capacity, whereas in CDMA, lack of accurate power control can reduce capacity. *For both systems, power control has the added advantage of reducing battery drain increasing the possible talk time*.

**Risk**

• TDMA systems have been widely deployed around the globe. CDMA systems are only just starting to emerge, so there is a much higher risk with CDMA that equipment will be delayed, will not provide the promised capacity, or will prove difficult to frequency plan, for example. This risk is continually reducing as experience with CDMA systems grows very rapidly.

**Cost**

• Everything eventually comes down to cost. At the moment, CDMA system components cost more than TDMA system components. However, because of the higher capacity of CDMA systems, fewer base stations are required, resulting in lower equipment bills and lower site and line rental costs. How the two facts balance depends on the actual difference in equipment costs and the extent to which the network is capacity limited. Certainly, in a highly capacity-limited situation, CDMA systems should prove less expensive. Other situations are less clear.

**Bandwidth flexibility**

• CDMA systems can increase the user bandwidth simply by reducing the number of bits in the spreading sequence. TDMA systems can also be bandwidth flexible by assigning more than one TDMA slot per frame to a user. Hence, both access methods can be made to be approximately equally flexible.

**11 TDMA or CDMA - COMPARISON OF ADVANTAGES AND DISADVANTAGES**

**Frequency Hopping versus Direct Sequence**

• CDMA systems come in two variants ***DS-CDMA*** and ***FH-CDMA***.

• The type of CDMA that has been discussed so far is known as direct sequence CDMA (DS-CDMA) because the input data is multiplied or spread by a sequence or codeword.

• There is an alternative known as frequency-hopped CDMA (FH-CDMA) where the bandwidth of the signal is not directly increased but the transmitter jumps from frequency to frequency. Because more than one frequency is used, the effect appears to be to spread the bandwidth. In practice, only one frequency is being used at one time, so the transmitted bandwidth is not increased, just the spectrum required.

• The FH is defined as "fast" when the jumps occur more than once in a bit period and "slow" otherwise. At the moment, fast FH is restricted to military applications.

• Readers will remember that FH was already introduced in the context of TDMA systems that move from channel to channel to avoid interference. By some quirk of history or definition, these are exactly the same thing, that is, FH-TDMA and FH-CDMA are identical.

## 11 TDMA or CDMA - COMPARISON OF ADVANTAGES AND DISADVANTAGES

**Summary Remarks**

• If the CDMA and TDMA debate was simple it would have been resolved long ago. When trying to understand the issues, the key point to remember is that both are simply ways of dividing up the spectrum. The only real issue is which one can divide up the spectrum with the lowest inefficiency and hence realize the greatest capacity.

• Initial results seem to show that CDMA is better at this than TDMA and so can provide a greater capacity.

***Some of the other important points to bear in mind are:***

• It is unlikely that there will be any significant range difference between the two systems,

• The advantage that CDMA has associated with not having to frequency plan the system is insignificant,

• CDMA systems perform less well when microcells are deployed,

• CDMA may be less costly but is more risky.

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# CDMA One - *THE END !*

# Thank you for your attention!

**(the detail material is hosted on the author's web page at the below link address)**

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