PLANNING AND DESIGN OF CDMA BASED CELLULAR NETWORK FOR DHAKA CITY

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JUNE 2002.

DEDICATED

TO

MY FATHER

PLANNING AND DESIGN OF CDMA BASED CELLULAR NETWORK FOR DHAKA CITY

A thesis submitted to the department of Electrical and Electronic Engineering (Communication and Electronics division), Bangladesh University of Engineering and Technology, Dhaka, Bangladesh in partial fulfillment of the requirements for the degree of

Master of Science in Electrical and Electronic Engineering.

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ABSTRACT

In cellular communication system, selection of the most appropriate access method is a challenging task. To meet this challenge, we have to be familiar with the technologies and system architectures on the CDMA digital cellular system.

CDMA development started in early 1989 after the NA-TDMA standard (IS-54) was established. In early 1990, QUALCOMM incorporated of San Diego, California, pioneered to introduce the intensive system concepts and the innovative implementation approaches on CDMA spread spectrum digital cellular systems. Most materials, particularly CDMA channel structure, presented in this research work are the embodiment of many of the principles and system architectures from IS-95.

This research work presents the planning and design steps of CDMA based Cellular Network for Dhaka city. The different stages of design such as determining the traffic demand at different zone of the coverage area, dividing the coverage area into a number of hexagonal cell according to the traffic demand, selecting the Grade of service, estimating the required number of traffic channels for a certain Grade of service and suggesting a Cellular Network according to previous calculation. A cell planning scheme of Dhaka city approximately 30km radius with centre at Mohakhali is proposed for frequency specturm of 5 MHZ as allocated to Citycell Digital. Cell planning is done in such a way to meet the increasing cellular demand up to 2010 and a total of 1200000 users can be connected. The increasing cellular demand is met up by decreasing the cell radius with minimum hardware. BTS antenna height for different electrical tilt angle, free space path loss, BTS antenna type selection, physical tilt angle of BTS antenna, position of MSC and number of trunk line from PSTN are calculated in this research work.

The field strength at corner points of each cell is calculated using modified Hata model based on a reference regarding the antenna height of the mobile station at 1.5 meters and calculated antenna height of the base station, the antenna gains of the base station and mobile station at 17 dB and 0 dB respectively. The signal strength at different floor inside a high rise building are also calculated. Results obtained are compared with those of predicted by Citycell Digital. The various factor can also be utilized in the cellular design e.g. Cell radius, handoff, transmission bit rate, GOS, Optimum power of transmitter and minimum allowable received power. Soft handoff among multiple cell base stations is considered for this design, which provides improved cell boundary performance and prevents dropped calls. The most important factor can also be utilized in the cellular design is accurate power control, which ensures a high level of transmission quality while overcoming the problem by maintaining a low transmitted power level for each terminals and hence a low level of interference to other user terminals.

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LIST OF ABBREVIATIONS

ABC	Administration and Billing Centre
A-ch	Access Channel
A/D	Analogue to Digital
AGR	Annual Growth Rate
AMPS	Advanced Mobile Phone Systems
ANT	Antenna
AUC	Authentication Centre
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
BTTB	Bangladesh Telephone and Telegraph Board
CBS	Cell Broadcast Service
CDMA	Code Division Multiple Access
CRC	Cyclic Redundancy Cheek
CTIA	Cellular Telecommunication Industry Association
D/A	Digital to Analogue
DCS	Digital Cellular Systems
DEM	Demodulator
DMC	Dhaka Municipal Corporation
DS	Direct Sequence
EIR	Equipment Identity Register
ETACS	Extended Total Access Communication System
ETSI	European Telecommunication Standard Institute
FDD	Fiber Distributed Data
FDMA	Frequency Division Multiple Access
FEC	Forward Error Check
GOS	Grade of Service
GP	Grameen Phone
GSM	Global System for Mobile Communication
HES	Household Expenditure Survey
HLR	Home Location Register
LA	Location Area
LAC	Location Area Code
LCC	Lost Call Cleared

LE	Local Exchange
MAHO	Mobile Assisted Hand Over
ME	Mobile Equipment
MS	Mobile Station
MSC	Mobile Switching Centre
MTSO	Mobile Telephone Switching Office
MUX	Multiplexer
NA	North American
NTT	Nippon Telegraph and Telephone
OAS	Operator Assistance Service
O-H	Okumara-Hata
OMC	Operation and Maintenance Centre
PA	Power Amplifier
P-ch	Pilot/Paging Channel
PCS	Personal Communication Service
PN	Pseudo Noise
PSTN	Public Switch Telephone Network
PTT	Post Telephone and Telegraph
QPSK	Quadrature Phase Shift Keying
Rx	Receiver
SIM	Subscriber Identity Module
SMA	Statistical Metropolitan Area
SMS	Short Message Service
S/P	Spread Phase
SRCH-WIN	Search Window
SS	Switching System
TACS	Total Access Communication Systems
T-ch	Traffic Channel
TDMA	Time Division Multiple Access
TMIB	Telecom Malaysia International Bangladesh
Tx	Transmitter
VLR	Visitor Location Register
VOCODER	Voice Coder

LIST OF SYMBOLS

Kbps	Kilo bit per second
bps	Bit per second
KHz	Kilohertz (10^3 Hertz)
dB	Decibel
h_B	Base station antenna height
h_m	Mobile station antenna height
P_L	Path loss
G_T	Transmitter antenna gain
G_R	Receiver antenna gain
P_T	Transmitter power
P_R	Receiver power
D	Delay operator
g	generator sequence
R	Code rate
K	Repeating times
m	Number of encoder stage
E	Erlang
P	Received power from each MS at the BTS
W	Bandwidth of CDMA channel
R	Maximum bit rate of Vocoder
I_{SC}	Own cell Interference
I_0	Thermal noise and total Interference
N	Total number of MS communicating with the BTS at the time
f	Other cell Interference ratio
N_0	Thermal noise
η	Ratio of thermal noise density to total interference density including the thermal noise density
V	Voice activity
F	Reduction factor
NF	Receiver noise figure
E_b	Received per channel
G_A	Antenna gain factor
G_V	Voice activity gain
B	Loss probability (Grade of service)

a	Traffic in erlang
n	Number of channels
r	Cell radius
ψ	Electrical antenna tilt angle
γ	Sector radius
H	Antenna height
f_c	Carrier frequency
d	Distance between BTS and MS in km
P_{tot}	Total power
P_P	Pilot channel power
P_P	Paging channel power
P_S	Sync channel power
P_{tr}	Traffic channel power

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CHAPTER- 1
INTRODUCTION

1.1 INTRODUCTION

The fundamental ideas of cellular radio were originally proposed by Bell Laboratories soon after the second world war. But at that time, the technology available didn't allow a system to be implemented. Only during the 1980s have working cellular radio systems been introduced into the public service. The main attractions of cellular radio are its ability to cater for a wide range of traffic loading and its ability to handle far more customer than non-cellular system. The demand for cellular telecommunication services is growing at a very fast rate then expected. Bangladesh has recently adopted this technology. Dhaka city was first brought under cellular network in Bangladesh and only one company was allowed to install the network. Now-a-days several companies are involved in the same task. But the cellular communication in the city is not without problems. The poor signal reception, improper hand off etc. are the common complains from the user. The main cause of such problems is the improper planning and design of cellular networks. Dhaka is one of the most densely populated cities in the world. Moreover the city was not developed with proper planning. So the city structure in not uniform. Field calculation at different points of city is a difficult job. The cellular networks designed without considering the irregularities and signal obstacles can't satisfy the users. The design of cellular telecommunication networks considering the real situation of the city is now a prime job.

1.2 INTRODUCTION TO CELLULAR CDMA

CDMA is a "spread spectrum" technology. Which means that it spreads the information contained in a particular signal at interest over a much-greater bandwidth than the original signal.

Techniques involving spread spectrum (ss) modulation have been evolving over the last 40 years spread spectrum techniques were well established for anti-jam and multipath applications as well as for accurate ranging and tracking. These spread spectrum (ss) techniques are also proposed for CDMA to support simultaneous services for digital communication among a large community of users. CDMA is an attractive technique for wireless access to broadband services. The CDMA system is in full compliance with the cellular Telecommunication Industry Association (CTIA) requirements as a candidate for standardization (IS-95).

Typical digital cellular systems can be listed such as GSM (European scheme, 1990), NA-TDMA (North American IS-54 scheme, 1990), and CDMA (US IS-95 scheme, 1993). CDMA development started in early 1989 after the NA-TDMA standard (IS-54) was established. A CDMA feasibility test was held in November, 1989. The CDMA IS-95 intermediate standard of the Electronic Industries Association was issued in December 1992. The CDMA system can employ dual-mode subscriber units to provide compatibility with the analogue system.

The great attraction of CDMA technology from the beginning has been the promise of extraordinary capacity increase over narrowband multiple access wireless technologies. Simple models suggest that the capacity improvement may be more than 20 times that at the existing narrowband cellular standards, such as AMPS in North America. Historically, the capacity was calculated using simple arguments. Reality, of course, is much more complicated than the idealized models. Real cell coverage areas are highly irregular, not the neat hexagons found in textbook models. Offered load is not spatially uniform, changes dramatically with time-of-day, and is often subject to other uncontrollable influences.

1.3 CDMA CELL COVERAGE

For CDMA cellular systems, the service area is divided into hexagonal cells shown in figure 1.1. Each cell contains a base station which is connected to the Mobile telephone switching office (MTSO) prior to voice encoding and decoding. In each cell there are two links consisting of the forward and reverse CDMA channels between the base station and each mobile station in the cell. The forward CDMA channel interprets the forward link from a base station to a mobile station in the cell. The reverse CDMA channel denotes the reverse link from the mobile station to the base station.

CDMA reuses the cellular frequency and controls system capacity effectively because it is inherently an excellent anti-interference mode.

The forward CDMA channel consists of one or more code channels that are transmitte on a CDMA frequency assignment using a particular pilot PN offset. Each base station uses a time offset of the pilot PN sequence (called a spreading pseudonoise sequence) to identity a forward CDMA channel. Time offset can be reused within a CDMA cellular system.

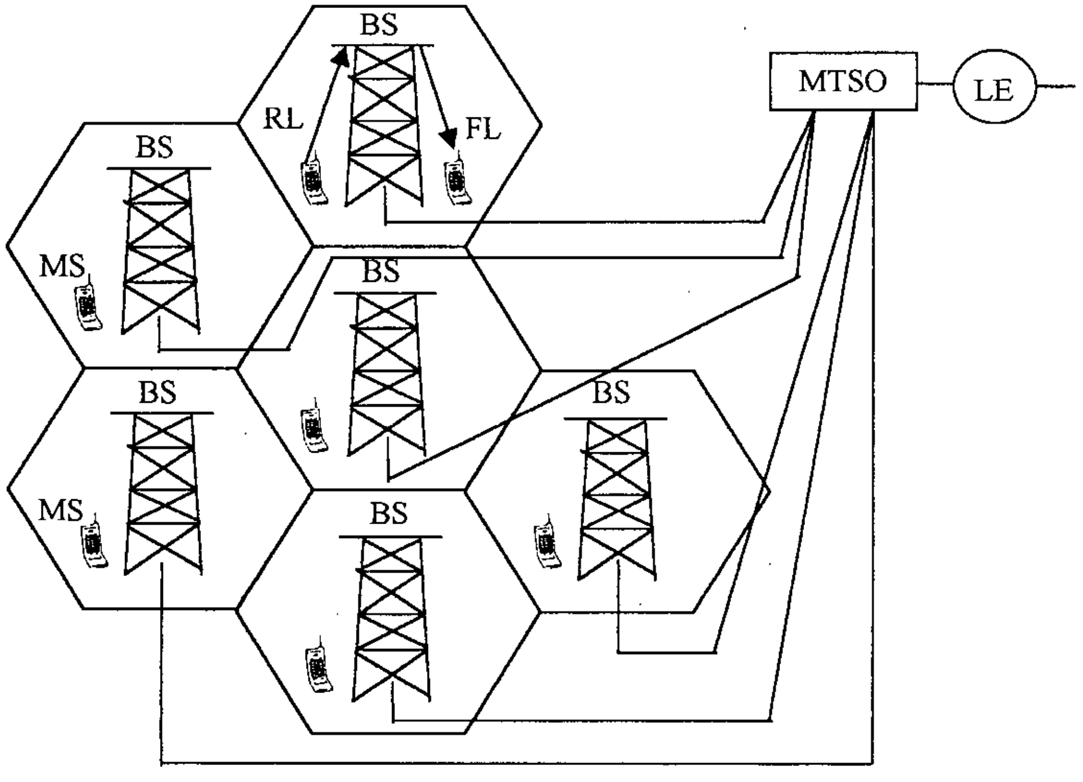


Figure 1.1 CDMA forward/reverse cellular link geometry in hexagonal cell coverage area.

Each code channel transmitted on the forward CDMA channel is orthogonally spread by the appropriate Walsh function to provide orthogonal channelization among all code channels and is then spread by a quadrature pair (i.e., in-phase and quadrature-phase) of pilot PN sequences in order to transmit them by Quadrature phase shift keying (QPSK) waveform.

The reverse CDMA channel is composed of access channels and reverse traffic channels. The access channel is used for short signaling message exchanges by providing for call origination, response to pages, orders, and registrations. A reverse traffic channel is used to transport user and signaling traffic from a single mobile station to one or more base station. All data to be transmitted on the reverse CDMA channel are convolutionally encoded for error correction, block interleaved to avoid burst errors and to improve the system performance by the access redundancy, modulated by the 64-ary Walsh function to provide orthogonal channelization, and direct-sequence spread by the long code to achieve limited privacy prior to transmission.

1.4 CELL SHAPE IN A CELLULAR SYSTEM

The region of coverage of a base station is called a cell. The hexagonal cell shape shown in figure 1.2 bellow is a simplistic model of the radio coverage for each base station. It might seem natural to chose a circle to represent the coverage area of a base station. But adjacent circles cannot be overlaid upon a map without leaving gapes, Thus when considering geometric shapes which cover an entire region without overlap, the sensible choices are a square; an equilateral triangle; and a hexagon. The hexagonal shape is used in practice because:

1. For a given distance between the center of a polygon and its farthest points, the hexagons has the largest area. So by using hexagonal geometry, the fewest number cells could cover a geographic region.
2. The hexagon closely approximate a circular radiation pattern which would occur for an omni direction base station antenna and propagation in free space.

Since actual radio coverage of a cell depends on many factor and not circular, hexagonal shaped cells are artificial and such a shape cannot be generate in the real world.

The real cell shapes along with ideal shape is shown in figure 1.3.

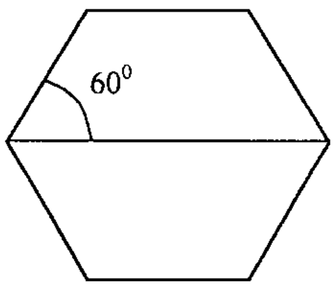


Figure 1.2 Hexagonal cell

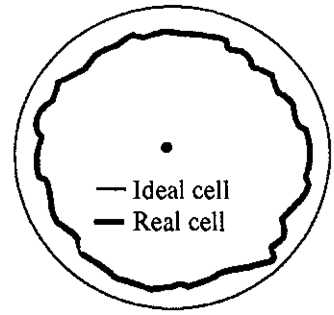


Figure 1.3 Real and Ideal cell shape

When using hexagons to model coverage areas, base station transmitters are located either in the centre of the cell or on one at the cell vertices.

Practical consideration may not allow base stations to be placed exactly at the center or at the corner of the hexagons.

1.5 DIFFERENT CELLULAR RADIO SYSTEM

The ultimate goal of a wireless communication service is to be able to simultaneously accommodate as many users as possible and still manage to maintain the quality of service for even the most disadvantage user at a maximum.

This has to be accomplished using the limited allocated spectrum. Multiple access schemes allow many mobile users to share the same bandwidth simultaneously without causing unacceptable interference to one another.

Therefore an effective multiple access scheme is vital in the success of a wireless communication system.

A verities of cellular radio systems exist now a days. They differs from each other by a number of factors such as, operating frequency, multiple access scheme, channel assignment strategy etc. The common systems are described bellow.

1.5.1 Analogue Cellular Radio system

Analogue cellular radio systems transmits analogue signal. The multiple access scheme used is Frequency Division Multiple Access (FDMA). Such systems can be classified by their operating frequencies: 450 MHz or 800 MHz. Also they can be distinguished by their channel bandwidth. The analogue cellular telephones used in the world are listed in Table 1.1.

Table 1.1 Different analogue cellular radio systems.

Systems	Country of use
Advanced Mobile Phone Systems (AMPS)	United states, Canada, Hongkong, China, Australia, Bangladesh ect.
Total Access Communication Systems (TACS)	England, Hongkong, China
Nippon Telegraph and Telephone (NTT)	Japan
Extended Total Access Communication System (ETACS)	England

Frequency Division Multiple Access (FDMA) assigns individual channels to individual users on demand. Once a channel is allocated to a given user, no other user has access to that channel until the call is terminated (AMPS systems). In FDD FDMA systems users are assigned a pair of frequencies; one for the uplink and one for the down link. During peak hours, many subscribers are unable to originate a call due to shortage of frequency channels. The Advanced Mobile Phone System (AMPS) uses FDD FDMA with channel bandwidth of 30 KHz.

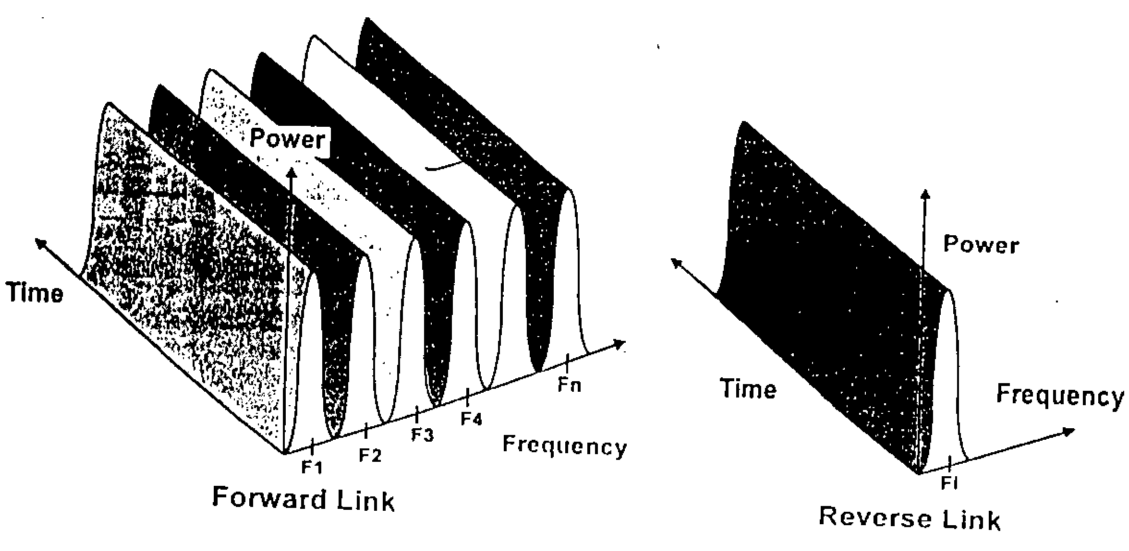


Figure 1.4 FDMA channelization.

1.5.2 TDMA Digital Cellular Radio System.

This system uses Time Division Multiple Access (TDMA) scheme to improve capacity. The use of digital radio transmission and advanced hand over algorithms between radio cells in networks provide increasing number of subscriber to be handled then analogue systems. In 1982 the Nordic Post, Telephone and Telegraph (PTT) outlined a common European Telecommunication service at 900 MHz. A standardization group called Global System for Mobile communication (GSM) was established to formulate the specifications. During 1982-85 discussions centred around whether to develop an analogue or digital system. In 1985 GSM decided to develop a digital system. In 1987 the narrow band TDMA scheme was chosen for GSM. European Telecommunication Standard Institute (ETSI) standardized following additional standards for GSM.

DCS-1800: DCS-1800 stands for Digital Cellular Systems at 1800 MHz. It is a new version of GSM and in 1990 the U.K. requested the start of a new version to the 1800 MHz band.

PCS-1900: PCS-1900 stands for personal Communication service at 1900 MHz. It is currently used only in U.S.A. The focus of PCS-1900 is on person to person communication rather than traditional station to station. Telephone users can then be reached at any time and any place by simply dialing one number.

In TDMA systems, the available system bandwidth which corresponds to an available time frame, is divided into time slots and in each time slot only one user is allowed to either transmit or receive.

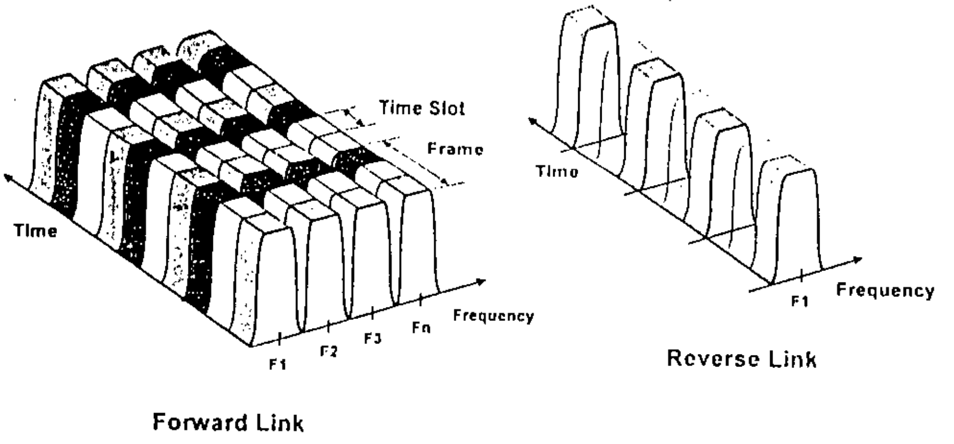


Fig. 1.5 TDMA channelization.

1.5.3 CDMA Digital Cellular Radio System.

CDMA stands for code Division Multiple Access, CDMA development started in early 1989 after the NA-TDMA standard was established. To design a cellular CDMA system, we first need to understand the mobile radio environment; then we can study whether the characteristics of CDMA are suitable for the mobile radio environment.

In CDMA, every user shares the same bandwidth and users are allowed to transmit or receive at will. In CDMA a users information signal is spread by means of a user specific code (spreading code) so that the transmitted signal occupies a bandwidth in excess of the minimum necessary to send the information.

In CDMA additional users add noise to the system, which can add a higher data error rate for all users. Capacity can be increased with some degradation to voice quality and/or reduction in the cellular coverage area. The power control scheme in a CDMA system is a requirement for digital cellular application. However, it was a challenging task and has been solved.

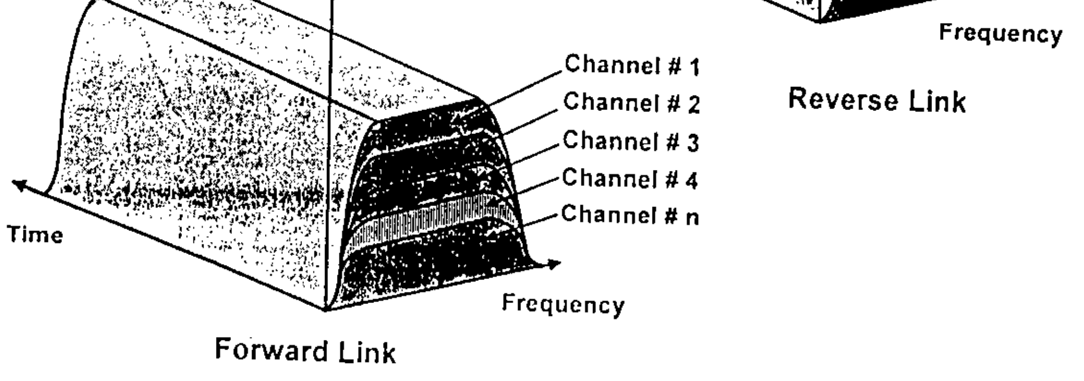


Fig. 1.6 CDMA channelization.

Table 1.2 Comparison of three radio systems.

	Digital System			*Analogue System*	
System Name	IS-95	PDC	GSM	NTT System	AMPS
Multiple Access	CDMA	TDMA		FDMA	
Channel Separation	1.25 MHz	25 KHz	200 KHz	6.25 KHz	30 KHz
Channel Number in 5 MHz	3 ch	200 ch	25 ch	800 ch	167 ch
Number of channel groups	1	12 (4-cell×3-sector)	9 (3-cell×3-sector)	21 (7-cell×3-sector)	21 (7-cell×3-sector)
Traffic ch. Number per RF channel	20 - 50 ch	6 ch	8 ch	1 ch	1ch
Operating Frequency band	0.8/1.9 GHz	0.8/1.9 GHz	0.8/1.9 GHz	0.8 GHz	0.8 GHz
Modulation System	QPSK OQPSK	$\pi/4$ shift QPSK	GMSK	FM	FM
Frequency Separation	45 MHz	130/48 MHz	45 MHz	55 MHz	55 MHz
Transmission Bit rate	1.2288 Mcps	42 kbps	270.833 kbps		
Voice Coding	QCELP (9.6 k/14.4 kbps) EVRC	VSELP PSI-CELP (11.2/5.6 kbps)	PRE-LTP VSELP (22.8/11.4 kbps)	Not applied	Not applied
Duplex System	FDD	FDD	FDD	FDD	FDD
Secret Communication	Extremely	Effective	Effective	Poor	Poor
Usable channel number per base station with 5 MHz	60~150 ch *a *a: 20×3=60	100 ch *b *b: 200÷12×6=100	22 ch *c *c: 25÷9×8=22	38 ch *d *d: 800÷21=38	8 ch *e *e: 167÷21=8

1.6 BENEFITS OF CDMA

When implemented in a cellular telephone system. CDMA technology offers numerous benefits to the cellular operators and their subscribers. The following is an overview of the benefits of CDMA.

1. Capacity increases of 8 to 10 times that of an AMPS analogue system.
2. Improved call quality, with better and more consistent sound as compared to AMPS system.
3. Simplified system planning through the use of the same frequency in every sector of every cell.
4. Enhanced privacy
5. Improved coverage characteristics, allowing for the possibility of fewer cell sites.
6. Increased talk time for portables.
7. Only one radio is needed at each site.

8. No equalizer needed. However in CDMA only a correlator is needed.
9. No hard hand-off. However a code sequence will be changed from one cell to another cell; This is called a soft hand-off.
10. In CDMA guard time does not exist.
11. In CDMA sectorization is used to increase capacity.
12. CDMA does not need a dynamic frequency assignment.
13. Both analogue and CDMA systems can operate in two different spectra.
14. CDMA is a natural waveform suitable for microcell and in-building because it is suceptable to noise and interference.

This summary of CDMA highlights the potential of increasing capacity in future cellular communications.

1.7 REVIEW OF PREVIOUS WORKS

CDMA development started in early 1989, after the NA-TDMA standard (IS-54) was established. A CDMA feasibility test was held in November 1989. In early 1990, QUALCOMM Incorporated of San Diego, California, pioneered to introduce the intensive system concepts and the innovative implementation approaches on CDMA spread spectrum digital cellular systems. This CDMA system was standardized and is known as the IS-95 standard of the Telecommunications Industry Association and the Electronic Industries Association (TIA/EIA/IS-95).

In the previous years, GSM based design was done in the department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka. Design and planning of a fixed cellular network for Bangladesh was done by Md. Imdadul Islam in september 1998.

Planning and design of GSM based cellular telecommunication network for Dhaka city was done by Md. Rofiqul Hassan Ghani in may 1999.

Also propagation-path losses characterization for 900 MHz cellular communication in Dhaka city was done by Md. Ramjan Ali in may 2001. But CDMA based planning & design was never done in Bangladesh.

1.8 OBJECTIVES OF THE WORK/THESIS

1. To plan and design of CDMA based cellular Network for the Dhaka city considering the demand and performance of other cellular systems (e.g. GSM, AMPS etc.) and also existing CDMA system.
2. To develop a CDMA based cellular Network for Dhaka city and its adjoining areas to meet the growing demand in mobile communication upto the year 2010.
3. To determine BTS antenna height, free space path loss, BTS antenna type, physical tilt angle of BTS antenna, BTS and MS transmitter power level, position of MSC and number of trunk line from PSTN etc.
4. To determine the field strengths in various cells of the coverage area and inside the building.

1.9 ORGANIZATION OF THE THESIS

Chapter 1 presents a general overview of the CDMA digital cellular system, brief history of previous works. Objectives of this thesis are also mentioned in this chapter. Chapter 2 covers Network configuration, link budget and structural layout of CDMA channels which is simply explained in terms of modulation and multiple access based on spread spectrum communications. Chapter 3 introduces fundamental and practical elements essentially required for CDMA channel operation. Chapter 4 describe Base station and Mobile station call processing of CDMA code channels. Chapter 5 covers demand forecasting for Dhaka city from 2000 to 2010 including population of Dhaka statistical metropolitan areas, distribution of monthly income, employment status and a comprehensive cell planning with traffic distribution of Dhaka city. BTS antenna height for different electrical tilt angle, free space path loss, BTS antenna type selection, physical tilt angle of BTS antenna, position of MSC and number of trunk line from PSTN are calculated in this chapter. The field strength at cell boundary and different floor of a high rise building are also calculated in this chapter. Chapter 6 provides CDMA performance engineering including power control, hand off strategies, search window sizes and improving capacity in cellular systems. Chapter 7 presents conclusion of the thesis and further recommendation.

CHAPTER- 2
BUILDING BLOCKS OF CDMA CELLULAR SYSTEM

2.1 INTRODUCTION

A CDMA cellular system is a combination of different networks elements. Each elements performs a unique function and every element is essential for proper functioning of the system. For designing and physical implementation of a cellular system, operation of each block should be understood, the key building blocks of CDMA system and its operation is discussed in the next sections.

2.2 BASIC BUILDING BLOCKS

A cellular mobile system consists of several building blocks. They are,

- Mobile Station (MS)
- Base Station (BS)
- Mobile Switching Centre (MSC)
- Data bases
- Operation and Maintenance centre.

Each of these performs a unique function. Each function is required for mobile system operation.

Mobile Station (MS): A mobile station (MS) is used by a mobile subscriber to communicate with the cellular system. Several types of mobile station exist, each allowing the subscriber to make and receive calls. The range or coverage area of a mobile station depends on the output power of the mobile station.

The MS consists of two independent parts:

- Subscriber Identity Module (SIM-card)
- Mobile Equipment (ME)

The SIM card is a card with information about the subscription. The ME is the actual telephone.

Base Station (BS): A mobile station communicates with the mobile system using a radio channel to a base station (BS). The base station is responsible for communication, over the air, both to and from the mobile station. The base station is made up of antennas, transmitters, receivers and control units. All radio-related functions are performed in the Base Station System (BSS). These include:

- Base Station Controller (BSC)
- Base Transceiver Station (BTS)

Base Station Controller (BSC): The Base Station Controller (BSC) provides all the radio related functions. It is a high capacity switch that provides functions including handover, cell configuration data, and channel assignment. A number of BSCs are served by a MSC.

Base Transceiver Station (BTS): Base Transceiver Station (BTS) handle the radio interface of the mobile station. The BTS is the radio equipment (transceivers and antennas) needed to serve each cell in the network. A group of BTSs are controlled by a BSC.

Mobile Switching Centre (MSC): The mobile Switching Centre (MSC) is responsible for all switching functions related to call processing. The MSC has interfaces with the base station on one side and the external networks on the other side. Each base station is connected to a MSC.

Database: Database are used to manage mobile subscribers. The database, stores subscriber information. This information includes, data about specific service and location of the mobile station. Depending upon the mobile network type, there can be one or several data bases.

Operation and Maintenance Centre (OMC): The Operation and Maintenance Centre (OMC) is responsible for monitoring and controlling the mobile network. The complex equipment provides monitoring staff with information regarding alarm handling, trouble-shooting, routine maintenance and other information.

The operation and maintenance center (OMC) handles error messages originating from the network. OMS has access to both the switching system (Via MSC) and the Base Station System (Via BSC). Network elements are shown in figure 2.1.

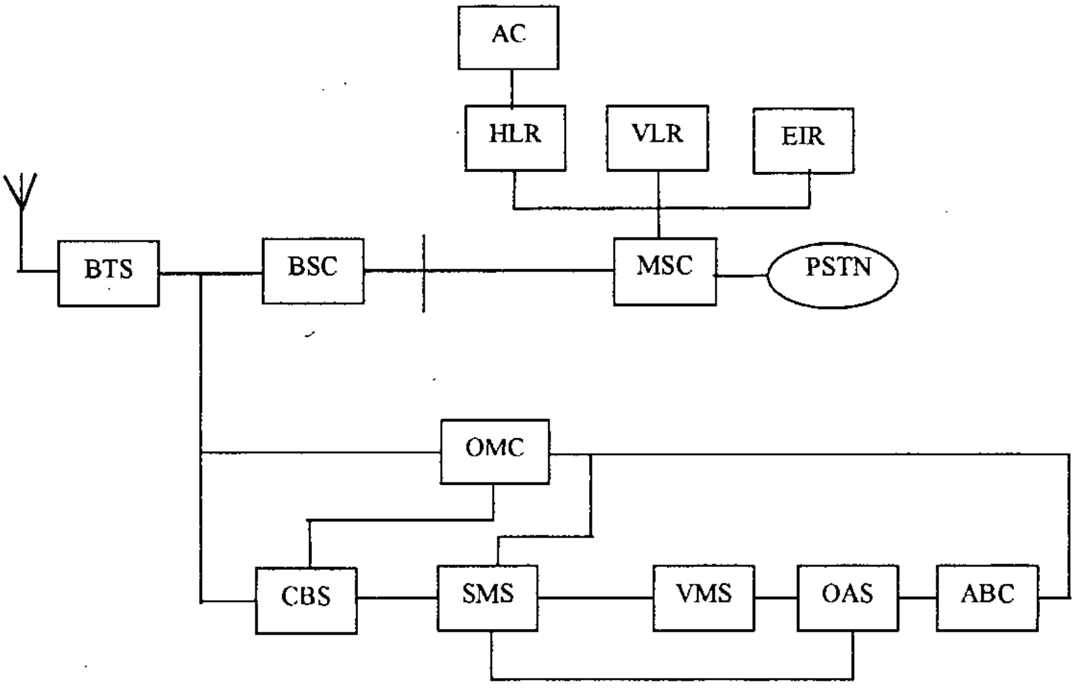


Figure 2.1 Mobile Telecommunication System Architecture

Abbreviations:

ABC Administration and Billing Center
AC Authentication Center
BSC Base Station Controller
BTS Base Transceiver Station
CBS Cell Broadcast Service
EIR Equipment Identity Register
HLR Home Location Register
MS Mobile Station
MSC Mobile Services Switching Center
OAS Operator Assistance Service
OMS Operation and Maintenance Center
SMS Short Message Service
VLR Visitor Location Register
VMS Voice Mail Service.

2.3 NETWORK CONFIGURATION OF CDMA CELLULAR SYSTEM

A network configuration of CDMA cellular system is shown in figure 2.2.

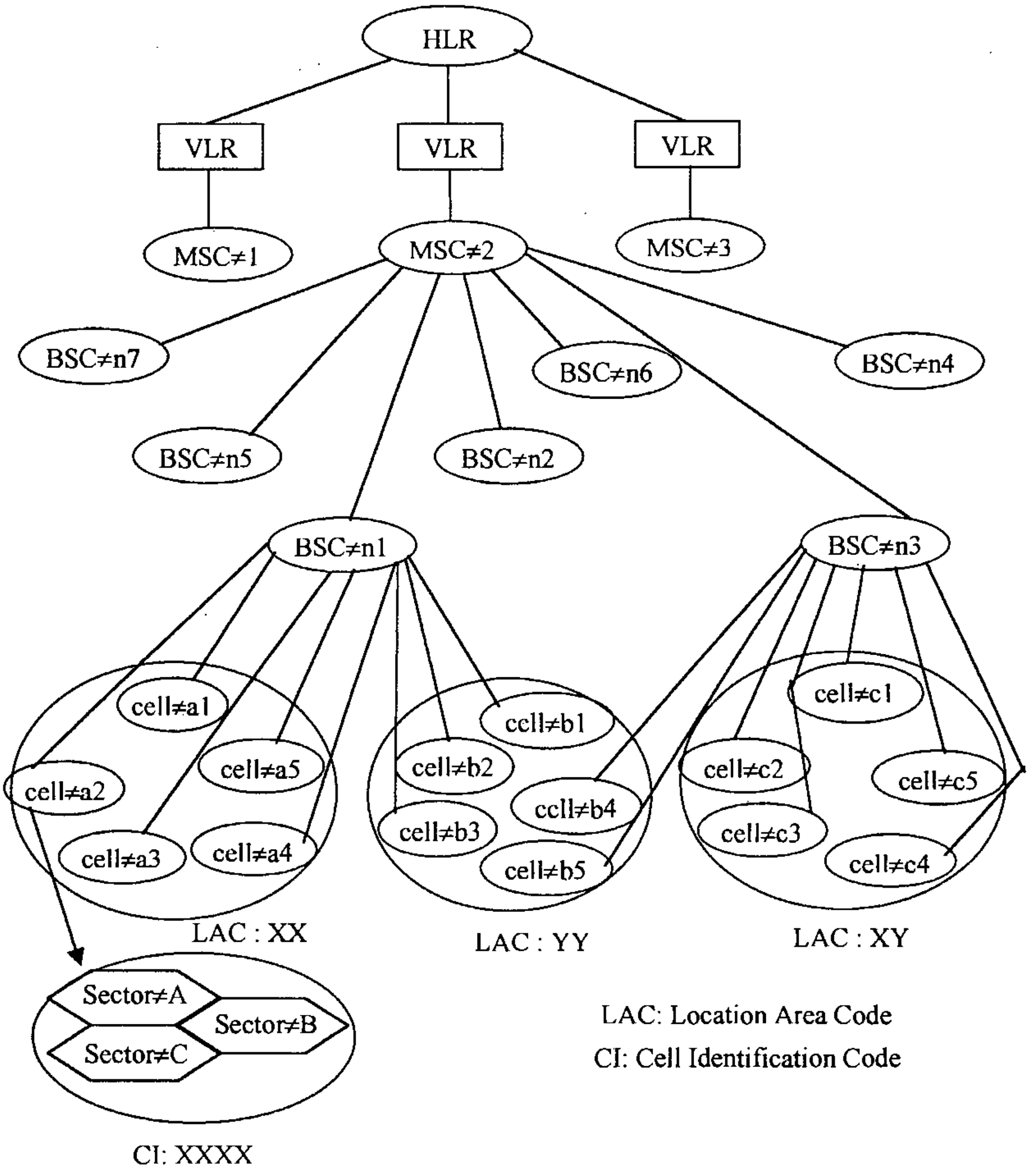


Figure 2.2 CDMA network configuration

A cellular network is divided into three major systems:

* Switching System (SS)
* Base Station System (BSS)
* Operation and Maintenance Center (OMC)

Each of these contain a number of functional units which make up the entire system. The functional units are parts in the various hardware units.

Switching System: Switching System is responsible for performing call processing and subscriber related functions. It includes the following functional units:

* Mobile Switching Center (MSC)
* Home Location Register (HLR)
* Visitor Location Register (VLR)
* Authentication Center (AUC)
* Equipment Identity Register (EIR)

Mobile Switching Centre (MSC): The mobile switching centre (MSC) performs the telephony switching functions of the system. It controls calls to and from other telephony and data systems, such as a Public Switched Telephone Network (PSTN), Integrated Services Digital Network (ISDN), Public Land Mobile Network (PLMN), Public Data Networks and possibly some private networks.

Gateway: A gateway is a node that interconnects two networks, If a person in the fixed network (PSTN) wants to make a call to a mobile subscriber, the exchange in PSTN will connect the call to a gateway. The gateway function is often carried out in MSC known as the GATEWAY MSC (GMSC). All MSCs in the network can work as a gateway.

Home Location Register: The Home Location Register (HLR) database stores and manages all mobile subscriptions belonging to a specific operator. The HLR is considered the most important database because it stores permanent data about subscribers, including subscribers supplementary services, Location information, and authentication parameters. When a person buys a subscription, it is registered in the operators HLR. The HLR can implemented with the MSC or as a stand-alone database.

Visitor Location Register: The Visitor Location Register (VLR) database contains information about all mobile stations currently located in the MSC service area. VLR contains temporary subscriber information needed by the MSC to provide service for visiting subscribers. The VLR can be seen as a distributed HLR. When a mobile station roams into a new MSC service area, the VLR connected to that MSC requests and stores data about the mobile station from the HLR. If the mobile station makes a call at another time, the VLR will already have the information needed for all set-up. When a subscriber moves to a new MSC service area (of a particular operator) VLR request use to update HLR.

Authentication Centre (AUC): A database called the Authentication Centre (AUC) is connected to the HLR. The function of the AUC is to provide the HLR with authentication parameters and ciphering keys. Both provide system security. The AUC protects network operators from fraud.

Equipment Identity Register: The Equipment Identity Register (EIR) database contains mobile equipment information which helps to block calls from stolen unauthorized, or defective mobile stations for example, mobile equipment reported stolen can be barred from the network.

2.4 STRUCTURAL LAYOUT OF CDMA CHANNELS

The Overall Structural layout of forward/reverse CDMA channels are shown in figs. 2.3 And 2.4 respectively.

2.4.1 Forward link

The forward CDMA link consists of the pilot channel, sync channel, paging channels, and a number of forward traffic channels. Forward CDMA channel consists of 64-code channels, the forward CDMA link comprises the pilot channel, one sync channel, seven paging channels, and 55 forward traffic channels.

The pilot channel is an un-modulated, direct-sequence spread spectrum signal transmitted at all times by each CDMA base station. The mobile station monitors the pilot channel to acquire the timing of the forward CDMA and provides a phase reference for coherent demodulation. Code channel number zero (W_0) is always assigned to the pilot channel.

The sync channel is assigned to the code channel number 32 (W_{32}) which transports the synchronization message to the mobile station. More importantly, the sync channel is an encoded, interleaved, spread, and modulated spread spectrum signal that is used by mobile stations to acquire initial time synchronization.

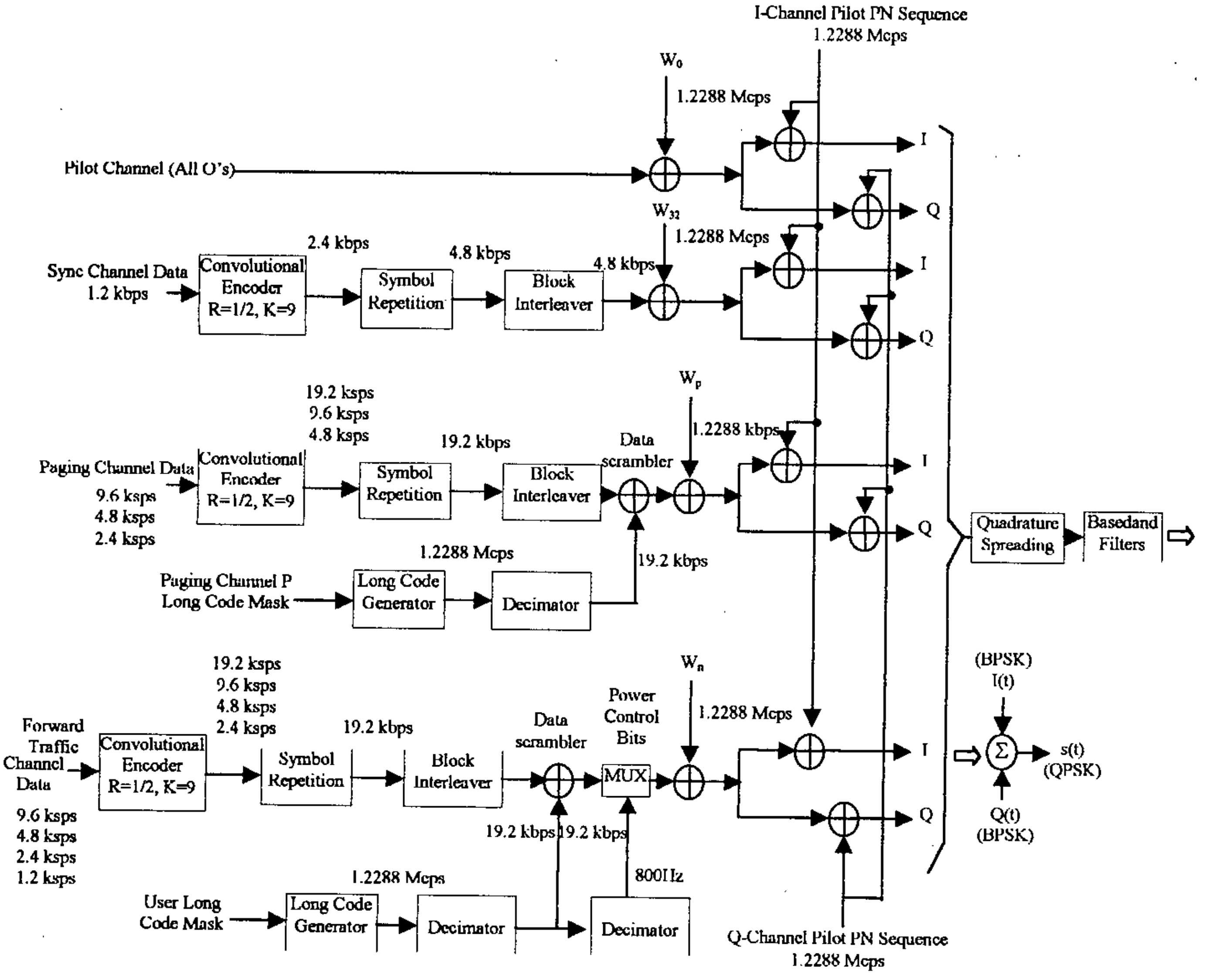


Figure 2.3 CDMA forward link structure

The paging channel is also an encoded, interleaved, spread and modulated spread spectrum signal used for transmission of control information and pages from a base station to a mobile station. Paging channels are assigned to code channels numbers one through seven (W_1-W_7) in sequence.

The forward traffic channel is used for the transmission of user and signaling traffic from the base station to a specific mobile station during a call. The maximum number of forward traffic channels is equal to 63 minus the number of sync and paging channels operating on the same forward CDMA channel.

Data rates at the channel input are as follows:

1) The pilot channel sends all O's at a 19.2 kbps rate,
2) The sync channel operates at a fixed rate of 1200 bps,
3) The paging channel supports the fixed data rate operation at 9600, 4800 or 2400 bps, and
4) The forward traffic channel supports variable data rate at 9600, 4800, 2400 or 1200 bps.

The sync channel, paging channel and forward traffic channel are convolutionally encoded for error correction prior to transmission, but the pilot channel does not use convolutional encoding. Code symbols are generally defined as the output of an error-correcting encoder. Information bits are input to the encoder and code symbols are output from the encoder. For all code channels except the pilot channel, each encoded symbol is repeated prior to block interleaving whenever the information rate is lower than 9600 bps.

For paging and forward traffic channels, repetition depends on the data rate of each channel. Each code symbol at the 4.8 kbps data rate is repeated once (2 of each symbol). Each code symbol at the 2.4 kbps data rate is repeated 3 times (4 of each symbol). Each code symbol at the 1.2 kbps data rate is repeated 7 times (8 of each symbol). Thus, for all the data rates (9.6, 4.8, 2.4 and 1.2 kbps), symbol repetition will result in a constant modulation symbol rate of 19.2 kbps. For a sync channel, each encoded symbol is repeated once (two of each symbol) and the modulation symbol rate is 4800 bps.

All symbols after repetition on the sync channel, paging channel and forward traffic channel are block interleaved. The purpose of using block interleaving is to protect the date from burst error while sending them through a multipath fading environment. After interleaving, each code channel in the forward CDMA channel is orthogonally spread by one of 64 Walsh functions and is then spread by a quadrature pair of pilot PN sequences at a fixed chip rate of 1.2288 Mbps. The binary data (O's and 1's) spread in quadrature are applied to the base band filters. Following the base band filtering, the forward CDMA channel combines the respective Binary Phase Shift Keying (BPSK) data modulated with the carriers to produce Quadrature Phase Shift Keying (QPSK) just before transmission.

Data scrambling applies to the paging channel and the forward traffic channel as well. Data scrambling is performed on the block interleaver output at the modulation symbol rate 19.2 kbps. Referring to figure 2.3 data scrambling is accomplished by performing the modulo-2 addition of the interleaver output with the decimated binary value of the long code. The long code is a PN sequence with period 2^{42}-1 that is used for scrambling on the forward CDMA channel (i.e. paging and forward traffic channels) and spreading on the reverse CDMA channel (i.e. access and reverse traffic channels).

The long code mask is a 42-bit binary number that creates the unique identity of the long code. Each PN chip of the long code is generated by the modulo-2 inner product of a 42-bit mask and the 42 bit LFSR stage in the long code generator. The long code operating at 1.2288 MHz clock rate is equivalent to the PN chip sequence which is the output of the long code generator. Note that a PN chip is defined as one bit in the PN sequence. When the long code is divided into every 64 bits is used for data scrambling at a 19.2 kbps rate. The function of the decimator in figure 2.3 is to reduce the size of the long code by taking one out of every 64 ($=1.2288\times10^6$ / 192×10^2) bits.

The base station does not insert a power control sub channel on the paging channel. But a power control sub channel on the forward traffic channel continuously transmits the power control bits at a rate of 800 bps, i.e. one bit (0 or 1) every 1.25ms (=1/800). A '0' power control bit indicates to the mobile station that it should increase the mean output power control level, and a '1' power control bit indicates to the mobile station that it should decrease the mean output power level. Thus the mobile station will adjust its mean output power level in response to each valid power control bit received on the forward traffic channel.

2.4.2 Reverse link

The reverse CDMA channel is composed of access channels and reverse traffic channels. Figure 2.4 shows the overall structure of the reverse CDMA channel.

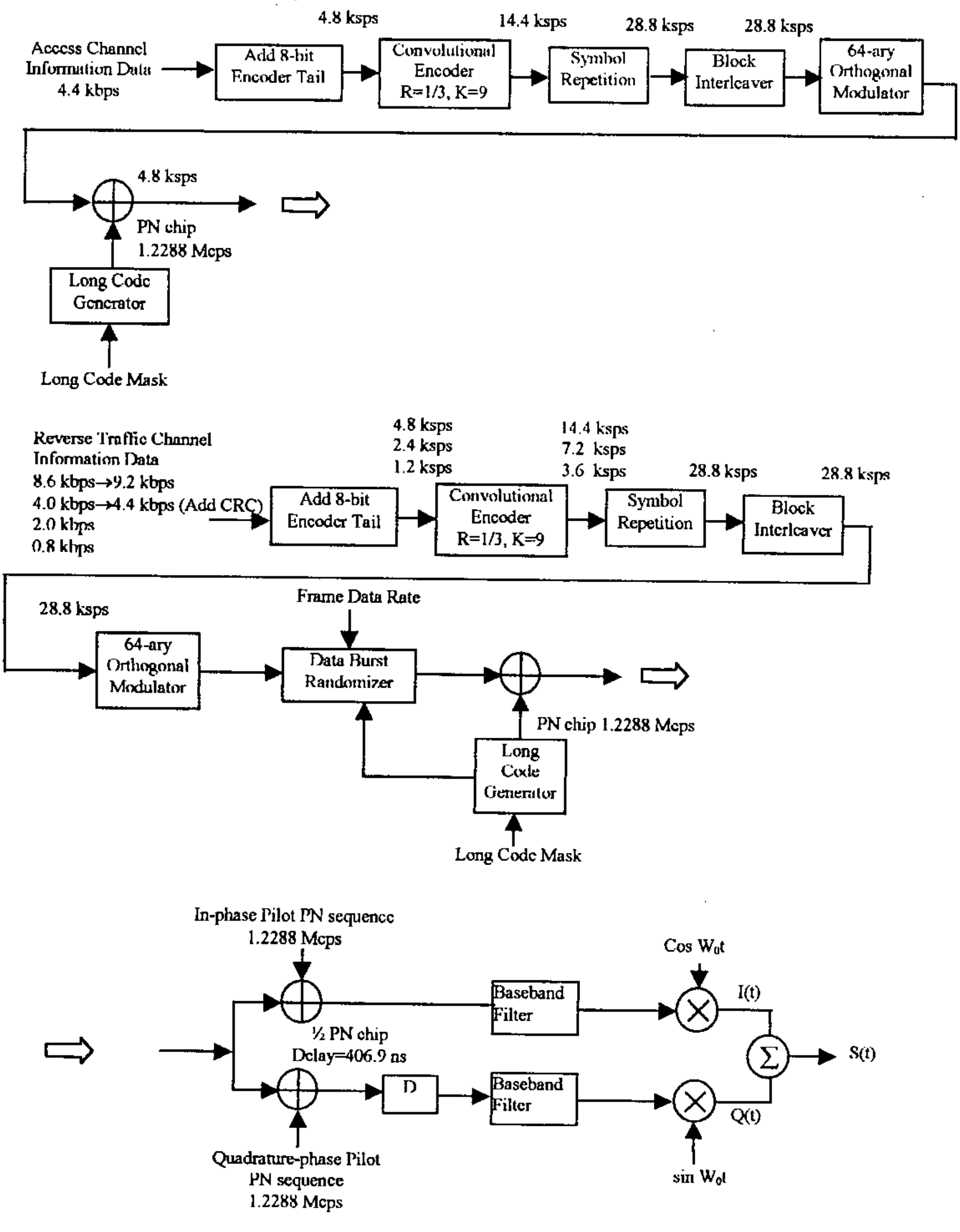


Figure 2.4 : CDMA reverse link structure.

Data transmitted on the reverse CDMA channel is grouped into 20 msec frames. All data transmitted on the reverse CDMA channel is convolutionally encoded for random-error correction, block interleaved for protection from burst errors, modulated by the 64- ary Walsh codes, consisting of each 64 chips long, and direct sequence spread by the long code of period 2^{42}-1 chips prior to transmission.

The data burst randomizer is not used when the mobile station transmits on the access channel. But in the reverse traffic channel, the data burst randomizer generates a masking pattern of 0s and 1s that randomly masks out the redundant data generated by the code repetition. The reverse traffic channel and the access channel are direct sequence spread by the long code. This spreading operation involves modulo-2 addition of the output stream from the data burst randomizer and the long code. Following the direct sequence spreading, the reverse traffic channel and access channel are spread in quadrature as shown in figure2.4. Notice that the Q-channel data spread by the quadrature phase pilot PN sequence is delayed by half of a chip time (406.9 ns) with respect to the I-channel data spread by the in phase pilot PN sequence.

Data transmitted on either the reverse CDMA channel or the forward CDMA channel are grouped in 20 ms frame. [Reference: Dr. Man Young Rhee, CDMA Cellular Mobile Communications and Network Security. Prentice Hall PTR, 1998].

2.5 CHARACTERISTICS AND FUNCTION OF CDMA CHANNEL LINK

Sinee CDMA uses forward and reverse channels, functional relationships exist between the base station and the mobile station in a cell coverage area. The following summary explains the functions of the base/ mobile stations and the characteristics of all code channels in the CDMA channel. This brief survey includes system acquisition, timing, synchronization, interleaving, orthogonal channelization, spreading techniques, power control, call processing, handoff procedures, authentication and message privacy.

Four overhead messages are conveyed between the base and mobile station in order to meet the required functions in the CDMA cellular system is given in table 2.1.

Table 2.1 Overhead messages of CDMA channel link.

System parameter messages	Contains paging channel, registration parameters, parameter to aid pilot acquisition, etc.
Access parameter message	Contains access channel and control parameters. Some of these control parameters provide dynamic feedback to the mobile station to control its transmission rate, and thus serves to stabilize the access channel.
Neighbour list message	Contains information to speed handoff to a neighboring base station, including the time offset of the pilot PN and the basic neighbor configuration.
CDMA channel list message	Lists CDMA frequency assignments that contain paging channels. This allows the mobile station to correctly determine where to find its paging channel.

Reference: Dr. Man Young Rhee, CDMA Cellular Mobile Communication and Network security. Prentice Hall PTR, 1998.

2.6 LINK BUDGET

The equipment necessary for cellular network is called link budget. The BTS equipment are given in below.

(a) BTS basic and expansion racks are:

1. LED
2. FAN
3. RF Shelf
4. COM Shelf
5. HPA Shelf

(b) Primary antenna

(c) Secondary antenna

(d) GPS antenna

Redundancy configuration of BTS cards are given in the table 2.2.

Table 2.2 Redundancy configuration of BTS cards

Shelf Name	Card Name	Redundancy configuration	Protection method
	FRC	1 + 1	Hot standby
	TRX	1 + 1	Hot standby
RF shelf	MDC	N + 1	Cold standby
	BTSC	1 + 1	Cold standby
	ADC	1 + 1	Hot standby
	LTC	1 + 1	Hot standby
	T-HYB	Not applied	
	R-HYB	Not applied	
	LNA	Space diversity	
COM shelf	GPSR	Parallel running	Hot standby
	RSD	Parallel running	Hot standby
	HKC	Not applied	
	HPA	Parallel running	Parallel operation

Hot standby: Communication service will be maintained by the protection switching operation even if short interruption will occur.

Cold standby: Communication service will not be maintained by the protection switching operation.

The BSC equipment are given in below.

(a) BDP Shelf
(b) ASP Shelf
(c) VHP Shelf
(d) CCP Shelf

Redundancy configuration at BSC cards are given in the table 2.3.

Table 2.3 Redundancy configuration at BSC cards.

Shelf Name	Card Name	Redundancy configuration	Protection method
	ASW	1 + 1	Hot standby
	ASI	1 + 1	Hot standby
	ASC	1 + 1	Hot standby
	GCD	Parallel running	Hot standby
ASP	RCD	1 + 1	Hot standby
	TIC	Not applied	
	IOR	1 + 1	Hot standby
	RRS	Not applied	
	IOB	1 + 1	Hot standby
	MPC	N + 1	Hot standby
CCP	DVC	Not applied	
	GCM	1 + 1	Hot standby
	GDM	1 + 1	Hot standby
	OWC	Not applied	
	BDC	1 + 1	Hot standby
	BDR	Not applied	
LTP	BEI	N + 1	Hot standby
	IOR	1 + 1	Hot standby
	SSC	N + 1	Hot standby
	ATC	N + 1	Hot standby
	ATI	1 + 1	Hot standby
	MXI	1 + 1	Hot standby
VHP	MXC	1 + 1	Hot standby
	VHC	Not applied	
	RLC	Not applied	
	SVC	Not applied	
	EIT	Not applied	

Necessary software for BTS and BSC:

BSC

BSC Program File	3M bytes
BSC System Data File	128k bytes (depends on the system scale)
Offline Station Data File	128k bytes (depends on the system scale)
Online Station Data File	512k bytes (depends on the system scale)
Subscriber Data File	

BTS

BTS Program File	640k bytes
MDC Program File	512k bytes
Offline Parameter File	64k bytes (depends on the system scale)
Online Parameter File	64k bytes (depends on the system scale)

2.7 MOBILE STATION IDENTIFICATION NUMBER

The mobile station identification number (MSIN or MIN) is defined according to the International mobile station identity (IMSI) in the ITU-T Recommendation E.212. The IMSI is structured as shown in Figure 2.5.

IMSI may not exceed 15 digits. IMSI consists of two parts. The first part is the Mobile Country Code (MCC) with 3 digits. The next part is the National Mobile Station Identity (NMSI). In this standard, IMSI consists of an MCC of 3 digits, an MNC of 2 digits and an MSIN of 10 digits.

Mobile country code (MCC) 3 digits	Mobile network code (MNC) 2 digits	Mobile station identification number (MIN) 10 digits
	← National mobile station identity (NMSI) →	
← International mobile station identity (IMSI) →		

The mobile station identification number (MSIN)[1], as shown in Figure 2.5, is a 34-bit binary number which is derived from a 10-digit directory telephone number according to the following procedure.

Suppose a 10-digit telephone number is $D_1D_2D_3D_4D_5D_6D_7D_8D_9D_{10}$, where $D_1D_2D_3$ is and area code, $D_4D_5D_6$ denotes a switching station, and $D_7D_8D_9D_{10}$ represents an individual phone number.

1. The first three digits are mapped into 10 bits (corresponding MSIN2) by the following coding algorithm:
   - Represent the 3-digit field as $D_1D_2D_3$ with the digit 0 having the value 10.
   - Compute $100\,D_1+10D_2+D_3-111$.
   - Convert the result computed above to binary using a standard decimal-to-binary conversion.

2. The second three digits are mapped into the 10 most significant bits of MSIN1by the coding algorithm described in (1) above.

3. The last four digits are mapped into the 14 least-significant bits of MSIN1 as follows:
   - The first digit should be mapped into four bits by a Binary-Coded-Decimal (BCD) conversion.
   - The last three digits are mapped into 10 bits by the coding algorithm described in (1).

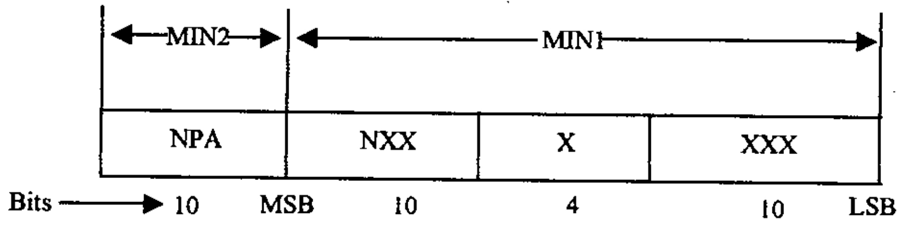


Figure 2.5 Mobile station identification number (MIN).

CHAPTER- 3

ELEMENTS REQUIRED FOR CDMA CHANNEL OPERATION

3.1 INTRODUCTION

The forward CDMA channel consists of the pilot channel, sync channel, paging channels, and forward traffic channels. Each of these code channels is orthogonally spread by the appropriate Walsh function and is then spread by a quadrature pair of pilot PN sequences at a fixed chip rate of 1.2288 Mcps.

The reverse CDMA channel is composed of access channels and reverse traffic channels. All data transmitted on the reverse CDMA channel is convolutionally encoded, block interleaved, modulated by the 64-ary orthogonal modulation, and direct-sequence spread by the long code prior to transmission.

This chapter defines several prerequisites that are essential elements for CDMA channel operation.

3.2 VOCODER

For the most part, the encoding/decoding algorithms have been concerned primarily with reproducing the input waveform as accurately as possible. Thus they assume little or knowledge of the nature of the signal they process and are basically applicable to any signal occurring in a voice channel. Exceptions occur when sub band coding and adaptive predictive coding are designed for relatively low bit rates (20 kbps or less). At these bit rates the encoders have been closely tailored to the statistics of a speech signal and cannot provide comparable quality for other signals.

The digitization procedures described in this section very specifically encode speech signals and speech signals only. For this reason these techniques are referred to collectively as "Vocoders", an acronym for voice coders. Since these techniques are designed specifically for voice signals, they are not applicable to portions of the public telephone network in which other analogue signals (such as modem signals) must be accommodated. Further more, vocoders typically produce unnatural or synthetic sounding speech.

The basic goal of a vocoder is to encode only the perceptually important aspects of speech with fewer bits than the more general waveform encoders. Thus they can be used in limited bandwidth applications where the other techniques cannot.

CDMA Vocoder:

- Speech from PSTN is digitzed into low bit rate data.
- IS-95 specifies two basic data rat sets: 8 kbps and 13 kbps for full rate speech. With more bits added for detection, the data to be transmitted has a rate of 9.6 kbps or 14.4 kbps, respectively.
- IS-95 also specifies variable rate transmission so that lower rate transmission is possible when the speaker is not talking.
- The vocoder will automatically adjust the data rate as the voice activity changes. A decision on the data rate is made every 20 msec.
- Four rates are specified in each rate set: full rate, ½ rate, ¼ rate and 1/8 rate.

Some of the main applications for vocoders are recorded messages, encrypted voice transmission over narrowband HF radio, digital cellular radio, analogue telephone circuits, computer output, and games.

The most basic vocoding techniques are:

The channel vocoder

The formant vocoder and

The linear predicative coder.

3.3 ERROR CHECK METHOD (CYCLIC REDUNDANCY CHECK)

Input Data: $D(x) = x^n + x^{n-1} + x^{n-2} + \dots\dots\dots + x + 1$

Generator Polynomial: $G(x) = x^m + x^{m-1} + x^{m-2} + \dots\dots\dots + x + 1$

Put;

$$\begin{aligned} H(x) &= x^m \,.\, D(x) / G(x) = x^m \,.\, (x^n + x^{n-1} + x^{n-2} + \dots\dots + x + 1 \\ &= Q(x) \,.\, G(x) + x^k + x^{k-1} + x^{k-2} + \dots\dots\dots + x + 1 \;;\; k<m \\ &= Q(x) \,.\, G(x) + R(x) \end{aligned}$$

Where Residue : $R(x) = x^k + x^{k-1} + x^{k-2} + \ldots\ldots\ldots + x + 1$

Transmit Data : $F(x) = x^m . D(x) + R(x) = Q(x) . G(x) + R(x) + R(x)$

Modulo 2 [Residue of $x^m . D(x) / G(x) + R(x)$] = Modulo 2[$R(x) + R(x)$] = 0

$x^m . (x^n + x^{n-1} + x^{n-2} + \ldots\ldots + x + 1)$	$x^k + x^{k-1} + x^{k-2} + \ldots\ldots + x + 1$
Information bits sequence	Frame check sequence

Received Data : $F'(x) = [x^m . D(x) + R(x)]'$

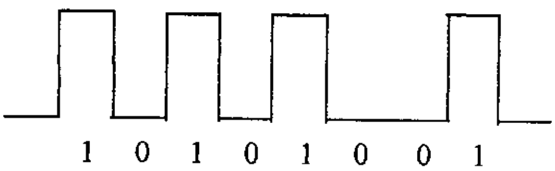
CRC Check : $F'(x) / G(x) = [x^m . D(x) + R(x)]' / G(x)$

If there is no error bit, residual of $F'(x) / G(x)$ should be zero.

If there is one error bit, residual of $F'(x) / G(x)$ will be $x^r + x^{r-1} + x^{r-2} + \ldots\ldots + x + 1$.; $r<m$

Transmitter side

Information Bit sequence



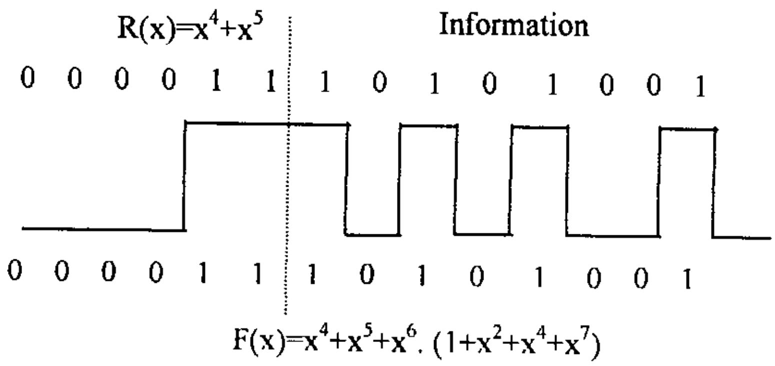
Cyclic Redundancy Code Generator

$$G(x) = 1 + x^2 + x^4 + x^5$$

$$\frac{x^6 . D(x)}{G(x)} = \frac{x^6 . (1 + x^2 + x^4 + x^7)}{1 + x^2 + x^4 + x^6}$$

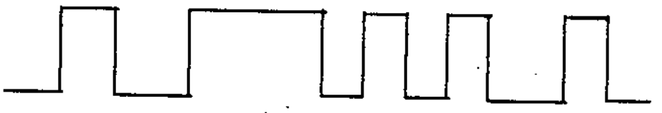
$$= x^4 + x^5 + x^7, \textit{ with residue } x^4 + x^5$$

$$R(x) = x^4 + x^5 : \text{Residue.}$$



Transmited Bit sequence

Receiver side



0 1 0 0 1 1 1 0 1 0 1 0 0 1

$F(x) = x + x^4 + x^5 + x^6 +. (1 + x^2 + x^4 + x^7)$

Received bit sequence

Cyclic Redundancy Code Check

$$G(x) = 1 + x^2 + x^4 + x^6$$

$$\frac{F(x)}{G(x)} = \frac{x + x^4 + x^5 + x^6 + x^8 + x^{10} + x^{13}}{1 + x^2 + x^4 + x^6}$$

$x + x^2 + x^3 + x^4 + x^5 + x^7$, *with residue* $x + x^2 + x^4 + x^5$ → One Errored Bit

3.4 CHANNEL VOCODER

Channel vocoders ware first developed in 1928 by Homer Dudley. Dudley's original implementation compressed speech waveforms into an analogue signal with a total bandwidth of about 300 Hz. Based on the original concept, digital channel vocoders have been developed operating in the range of 1 to 2 kbps.

A major part of the encoding process of a channel vocoder involves determining the short-term signal spectrum as a function of time. As indicated in figure 3.1 a bank of band pass filters is used to separate the speech energy into sub bands that are full wave rectified and filtered to determine relative power levels. The individual power levels are encoded and transmitted to the destination.

In addition to measuring the signal spectrum, modern channel vocoders also determine the nature of speech excitation (Voice or unvoiced) and the pitch frequency of voiced sounds. The excitation measurements are duse to synthesize the speech signal in the decoder by passing an appropriately selected source signal through a frequency domain model of the vocal tract transfer function.

Voice excitation is simulated by a pulse generator using a repetition rate equal to the measured pitch period. Unvoiced excitation is simulated by a noise generator. Owing to the synthesized nature of the excitation, this form of a vocoder is sometimes referred to as a pitch excited vocoder.

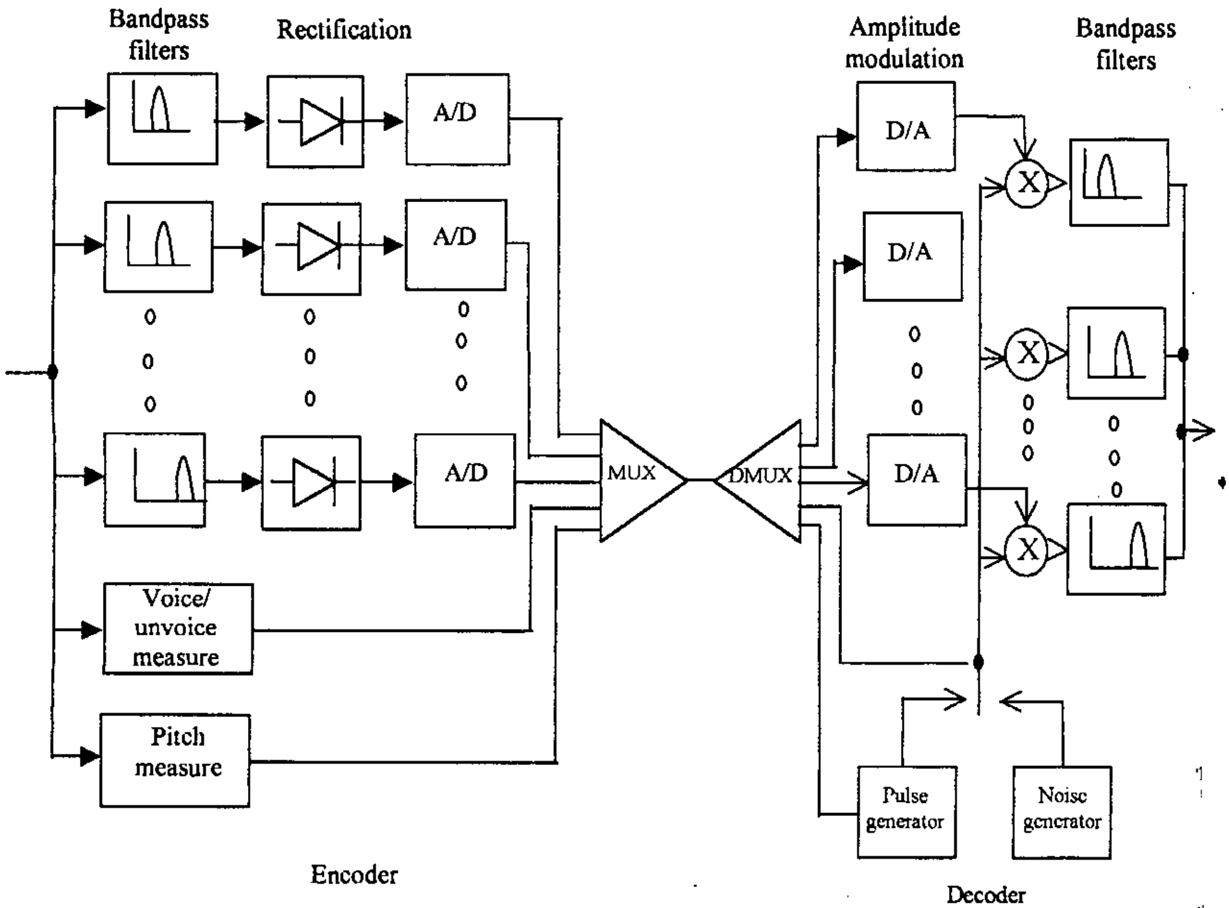


Figure 3.1 Channel vocoder.

As indicated in figure 3.1 a decoder implements a vocal tract transfer function as a bank of band pass filters whose input power levels are determined by respective subband power levels in the encoder. Thus outputs of each band pass filter in the decoder correspond to outputs of respective band pass filters in the encoder. Superposing the individual bands recreates in a spectral sense, the original signal.

The most difficult aspect of most vocoder realizations involves determining the pitch of voiced sounds. Further more, certain sounds are not clearly classifiable as purely voiced or purely unvoiced. Thus a desirable extension of the basic vocoder involves more accurate characterization of the excitation. Without accurate excitation information, vocoder output quality is quite poor and often dependent on both the speaker and the particular sounds being spoken. Some of the more advanced channel vocoders have produced highly intelligible, although somewhat synthetic sounding, speech at 2400 bps.

[Reference: John Bellamy, "Digital Telephony". Second Edition, John Wiley & Sons. INC., New York, Chap. 9, PP. 147-153, 1991.]

3.5 CONVOLUTIONAL ENCODING

Modern digital communication systems are often designed to transmit at very high data rates. Convolutional codes have been applied in many diverse system. For example, convolutional encoding/decoding has found application in not only CDMA mobile communications, but many space and satellite communications. To protect such systems from errors, convolutional codes are often used. The information data sequence divides it into much smaller blocks of length k and is encoded into codeword symbols of length n. An (n, k, m) convolutional code is implemented with a k-input, n-output linear sequential circuit with the memory order m. In general, n and k are small integers with k <n, but m is relatively large. In particular, when k=1, the information sequence is not divided into blocks so that the data sequence can be processed continuously. Therefore, the advance of convolutional coding spawned a number of practical applications to digital transmission over wire and radio (wireless) communication channels.

An (n, k, m) convolutional code designates the code rate R=k/n with encoder stages of m=k-1, where k is the constraint length of the code. The encoder memory order m is equal to the length of the data sequence delay. A set of n generator sequences for an m-stage encoder is generally described by

$$g_i^{(J)} = (g_{i,0}^{(J)}, g_{i,1}^{(J)}, ------------------ g_{i,m}^{(J)}) \quad (3.1)$$

Where i =1,2,........., k stands for the number of input terminals and j=1, 2, ...n for the number of modulo-2 adders (output terminals).

Equation (1) also can be expressed in the polynomial from as

$$g_i^{(j)}(D) = \sum_{\lambda=0}^{m} g_{i,\lambda}^{(j)} D^{\lambda} \tag{3.2}$$

Where D is the delay operator, and the power of D of each term corresponds to the number of units of delay for that term.

Each generator sequence is directly determined by the sequence of connections from the encoder stages to the respective modulo-2 adder, 1 representing a connection and 0 representing no connection.

The components of each generator sequence consist of (m+1) binary digits.

If the information sequence $d^{(i)} = (d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, \ldots\ldots\ldots\ldots)$ enters the encoder one bit at a time, then the encoder output sequence

$C^{(j)} = (C_0^{(j)}, C_1^{(j)}, C_2^{(j)}, \ldots\ldots\ldots\ldots)$ can be obtained by combining the discrete convolution of $d^{(i)}$ with $g_i^{(j)}$ such that.

$$C^{(j)} = \sum_{i=1}^{k} d^{(i)} * g_i^{(j)}, j = 1, 2, \ldots\ldots\ldots\ldots, n)$$

Where,

$$C_\lambda^{(j)} = \sum_{i=1}^{m} \sum_{i=1}^{k} d_{\lambda-i}^{(j)} g_{i,l}^{(j)}, l = 0, 1, \ldots\ldots\ldots\ldots, \lambda)$$

The base station convolutionally encodes the data transmitted on the forward DCMA channel, ie, sync, paging and forward traffic channels. The forward CDMA channel uses the (2,1,8) convolutional code representing a code rate R=1/2 and a constraint length of 9.

The generator sequences for this code are

$$g_1^{(1)} = 753(\text{octal}) = (111101011)(\text{binary})\text{and}$$

$$g_1^{(2)} = 561(\text{octal}) = (101110001)(\text{bainary}),\text{since a code rate is}\frac{1}{2},$$

two code symbols (output) are generated from each input data bit to the encoder.

The first output symbol $C_\lambda^{(1)}$ after initialization is a code symbol encoded with the generator sequence $g_1^{(1)}$ and the second output symbol $C_\lambda^{(2)}$ is a code symbol encoded with the generator sequence $g_1^{(2)}$.

As shown in fig. 3.2 convolutional encoding involves the modulo-2 addition of selected taps of a serially time-delayed data sequence.

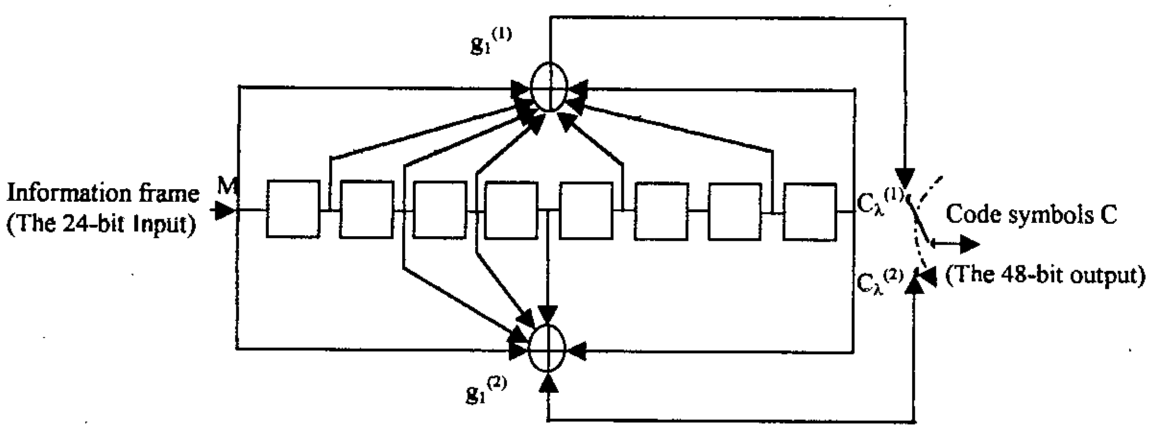


Figure 3.2 Convolutional encoding.

For the forward CDMA channel, each convolutionally encoded symbol is repeated K times prior to block interleaving whenever the information rate is lower than 9600 bps, as shown below.

Table 3.1 Repeating times for convolutionally encoded symbol.

Channel	Information rate (bps)	Repeating times (K)	Code repetition
Sync	1200	1	2
Paging	4800 9600	1	2
Forward traffic	1200 2400 4800 9600	7 3 1 0	8 4 2 1

3.6 BLOCK INTERLEAVING

Direct sequence spread spectrum CDMA supports simultaneous services for digital communication among a considerably higher community of users than any single user. This will be reflected in how this excess of dimensionality or redundancy is exploited to improve performance. Two processing techniques are considered to achieve improvements: interleaving for the excess redundancy and forward error-correcting coding.

Interleaving is the process of permuting a sequence of symbols. This reordering procedure to achieve time diversity is called interleaving and can be considered in two ways: Block interleaving and Convolutional interleaving. Interleaving also can be an effective technique to design codes for correcting multiple bursts or long bursts.

All symbols after repetition on the sync, paging, and forward traffic channels are block interleaved. The sync channel uses a block interleaver where the input symbol sequence is given in table 3.2.

Table 3.2 Sync channel Interleaver input (Array write operating)

1	9	17	25	33	41	49	57
1	9	17	25	33	41	49	57
2	10	18	26	34	42	50	58
2	10	18	26	34	42	50	58
3	11	19	27	35	43	51	59
3	11	19	27	35	43	51	59
4	12	20	28	36	44	52	60
4	12	20	28	36	44	52	60
5	13	21	29	37	45	53	61
5	13	21	29	37	45	53	61
6	14	22	30	38	46	54	62
6	14	22	30	38	46	54	62
7	15	23	31	39	47	55	63
7	15	23	31	39	47	55	63
8	16	24	32	40	48	56	64
8	16	24	32	40	48	56	64

Since Table 3.2 consists of 16 rows by 8 columns, it contains 128 modulation symbols at the modulation symbol rate of 4800 Sps. Hence the interleaver time span is 128/8400=26.66 msec. Table 3.2 is read down by columns from the left to the right. The first input symbol "1" is at the top left, the second input symbol "1" is just below the first input symbols, the 17^{th} input symbol "9" is just to the right of the first input symbol, and the last input symbol "64" is located at the rightmost bottom corner. On the other hand, the output symbol sequence is given in Table 3.3. The table is read the same way as table 3.2.

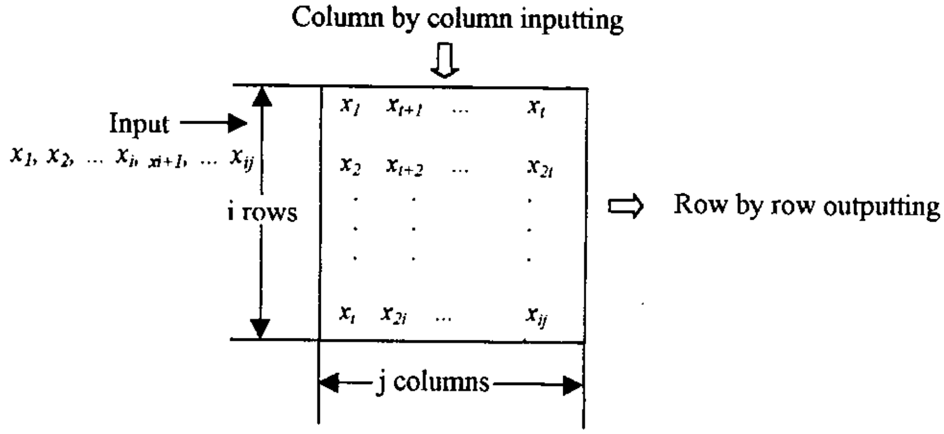
Table 3.3 Sync channel Interleaver output (Arrary read operation)

1	3	2	4	1	3	2	4
33	35	34	36	33	35	34	36
17	19	18	20	17	19	18	20
49	51	50	52	49	51	50	52
9	11	10	12	9	11	10	12
41	43	42	44	41	43	42	44
25	27	26	28	25	27	26	28
57	59	58	60	57	59	58	60
5	7	6	8	5	7	6	8
37	39	38	40	37	39	38	40
21	23	22	24	21	23	22	24
53	55	54	56	53	55	54	56
13	15	14	16	13	15	14	16
45	47	46	48	45	47	46	48
29	31	30	32	29	31	30	32
61	63	62	64	61	63	62	64

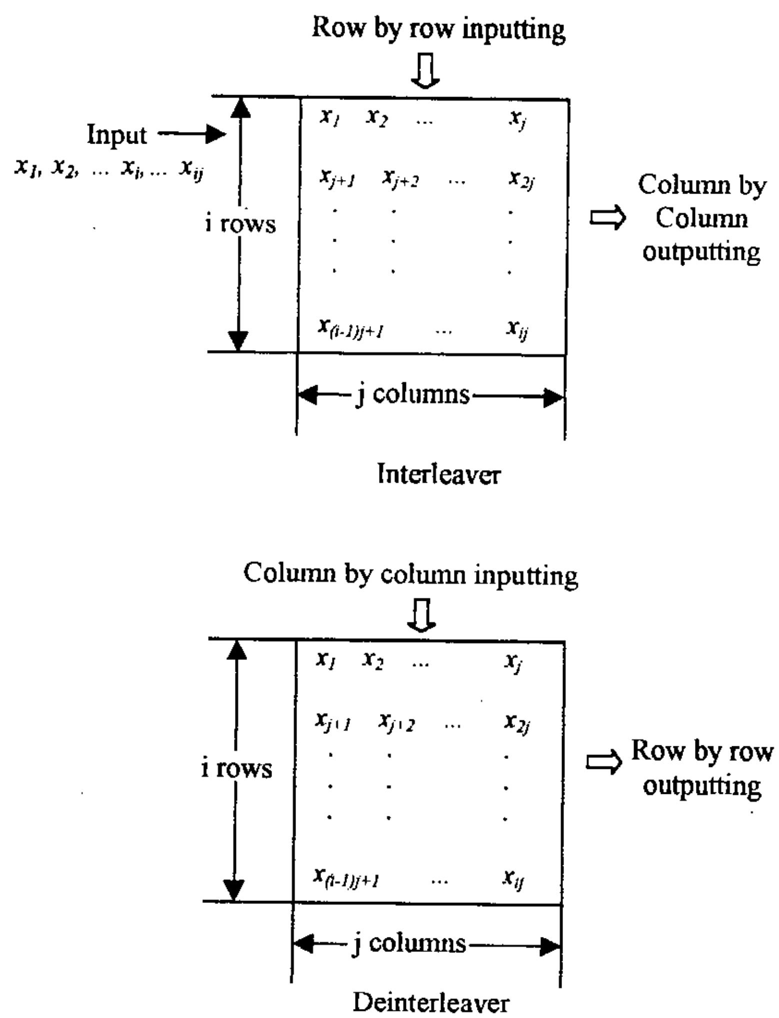
The repeated code symbols are written into the interleaver by columns filling the complete 16×8 matrix. This sync channel interleaver is an array with 16 rows and 8 columns, i.e., 128 cells. Thus we can say that the sync channel uses a block interleaver spanning 26.66 ms which is equivalent to 128 modulation symbols at the symbol rate of 4800 Sps.

Similarly, the paging and forward traffic channels use a block interleaver matrix of 24 rows by 16 columns equivalent to 384 modulation symbols at the modulation symbol rate of 19200 Sps. Now we see that the interleaver time span is 384/19200=20 ms.

Block interleaving is the data reordering procedure which can be considered as follows: Interleaved output symbols as long with i times as many coded symbols from the convolutional encoder can be achieved by interleaving (or interlacing), as shown in tables 3.2. and 3.3.



(a)



(b)

Figure 3.3 Block Interleaver.

If the convolutional code corrects random errors, the interleaved code corrects single bursts of length j or less.

3.7 ORTHOGONAL SPREADING USING WALSH FUNCTIONS

Each code channel transmitted on the forward CDMA channel is spread with a Walsh function at a fixed chip rate of 1.2288 Mcps to provide orthogonal channelization among all code channels. Modulation for the reverse CDMA channel is 64-ary orthogonal modulation. The modulation symbol is one of 64 mutually orthogonal waveforms generated using Walsh functions. One of 64 possible modulation symbols is transmitted for each six symbols, i.e., c_i, $0 \le i \le 5$.

Using a Hadamard matrix H_n, where n is a power of 2, i.e., $n=2^m$, Walsh functions are constructed to be shown as follows: A Hadamard matrix is an orthogonal n x n matrix of the entries + 1 and –1 with the property that any row differs from any other row in exactly $n/2$ positions. One row of the matrix contains all + 1s. The other rows contain evenly the + 1s and –1s of $n/^2$ each. Futhermore, all the entries in the first row and the first column of H_n have all + 1s. The n x n Hadamard matrices can exist only if n is a power of 2.

By changing the + 1 to 0s and the –1 to 1s, the Hadamard matrix for n=2 can be expressed by

$$H_2 = \begin{bmatrix} +1+1 \\ +1-1 \end{bmatrix} = \begin{bmatrix} 00 \\ 01 \end{bmatrix}$$

The Hadamard matrix for $n=2^6$ is the 64 x 64 orthogonal Walsh function Appendix-C. This 64 by 64 matrix can be generated by means of the following recursive procedure: For $n=2^m$, $0 \le m$ (a positive integer),

$$H_1 = 0 \qquad for\ m = 0$$

$$H_2 = \begin{bmatrix} H_1\, H_1 \\ H_1\, \overline{H_1} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \quad for\ m = 1$$

$$H_4 = \begin{bmatrix} H_2\, H_2 \\ H_2\, \overline{H_2} \end{bmatrix} = \begin{bmatrix} 0\,0\,0\,0 \\ 0\,1\,0\,1 \\ 0\,0\,1\,1 \\ 0\,1\,1\,0 \end{bmatrix} \quad for\ m = 2$$

$$H_8 = \begin{bmatrix} H_4\, H_4 \\ H_4\, \overline{H_4} \end{bmatrix} = \begin{bmatrix} 00000000 \\ 01010101 \\ 00110011 \\ 01100110 \\ 00001111 \\ 01101010 \\ 00111100 \\ 01101001 \end{bmatrix} \quad for\ m = 3$$

$$H_{2n} = \begin{bmatrix} H_n\, H_n \\ H_n\, \overline{H_n} \end{bmatrix}$$

Where $2n=2^{m+1}$ and H_n denotes the binary complement of H_n. The rows of Walsh matrix H_{64} form a linear binary code of block length n=64 and the minimum distance $d_{min}=n/2=32$.

Each code channel transmitted on the forward CDMA channel is spread with a Walsh function at a fixed chip rate of 1.2288 Mcps to provide orthogonal channelization among all code channels. The Walsh function spreading sequence is repeated with a period of 52.083 (=64/1.2288 Mcps) μs which is equal to the duration of one forward traffic channel modulation symbol.

Therefore, a code channel spread by using the Walsh function n (the row n of Hadamard Walsh matrix) is assigned to code channel number n ($0 \le n \le 63$). Code channel number zero is always assigned to the pilot channel. If the sync channel is present, it is assigned code channel number 32. If paging channels are present, they are assigned to code channel number one through seven in sequence. The remaining code channels are available for assignment to the forward traffic channels. Thus, each of these code channels is orthogonally spread by the appropriate Walsh function and is then spread by the quadrature pair of pilot PN sequences at a fixed chip rate 1.2288 Mcps.

For the reverse CDMA channel, the modulation symbol will be one of 64 mutually orthogonal waveforms generated using Walsh functions. Since the code symbol rate at the interleaver output is 28.8 ksps, the symbol rate at the orthogonal modulator output becomes 4.8 ksps or 307.2 kcps. These modulation symbols numbered 0 through 63 are selected according to the following formula:

$$MSI = c_0 + 2c_1 + 4c_2 + 8c_3 + 16c_4 + 32c_5$$

where MSI denotes the modulation symbol index; and c_i, $0 \le i \le 5$, represent each group of six code symbols output from the block interlever. Six code symbols are associated with one modulation symbol. The period of time required to transmit a single modulation symbol is equal to 1/4800=208.333μs. The period of time associated with 1/64 of the modulation symbol is referred to as a Walsh chip and will be equal to 1/(4800 x 64) = 1/307200 = 3.255μs. Within a Walsh code, Walsh chips are transmitted in the order of 0, 1, 2, ……., 63.

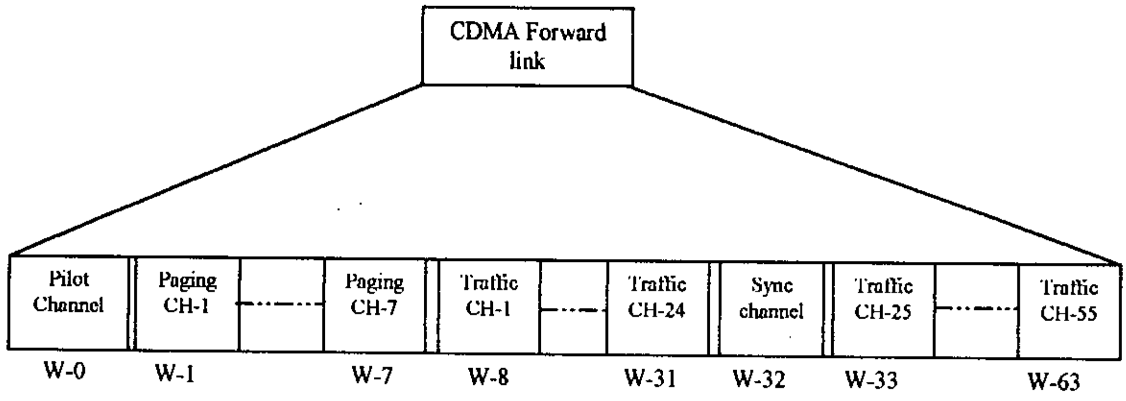


Figure 3.4a Walsh code assignment to forward traffic channel

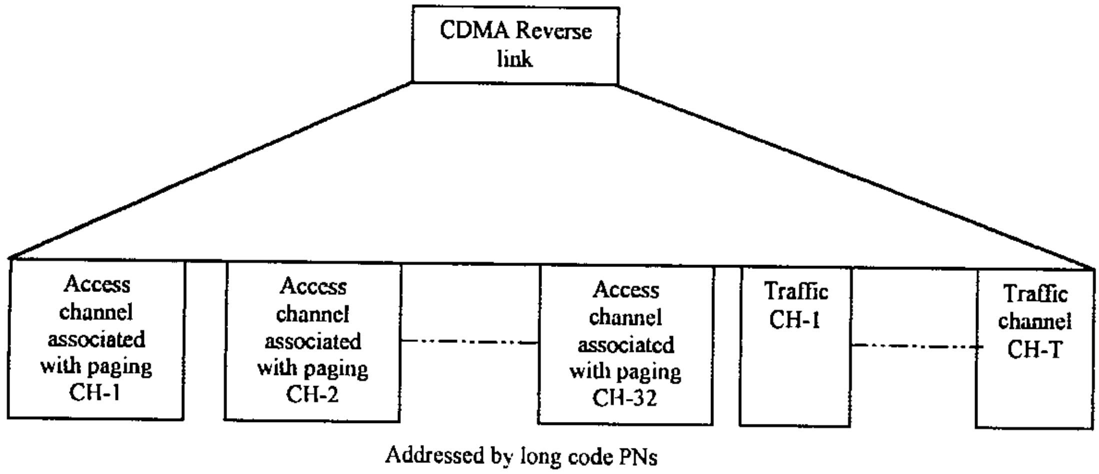


Figure 3.4b Walsh code assignment to reverse traffic channel.

3.8 DIRECT SEQUENCE SPREADING

The reverse traffic channel and the access channel on the reverse CDMA channel will be direct sequence spread by the long code to provide limited privacy. For the reverse traffic channel, the direct sequence (DS) spreading operation involves modulo-2 addition of the data burst randomizer output and the long code. The data burst randomizer generates a masking pattern of 0s and 1s that randomly masks out the redundant data generated by the code repetition. The masking pattern is determined by the data rate of the frame and by a block of the last 14 bits taken from the long code. For the access channel, the DS spreading operation involves modulo-2 addition of the 64-ary orthogonal modulator output and the long code.

Let $d_w(t)$ be the data sequence modulated by Walsh chips and T_b be the data bit time interval. The Walsh modulated data sequence is modulo-2 added by the spreading PN chips of the long code $c(t)$. Each pulse of $c(t)$ is called a chip and T_c denotes the chip time interval such that $T_b=4T_c$. The rate of the spreading PN sequence is fixed at 1.2288 Mcps. Since six code symbols are modulated by one of 64 time-orthogonal Walsh functions, the modulated symbol transmission rate is fixed at 28.8/6=4.8 ksps. Therefore, each Walsh chip is spread by four PN chips, that is, $1.2288 \times 10^6 / 307.2 \times 10^3 = 4$.

The direct sequence spreading of $d_w(t)$ by the long code PN chips of 1.2288 Mcps is shown in Fig. 3.5.

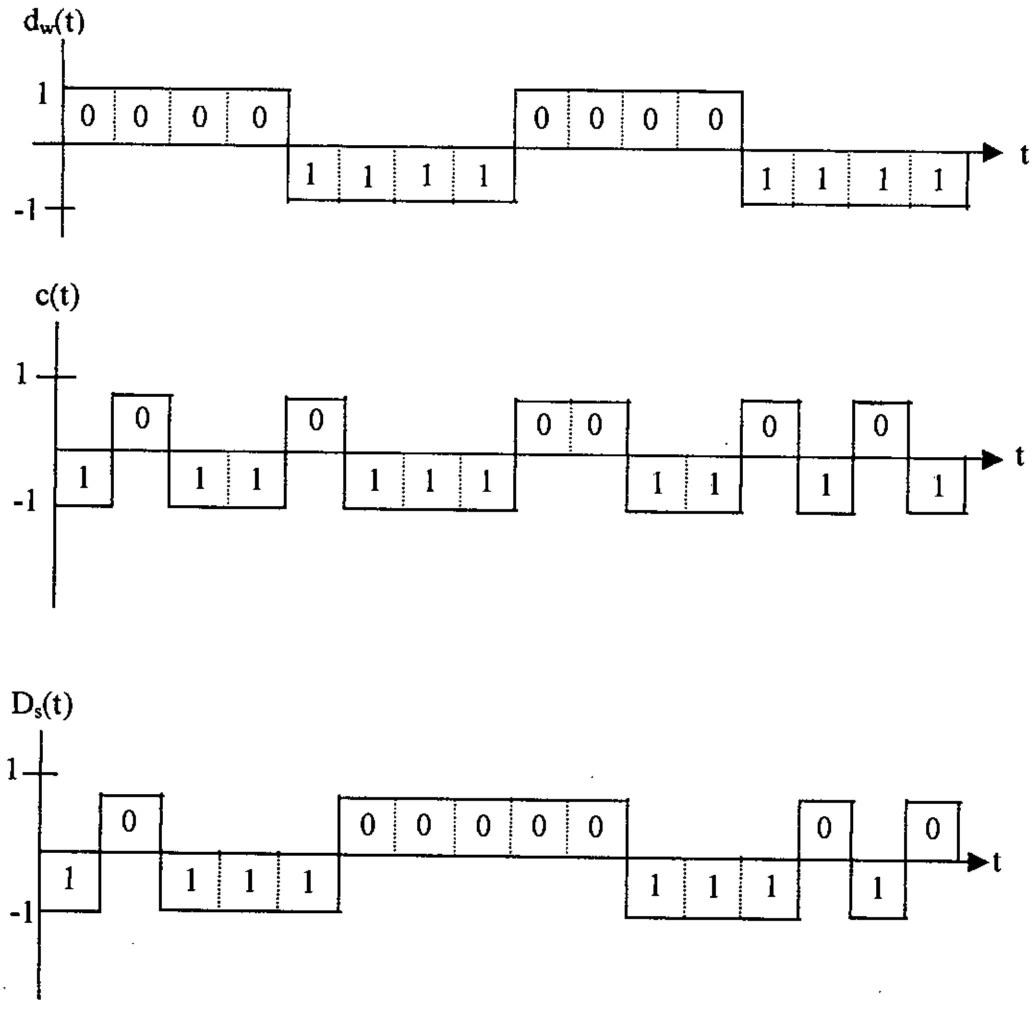


Figure 3.5 Direct sequence spreading of $d_w(t)$ by the long code PN chips $c(t)$.

3.9 QPSK AND OFFSET QPSK MODULATION

A spectrally efficient modulation technique for CDMA channels to maximize bandwidth efficiency requires simultaneous transmission on two carriers which are in phase quadrature. Quadrature modulation is of primary importance in a spread-spectrum system and is less sensitive to some types of jamming.

Let $d(t) = d_0, d_1 d_2, \ldots$ be the original data stream, $d(t)$ is bipolar pulses representing binary one (-1) or zero (+1) as shown in Fig 3.6 (a). This pulse data stream is divided into an in-phase stream $d_I(t) = d_0, d_2, d_4 \ldots$ (even bits) and a quadrature-phase stream $d_Q(t) = d_1, d_3, d_5, \ldots$ (odd bits) as illustrated in Figs 3.6 (b) and 3.6 (c). We notice here that $d_I(t)$ and $d_Q(t)$ have half the bit rate of $d(t)$, respectively.

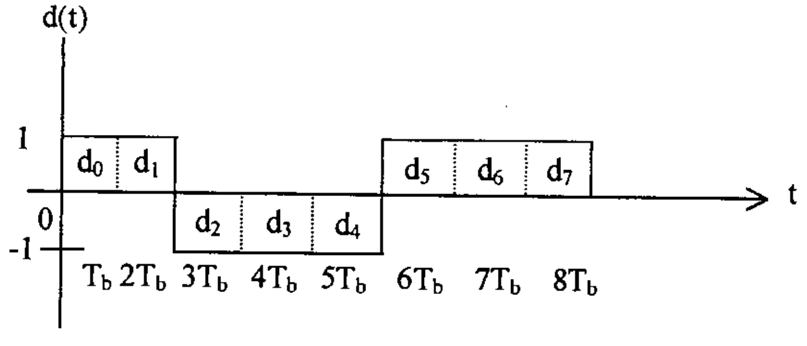


Figure 3.6a Original data stream $d(t)$

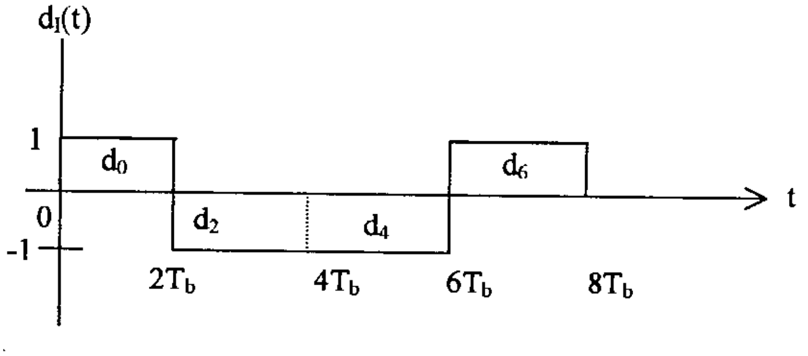


Figure 3.6b In-phase stream $d_I(t)$

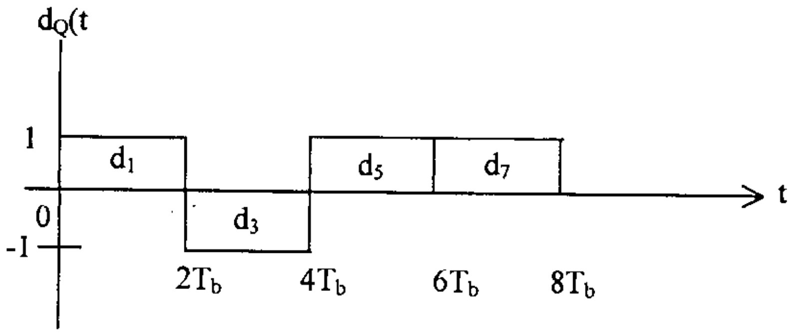


Figure 3.6c Quadrature-phase stream $d_Q(t)$

An orthogonal QPSK waveform *s(t)* is obtained by amplitude modulating $d_I(t)$ and $d_Q(t)$ each onto the cosine and sine functions of a carrier wave as shown in Fig 3.7.

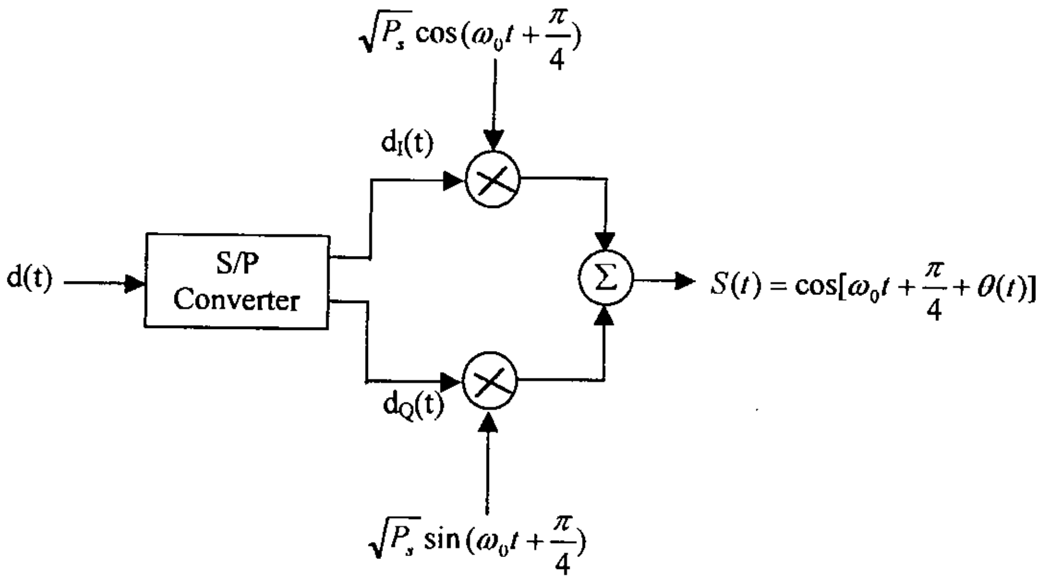


Figure 3.7 QPSK spread-spectrum modulator.

$$s(t)=\sqrt{P_s}\,d_I(t)\cos(\omega_0 t+\frac{\pi}{4})+\sqrt{P_s}d_Q(t)\sin(\omega_0 t+\frac{\pi}{4})$$

$$=\sqrt{2P_s}\,(\cos(\omega_0 t+\frac{\pi}{4})+\cos\theta(t)-\sin(\omega_0 t+\frac{\pi}{4})\sin\theta(t))$$

$$=\sqrt{2P_s}\,\cos[\omega_0 t+\frac{\pi}{4})+\theta(t)]$$

$$where \cos\theta(t)=d_I(t)/\sqrt{2}\ and \sin\theta(t)=-d_Q(t)/\sqrt{2}$$

$$whence\, \theta(t)=-\tan^{-1}(d_Q(t)/d_I(t)).$$

The in-phase stream $d_I(t)$ amplitude-modulates the cosine function with an amplitude of +1 (binary zero) or −1 (binary one), which produces a BPSK waveform. Similarly, the quadrature-phase stream $d_Q(t)$ modulates the sine function, resulting in a BPSK waveform orthogonal to that due to the cosine function. Thus, the summation of these two orthogonal components of the carrier yields the QPSK waveform.

Since both spreading waveforms, $d_I(t)$ and $d_Q(t)$, are only taken on values of ± 1, these spreading waveforms are assumed to be chip synchronous but otherwise totally independent of one another. The value of $\theta(t)$ will correspond to one of the four possible combinations of $d_I(t)$ and $d_Q(t)$. The output $s(t)$ of the QPSK modulator corresponding to the specific values of $d_I(t)$ and $d_Q(t)$ can be determined with respect to the phase-offset of $\theta(t)$ as follows:

Using $d_1(t) = \sqrt{2}\cos\theta(t)\ and\ d_Q(t) = -\sqrt{2}\sin\theta(t), s(t)\ cna\ be\ determined\ as\ follows:$

1. $For\ \theta(t) = -\frac{\pi}{4}, it\ gives\ d_I(t) = \sqrt{2}\cos(-\frac{\pi}{4}) = 1\ and$

   $d_Q(t) = -\sqrt{2}\sin(-\frac{\pi}{4}) = 1, whence\ s(t) = \sqrt{2Ps}\cos\omega_0 t.$

2. $For\ \theta(t) = \frac{\pi}{4}, it\ follows\ d_I(t) = \sqrt{2}\cos(\frac{\pi}{4}) = 1\ and$

   $d_Q(t) = -\sqrt{2}\sin(\frac{\pi}{4}) = 1, whence\ s(t) = -\sqrt{2Ps}\cos\omega_0 t.$

3. $For\ \theta(t) = \frac{5\pi}{4},\ we\ have\ d_I(t) = \sqrt{2}\cos(\frac{5\pi}{4}) = -1\ and$

   $d_Q(t) = -\sqrt{2}\sin(\frac{5\pi}{4}) = 1, whence\ s(t) = \sqrt{2Ps}\cos\omega_0 t.$

4. $For\ \theta(t) = \frac{3\pi}{4},\ we\ have\ d_I(t) = \sqrt{2}\cos(\frac{3\pi}{4}) = -1\ and$

   $d_Q(t) = -\sqrt{2}\sin(\frac{3\pi}{4}) = -1, whence\ s(t) = -\sqrt{2Ps}\cos\omega_0 t.$

Thus, the signal space for QPSK can be sketched as shown in Fig 3.8.

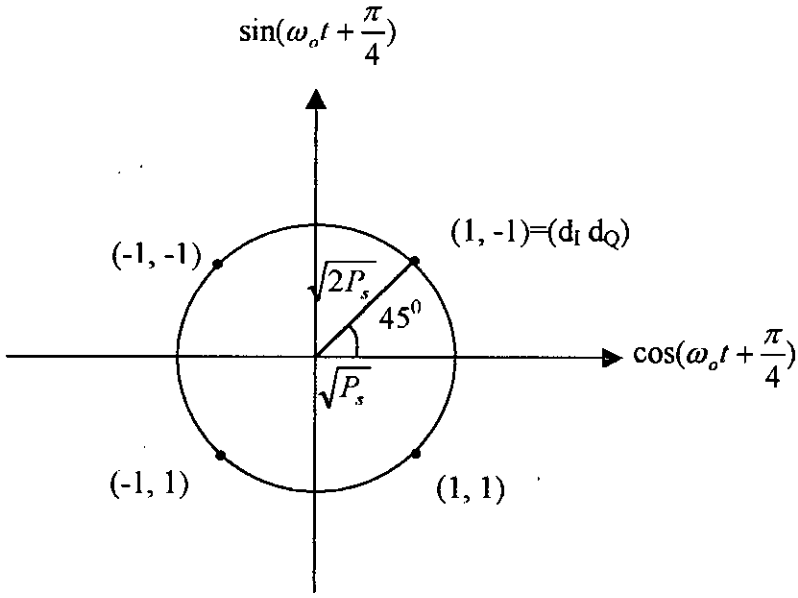


Figure 3.8 Signal space for QPSK.

The original data stream $d(t)$ with the duration T_b can be divided into the in-phase stream $d_I(t)$ and the quadrature-phase stream $d_Q(t)$ with each duration $2T_b$ by S/P converter (see Fig. 3.6) In QPSK the in-phase and quadrature-phase data streams are both transmitted at the rate of $1/2T_b$ bps and are synchronously aligned such that their transitions coincide in time. In non-offset QPSK, the two pulse streams of $d_I(t)$ and $d_Q(t)$ coincide in time. Due to this coincident alignment of $d_I(t)$ and $d_Q(t)$, the carrier phase changes only once every $2T_b$, resulting in any one of the four possible phases as shown in Fig. 3.8.

3.10 PN CODE

Time shifted bit sequences of the same PN codes have very small correlation with each other. This characteristic is used for identification of BTS and channelization of reverse link. PN codes are generated from prime polynomials using modulo-2 and used primarily for signal spreading.

- The same PN sequence is used throughout a CDMA system.
- Each cell/sector has its own unique PN offset.
- CDMA systems use a total of 512 different PN offsets.

Correlation of PN codes:

Correlation of PN code = Number of agreements – Number of disagreements.

1	0	0	1	0	1	1

1	0	0	1	0	1	1

Number of agreements = 1+1+1+1+1+1+1=7
Number of disagreements = 0+0+0+0+0+0+0=0
Correlation = 7-0 = 7, $7 \div 7 = 1$

Two types of PN codes are
(a) PN short codes
(b) PN long codes

3.10.1 PN short codes:

PN short codes are used for Quadrature spreading to identity sectors.

- PN Short codes also called I and Q spreading sequences.
- Based on 15 bit long pseudo random binary sequence.
- Repeat every 26.667 msec intervals
- Chip rate 1.2288 MHz.
- Period of $2^{15} = 32768$ Chips
- Identifies cell sites or sectors of cells.

Short code spreading:

Same PN short codes are used by mobiles. Extra ½ chip delay is inserted into the Q path to provide QPSK modulation. Allows for simpler, low cost mobile power amplifier. Each base station is assigned a time offset in its short codes.

Time offsets allow mobiles to distinguish adjacent cells/sectors. Also allows reuse of all Walsh codes in each cell/sector.

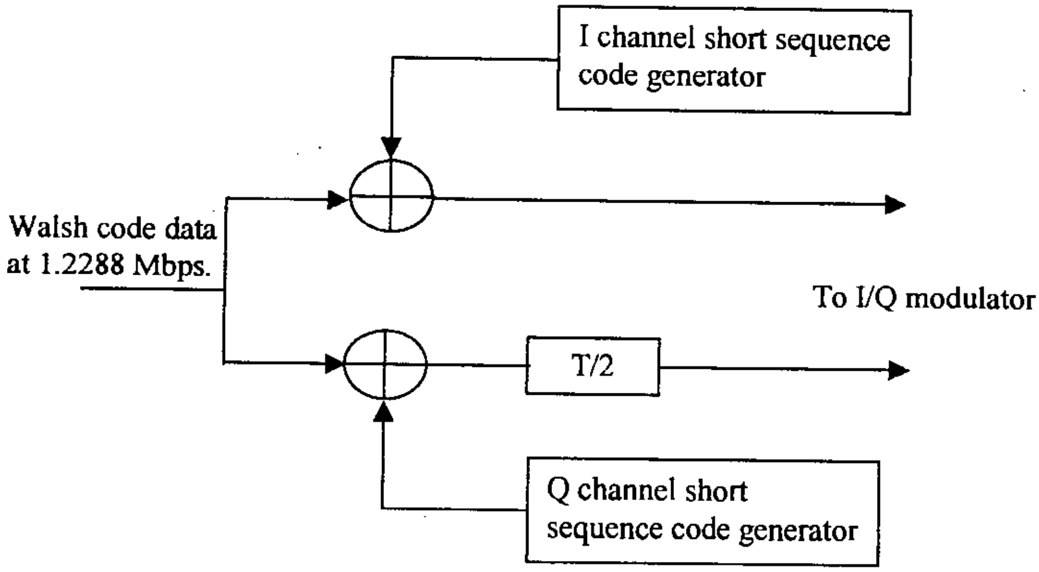


Figure 3.9 PN short code spreading.

Generation of PN Code:

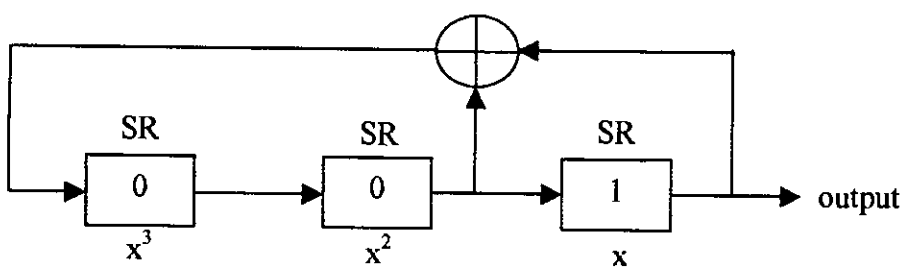
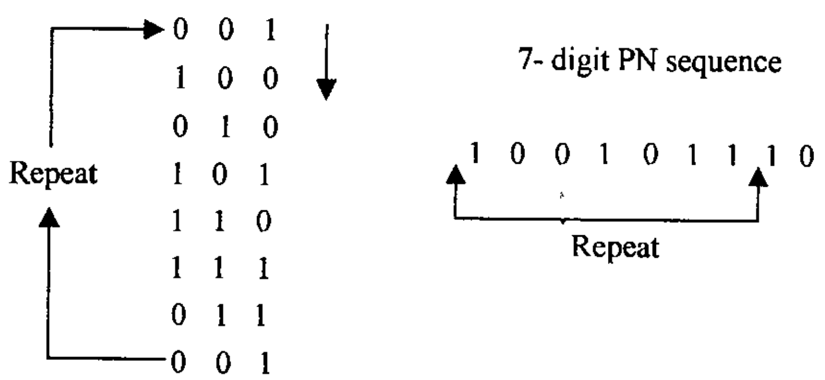


Figure 3.10 Generation of PN code.

Prime polynomial $Y = x^3 + x + 1$



3.10.2 PN long codes

PN long code is used for spreading of reverse link to identify individual reverse communication channels. Also used for scrambling a signal to provide privacy

The long code is a PN sequence with 2^{42}-1 that is used for scrambling on the forward CDMA channel and spreading the reverse CDMA channel. The long code uniquely identifies a mobile station on both the reverse traffic channel and the forward traffic channel. The long code is characterized by the long code mask that is used to form either the public long code or the private long code. The long code also separates multiple access channels on the same CDMA channel.

When transmitting on the access channel, direct sequence spread by the long code is applied before transmission. This spreading operation involves modulo-2 addition of the 64-ary orthogonal modulator output sequence and the long code, as shown in Fig. 3.11.

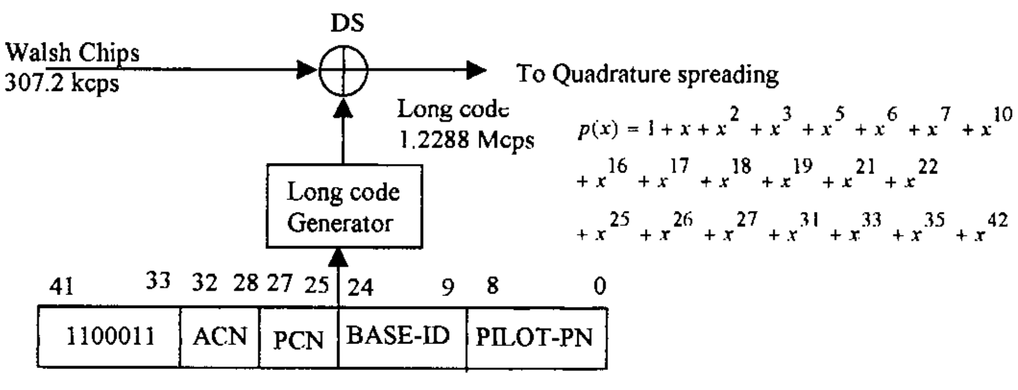


Figure 3.11 Access channel long code.

The long code is periodic with period 2^{42}-1 chips specifying by the LFSR tap polynomial *p(x)* of the code generator:

$$p(x) = 1 + x + x^2 + x^3 + x^5 + x^6 + x^7 + x^{10} + x^{16} + x^{17} + x^{18} + x^{19} + x^{21} + x^{22} + x^{25} + x^{26} + x^{27} + x^{31} + x^{33} + x^{35} + x^{42}$$

Each PN chip of the long code is generated by EX-Oring all AND gates resulting from a 42-bit mask and each output from LFSR 42 stages, as illustrated in Fig. 3.12.

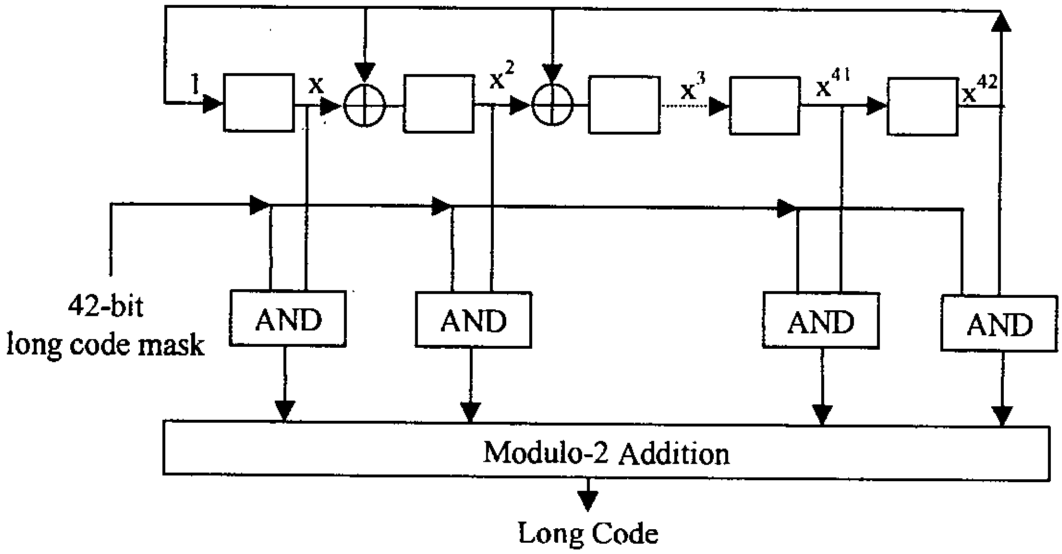
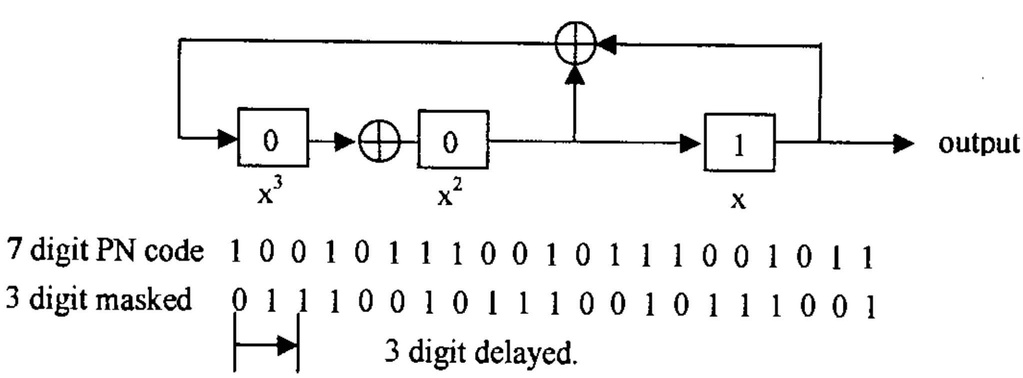


Figure 3.12 Long code generator.

The long code mask consists of a 42-bit binary sequence that creates the unique identity of the long code. The long code mask varies depending on the channel type on which the mobile station is transmitting. The long code generator, activated with the long code mask, which produces PN chips (1.2288 kcps) is shown in Fig. 3.12.

3.10.3 PN offset (Masking)

The PN offset masking procedure shows in fig. 3.13 where masked pattern is 011 and 3 digit delayed.



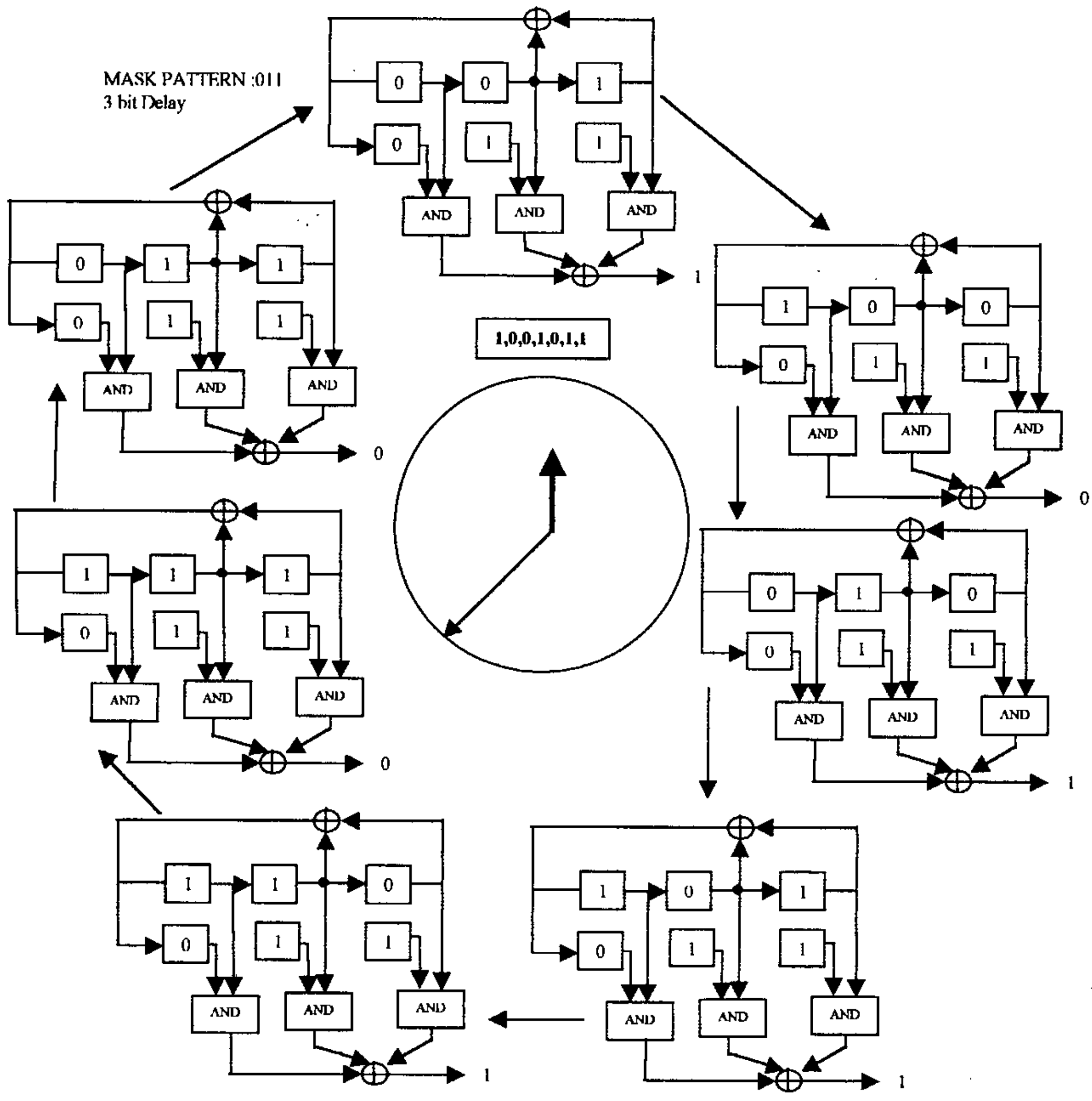


Figure 3.13 PN offset (masking).

3.11 DATA SCRAMBLING

Data scrambling is applied to the forward traffic channel as well as the paging channel. Data scrambling is performed on the block interleaver output at the modulation symbol rate of 19.2 ksps. Data scrambling is accomplished by performing the modulo-2 addition of the block interleaver output with the decimated sampling values (0 or 1) of the long code PN chips. This PN sequence is equivalent to the long code operation at 1.2288 MHz clock rate where only the first output bit of every 64 bits is used for the data scrambling at 19.2 ksps.

The forward traffic channel data is scrambled utilizing the long code generator. The data scrambling mechanism is illustrated in Fig. 3.14. The long code operation at 1.2288 MHz clock rate will generate the PN chip sequence which is the output of the long code generator.

When the long code is divided into the 64-bit length each, every first bit per 64 bits is the decimated sampling value and these decimated values are used for data scrambling at a 19.2 ksps rate. The function of the decimator is to reduce the size of long code by taking one bit from every 64-bit output.

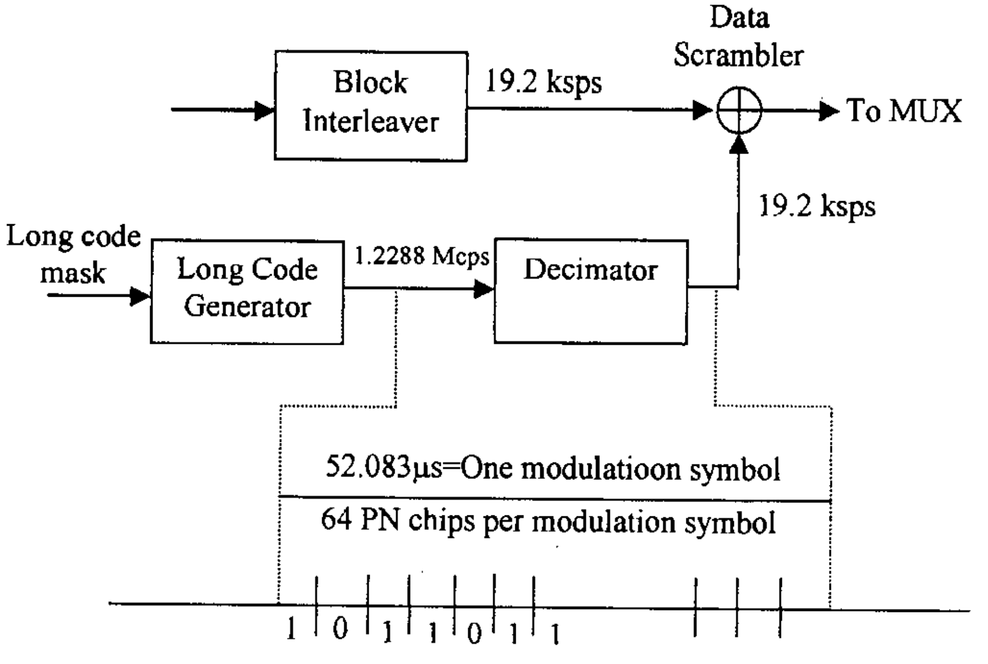


Figure 3.14 Data scrambling mechanism

Voice privacy is provided in the CDMA system by means of the private long code mask being used for PN spreading. Voice privacy control is provided on the traffic channels only. All calls are initialized using the public long code mask for PN spreading. The transition to private long code mask must not be performed if authentication is not performed. To initiate a transition to the private or public code mask, either the base station or the mobile station sends a long code transition request order on the traffic channel. The mobile station or the base station takes action in response to receipt of this order, respectively. The base station also can cause a transition to the public long code mask by sending the handoff direction message with the PRIVATE-LCN bit appropriately set.

3.12 CDMA CODE CHANNEL QUADRATURE SPREADING

Following direct sequence spreading, the reverse traffic channel and the access channel are spread in quadrature.

On the other hand, following orthogonal spreading on the forward CDMA channel, each code channel (pilot, sync, paging, or forward traffic channel) is spread in quadrature.

The spreading sequence is a quadrature sequence of length 215 or 32768 PN chips in length. This quadrature sequence is called the pilot PN sequence and is based on the following tap polynomials respectively:

$$P_I(x) = 1 + x^5 + x^7 + x^8 + x^9 + x^{13} + x^{15} \qquad \text{...... ....} \qquad (i)$$

for the in-phase I sequence

and

$$P_Q(x) = 1 + x^3 + x^4 + x^5 + x^6 + x^{10} + x^{11} + x^{12} + x^{15} \qquad \text{...... ....} \qquad (ii)$$

for the quadrature-phase Q sequence.

The I-phase and Q-phase pilot PN sequences also are obtained by means of the following reciprocal polynomials:

$$i(x) = x^{15} P_I(x^{-1})$$
$$= 1 + x^2 + x^6 + x^7 + x^8 + x^{10} + x^{15} \qquad \text{...... ....} \qquad (iii)$$

$$and\ q(x) = x^{15} P_Q(x^{-1})$$
$$= 1 + x^3 + x^4 + x^5 + x^9 + x^{10} + x^{11} + x^{12} + x^{15} \qquad \text{...... ....} \qquad (iv)$$

The maximum length LFSR sequences based on Eqs. (iii) and (iv) are of lentht 2^{15}-1 and can be generated by the following linear recursive operation:

$$i(n) = i(n-15) \oplus i(n-10) \oplus i(n-8) \oplus i(n-7) \oplus i(n-6) \oplus i(n-2)$$
$$and\ q(n) = q(n-15) \oplus q(n-12) \oplus q(n-11) \oplus q(n-10) \oplus a(n-9) \oplus q(n-5) \oplus q(n-4) \oplus$$
$$q(n-3).$$

where *i(n)* and *q(n)* for $1 \le n \le 32767$ are binary-valued 0 or 1 and $i(15)$=1 and $q(15)$=1, and $\oplus$ denotes the modulo-2 addition.

The I and Q pilot PN sequences, P_I and P_Q, are then generated from *i(n)* and *q(n)* under the initial content of LFSR, IC= (1000000000000000). P_I and P_Q can be computed using the polynomials *i(n)* and *q(n)* of length 2^{15}-1. That is,

1. *Using* $i(n) = i(n-15) = 0$ *for* $1 \le n \le 14, i(15) = 1.$ *and* $i(n) = \sum_{k=15.10.8.7.6.2} i(n-k)$
$16 \le n \le 32767,$ *the in – phase pilot PN sequence* P_I

is found by computing *i(n)* first and then inserting '0' in *i(n)* after 14 consecutive 0's.

2. *Similarly, using* $q(n) = q(n-15) = 0$ *for* $1 \le n \le 14, q(15) = 1.$ *and* $q(n)$
$= \sum_{k=15.12.11.10.9.5.4.3} q(n-k)$ *for* $16 \le n \le 32767,$ *from which the quadrature*

phase pilot PN sequence P_Q is found by inserting '0' at the 15^{th} in *q(n)*.

3.13 FRAME CONFIGURATION OF TRAFFIC DATA.

(Forward and Reverse channel)

The frame configuration of traffic data for forward and reverse channel is shown in figure 3.15.

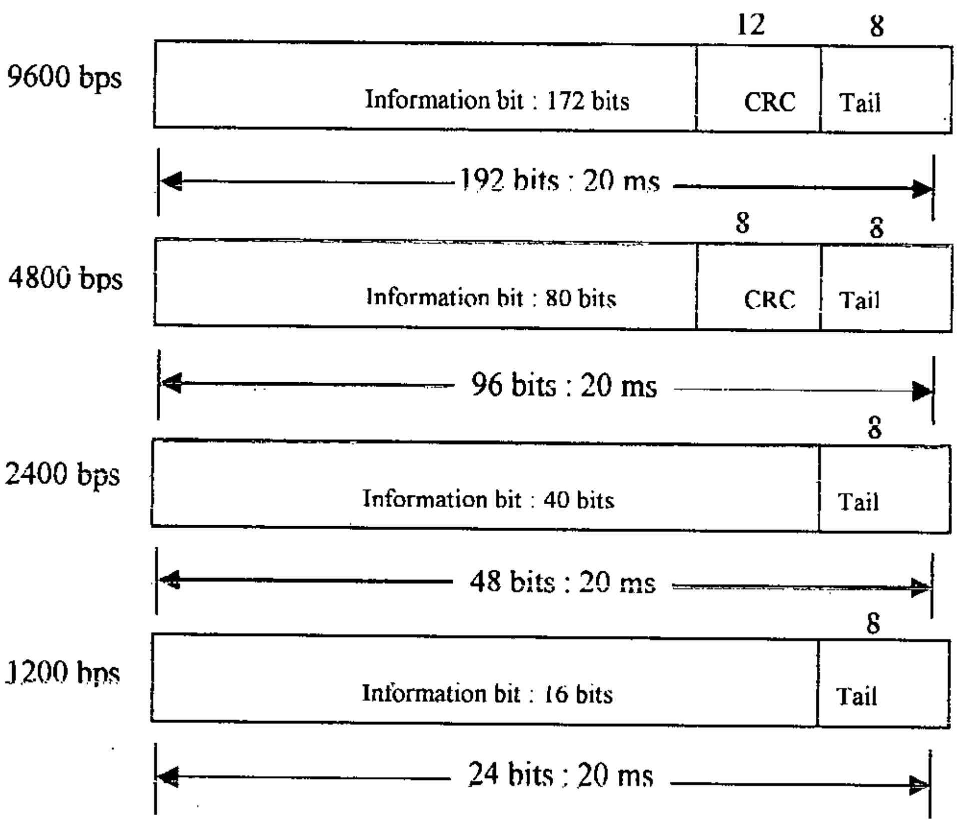


Figure 3.15 Frame configuration of traffic data.

The contents of 20 ms frames are shown in table 3.4.

Table 3.4 Contents of 20 ms frames

Date Rate R (bps)	1200	2400	4800	9600
Information rate	800	2000	4000	8600
Information bits per frame (IBPF)	16	40	80	172
Parity bits per frame (PBPF)	0	0	8	12
Data bits per frame (IBPF+PBPF+8)	24	48	96	192
Coded bits per frame (CBPF)	72	144	288	576
Repetitions (Transmission per code symbol)	8	4	2	1
Total bits per frame (BPF)	576	576	576	576

The downlink actually transmits the same data rate for all subrates by repeating each subframe, but reduces the interference by reducing the transmitted power for the frame by the corresponding rate factor.

CHAPTER- 4

CALL PROCESSING

4.1 INTRODUCTION

Call processing can be separated into two parts, mobile station call processing and base station call processing. Call processing refers to the technique of message flow protocols between the mobile station and the base station.

4.2 MOBILE STATION CALL PROCESSING

As illustrated in fig. 4.1 mobile station call processing consists of the following four state-

1. Mobile station initialization state: In this state, the mobile station must:

   - Select which system to use (Analogue or CDMA operation).
   - Acquire the pilot channel of the selected CDMA system within 20 ms.
   - Receive and process the sync channel message to obtain system configuration and timing information.
   - Synchronize its long code timing and system timing to those of the CDMA system.

2. Mobile station idle state: In this state, the mobile station monitors message on the paging channel. The mobile station can receive messages, receive an incoming call, initiate an originating call, initiate a registration, or initiate a message transmission.

3. System access state: In this state, the mobile station sends message to the base station on the access channel and receives message from the base station on the paging channel. The system access state consists of the following substates and the mobile station must:
   - Monitor the paging channel until it has received a current set of configuration messages.
   - Send an origination message to the base station.

- Send a paging response message to the base station.
- Send a response to a message received from the base station.
- Send a registration message to the base station.
- Send a data burst message to the base station.

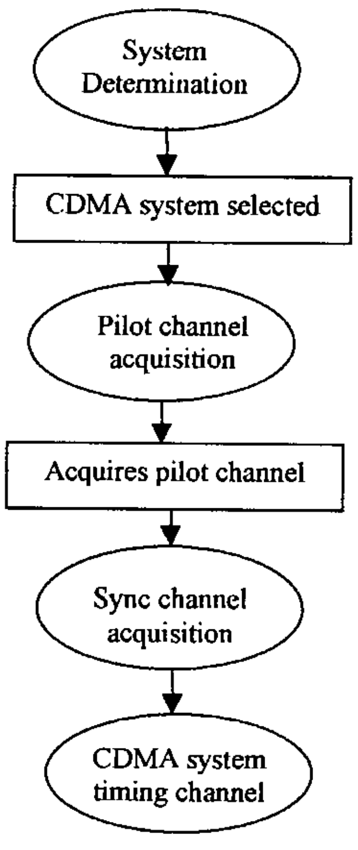


Figure 4.1 Mobile station initialization state.

The mobile station transmits on the access channel using a random access procedure. The entire process of sending one message and receiving an acknowledgment for that message is called an access attempt. Each transmission in the access attempt is called an access probe. The mobile station transmits the same message in each access probe in an access attempt. Each access probe consists of an access channel preamble and an access channel message capsule, Figure 4.2 shows the MS call processing states.

4. Mobile station control on the traffic channel state: In this state, the mobile station communicates with the base station using the forward and reverse traffic channels.

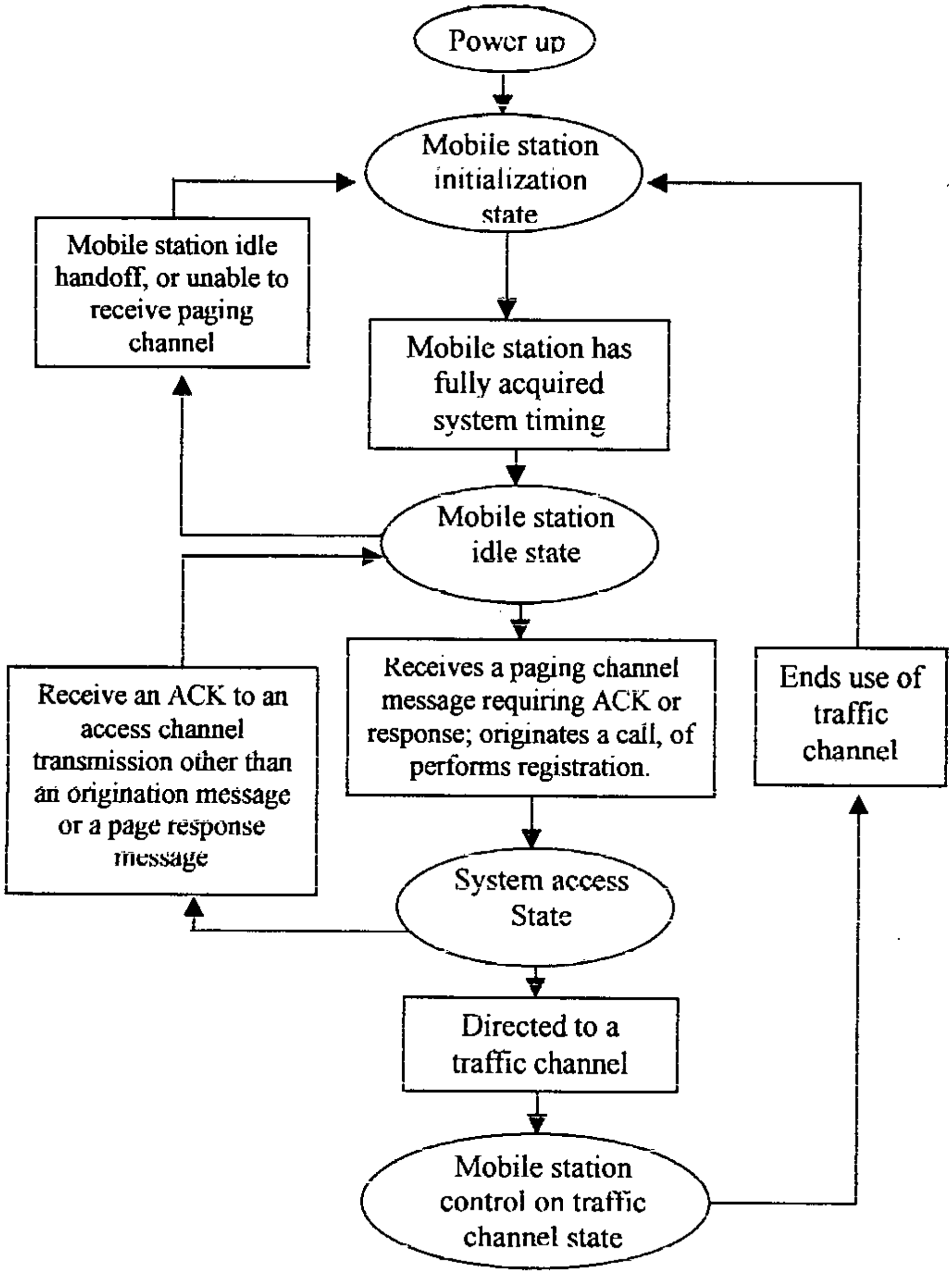


Figure 4.2 MS call processing states.

This state consists of the following sub states and the mobile station must:

- Verify that it can receive the forward traffic channel and begin transmitting on the reverse traffic channel.
- Wait for an order on an alert with information message.
- Wait for the user to answer the call.

- Exchange primary traffic packets with the base station under its primary service option application.
- Disconnect the call in this release substate.

[Reference: Dr. Man Young Rhee, "CDMA Cellular Mobile Communications and network security." Prentice Hall PTR, 1998]

4.3 MS/US CALLED SEQUENCE

MS/US		Base station
1. Receives page message	← P-ch	1. Sends general page message.
2. Sends page response message (MIN, ESN)	A-ch →	2. Receives page response message. 3. Tunes to assigned traffic channel using public long code. 4. Begins transmitting null traffic channel data on the forward traffic channel.
3. Receives channel assignment message. 4. Tunes to assigned traffic channel using public long code. 5. Receives N_{50m} consecutive valid frames from the base station 6. Begins sending traffic channel preamble on the reverse traffic channel.	P-ch ←	5. Sends channel assignment message CESN, CDMA ch, code ch 6. Receives traffic channel preamble from the mobile station.
7. Receives base station acknowledgement order.	T-ch ←	7. Sends base station acknowledgement order.
8. Begins transferring primary traffic packets to service option 1 and sending null traffic channel data on reverse traffic channel.		
9. Receives alert with information message	T-ch ←	8. Sends alert with information message (Ringback tone)
10. Sends acknowledgement	T-ch →	9. Receives acknowledgement
11. Applies ringback to mobile handset 12. Displays ON information on mobile display 13. Removes ringing to mobile handset 14. Sends connect order.		
15. Begins transmitting primary traffic packets from service option 1.	T-ch →	10. Receives connect order.
16. Receives acknowledgement. (User conversation)	←	11. Sends acknowledgement. (User conversation)

4.4 BASE STATION CALL PROCESSING

Base station call processing refers to the method relating to the message flow between the base station and the mobile station.

Base station call processing consists of the following types of processing.

1. **Pilot and sync channel processing:** During this processing, the base station transmits the pilot channel and sync channel which the mobile station uses to acquire and synchronize to the CDMA system while the mobile station is in the mobile station initialization state.
   - (a) The pilot channel is a reference channel which the mobile station uses for acquisition, timing, and as a phase reference for coherent demodulation. The base station continually transmits a pilot channel for every CDMA channel supported by the base station.
   - (b) The sync channel provides the mobile station with system configuration and timing information. The base station transmits at most one sync channel for each supported CDMA channel

2. **Paging channel processing:** During this processing, the base station transmits the paging channel which the mobile station monitors to receive message while the mobile station is in the mobile station idle state and the system access state. The base station may transmit up to seven paging channels on each supported CDMA channel. For each supported CDMA channel for which the base station transmits a sync channel, the base station transmit at least one paging channel.

3. **Access channel processing:** During this processing, the base station monitors the access channel to receive messages which the mobile station sends while the mobile station is in the system access state.

Each access channel is associated with a paging channel. Up to 32 access channels can be associated with a paging channel. The number of access channels associated with a particular paging channel is specified in the access parameters message sent on that paging channel. The base station continually monitors all access channels associated with each paging channel that the base station transmits.

4. **Traffic channel processing:** During traffic channel processing, the base station uses the forward and reverse traffic channels to communication with the mobile station while the mobile station is in the mobile station control on the traffic channel state.

Traffic channel processing consists of the following sub states:

- Traffic channel initialization sub state:
  In this sub state, the base station begins transmitting on the forward traffic channel and receiving on the reverse traffic channel.
- Waiting for order sub state:
  In this sub state, the base station sends the alert with information message to the mobile station.
- Waiting for answer sub state:
  In this sub state, the base station waits for the connect order from the mobile station.
- Conversation sub state:
  In this sub state, the base station exchanges primary traffic bits with the mobile stations primary service option application.
- Release sub state:
  In this sub state, the base station disconnects the call.

It will be shown that the base station performs special functions and actions in one or more of the traffic channel processing sub states.

[Reference: Dr. Man Young Rhee, "CDMA Cellular Mobile Communication and Network Security." Prentice Hall PTR, 1998]

4.5 TEN MINUTES IN THE LIFE OR A CDMA MOBILE PHONE

- Turn On Process
  - Ø System Access
- Travel
  - Ø Idle State Hand-off
- Call Initiation
  - Ø System Access
- Continue Travel
  - Ø Soft Hand-off Initiation
  - Ø Terminate soft hand-off
- End Call

CDMA Turn On Process

- When the mobile turns on it tunes to the pre-programmed frequency of the CDMA service in the local area.
- It finds the receivable base stations (search for all pilot signals) and synchronizes to the strongest pilot.
- It establishes frequency reference and time reference.
- The mobile demodulates the sync channel (Walsh #32).
- The Sync channel provides master clock information by sending the state of the 42 bit long code shift register 320 msec in the future. The Sync channel contains other parameters as well.
- The mobile starts listening to the Paging channel and waits for a page that is directed to its phone number.
- The mobile will often register with a base station so that the base station can do location based paging rather than system wide paging.

CDMA Travel

- The mobile continuously scans for alternative pilot tones at different time offsets.
- When another pilot tone (from another base station or sector in the same base station) is found to be stronger than the current pilot tone the mobile will go through an **Idle Hand-Off**.
- The mobile location register is updated in the CAMA system.

CDMA Call Initiation

- The user decides to make a call. The number is keyed in and the send key is hit.
- The mobile uses the Access Channel to contact the base station by sending the access probes.
- Closed loop power control is not yet active. The mobile uses the open loop power control to estimate the initial transmit level.
- Multiple access probes are allowed with random time between tries to avoid collisions with other access users on the access channel.
- After each access probe, the mobile listens to the paging channel for a response from the base station.

- The Base Station responds with assignment of traffic channel (Walsh Code for the forward channel). The traffic channel uses different long codes than the paging channels.
- The Base Station initiates the land link (PSTN) and conversation can take place.

CDMA Soft Hand-Off

- During a call the mobile encounters another pilot with sufficient power.
- The mobile requests from its servicing base station to initiate soft handoff with the additional cell.
- The servicing base station passes the request to the MTSO which contacts the second base station and gets a Walsh code assignment.
- The Walsh code assignment is sent to the mobile by the servicing base station.
- The MTSO connects a land link to the second base station.
- The mobile combines the downlink signals from both base stations by using the two pilot signals as coherent phase references.
- At the MTSO the uplink signals are examined from the output of each base station and the better one is chosen for each 20 msec block.
- The first base station pilot power degrades at the mobile.
- The mobile asks from the new base station to have the soft handoff terminated.
- At this point the mobile is being power controlled by the second base station.
- The soft handoff request is passed from the second base station to the MTSO and the first base station stops transmitting and receiving.
- The mobile is only on the second base station.

CDMA End of Call

- End of call can be initiated either by the mobile or the land side. In either case, transmissions are stopped and land line connection is broken.
- When the mobile is turned off, it generates a power down registration that tells the system that it is no longer available for incoming calls.
- If the mobile is not tuned off, it stays idle, continually searching for alternate pilots.

CHAPTER- 5

CELLULAR DESIGN AND CELL PLANNING FOR DHAKA CITY

5.1 INTRODUCTION

Dhaka is one of the most densely populated city in the world. The city was not developed with a proper design. So the city structure is not uniform. The oldest part of the city consists of densely packed buildings of lower height (mainly 3 to 4 storied). On the other side the commercial area Motijheel, Dilkhusa etc. consists of some high rise buildings. Both the old city and commercial part are densely populated. The residential region Dhanmondi, Lalmatia, Mohammedpur, Mirpur, Gulshan, Banani etc. has almost same types of structure. Since we considered the coverage area 30 km radius with centre at Mohakhali. So this includes some sub-urban and rural areas not under Dhaka Municipul Corporation (DMC). We considered the greater Dhaka metropolitan areas (SMA). Due to the varieties in city structure and population density, the cellular design for Dhaka city need special considerations. To ensure adequate coverage and to avoid interference, every cellular network requires cell planning. The major activities involved in cell planning are: Traffic and coverage analysis, Estimating system growth, System design and evaluation. Cell planning begin with traffic and coverage analysis.

For lost call cleared (LCC) system Erlang-B table is used to estimate the number of traffic channel to be used for a certain Grade of service. Based on traffic calculation, the cell designing is not only for the initial network, but also to adapt smoothly to the demand of traffic growth.

The cellular communication in the Dhaka city is not yet free from problems. The poor signal reception, improper handoff, etc. Are the common complains from the user. The main cause of such problems is the improper planning and design of cellular network. Dhaka is one of he most densely populated cities in the world. Moreover the city has been developed without proper planning. The cellular networks designed with due consideration of the irregularities and signal obstacles can satisfy the users.

The main objective of the research is to plan and design of CDMA based cellular network for the Dhaka city by considering the performance of other cellular systems (eg. GSM, AMPS etc.) and also existing CDMA system. A CDMA based cellular network will be developed for Dhaka city and its adjoining areas to minimize noise and interference effects for mobile communication.

A property designed CDMA cellular Network will be helpful to give best services to the cellular users. Also maximum utilization of the resources in implementing the system will be achieved.

For a well designed cellular system, the design steps consists of,

- ♦ Determining the traffic demand at different part of the coverage area.
- ♦ Dividing the coverage area into a number of hexagonal cell according to the traffic demand.
- ♦ Selecting the Grade of service.
- ♦ Estimating the required number of traffic channels for a certain Grade of service.
- ♦ Suggesting a cellular network according to previous calculation.

The design should be evaluated by calculating followings:

- ♦ Co channel and adjacent channel interferences.
- ♦ The signal coverage at different points on a cell.

This CDMA Cellular Network design is accomplished by considering the following criteria.

- Different region of the city will be identified according to the population density, number and height of the high rise buildings, number of small building etc.
- The city will be divided into a number of cells. The geographical location of cell sites will be decided for optimum performance.
- After designing the cell positions, location of the base stations will be determined for uniform field strength throughout the cell.
- Transmitting power level, antenna type, radiation pattern etc. will be determined accordingly.
- Position of MSC and number of trunks necessary to accommodate peak traffic for mobile users will be determined considering the existing facilities of BTB exchanges.
- Also calculate the field strength at the cell boundary and different floor of a high rise building for each position of the base station.

5.2 DESIGN INPUTS

The cellular design mainly depends on

1. Amount of frequency spectrum allocated
2. Coverage area
3. Cellular technology
4. Expected quality of service
5. Most busy hour traffic (per subscriber)
6. Number of subscriber to be accommodate
7. Distribution of subscribers

Inputs of the proposed design is discussed below.

1. **Allocated Spectrum :** Bangladesh Telephone and Telegraph Board (BTTB) allocates spectrum to the mobile operators. Recently it allocated 5 MHz spectrum to each of the commercial cellular operators in Dhaka city. For this design we consider a 5 MHz spectrum.

2. **Coverage area :** The proposed Dhaka mega city has an area of 1353 km^2. We consider the greater Dhaka city approximately 30 km radius with center at Mohakhali. This includes some sub-urban and rural areas not under Dhaka Municipal Corporation (DMC). The traffic demand at this sub-urban area is low compared to the that of municipal area. So at this time greater Dhaka consists of Dhaka, Narayangonj & Gazipur district is considered for cellular design.

   The area of Dhaka, Narayangonj & Gazipur district are 1463.60 km^2, 759.57 km^2 & 1741.53 km^2. So total area is 3964.7 km^2. But we consider the area approximately 3000 km^2 which covered whole Dhaka and Narayangonj & partial area of Gazipur district (Gazipur sadar, Kaliakair & Kaliganj thana).

3. **Cellular Technology :** A verities of cellular radio systems exist now a days. They differs from each other by a number of factors such as, operating frequency, multiple access scheme, channel assignment strategy, handoff etc. To take the advantage of digital system CDMA (Code Division Multiple Access) is selected as design technology.

4. **Expected Quality of Service :** Grade of service is one of the key indicators of cellular quality. GOS is a measure of the ability of a particular user to access a trunked system during the busiest hour. GOS is typically given as the likelihood that a call is blocked, or the likelihood of a call experiencing a delay greater than a certain queuing time. For CDMA system 2% - 5% GOS is considered to be suitable. For our design purpose we take expected Grade of service 2%.

5. **Most Busy Hour Traffic (per subscriber) :** Traffic per user depends on a number of factors and varies from time to time. The busy hour is based upon customer demand at the busiest hour during a day, week, month, or year. The busy hour for cellular radio systems typically occurs during rush hours, between 4-6 p.m. on a Thursday or Friday evening.

Assuming that each mobile user makes 1 call per hour and average call duration is 1.5 minutes,

Traffic per user = No. of call per hour × call duration in hour

$$= \frac{1 \times 1.5}{60}$$

$$= 0.025 \text{ Erlang } (E)$$

The following table shows different calling rate at busy hour/user.

No. of call per hour	Call duration in minute	Calling rate at busy hour per user in erlangs
1	1.0	0.016
1	1.5	0.025
1	2.0	0.033
1	2.5	0.0416
1	3.0	0.05
1	3.5	0.058

* Standard busy hour traffic is 25 mE to 30 mE

5.3 DEMAND FORECASTING

Telecommunication plays an important role in economic growth around the world. Tele density and per capital income of a country are known to be closely related. Bangladesh has one of the lowest Tele-densities in the world. Since the demand for new telephone connections in Bangladesh is huge, the state owned fixed line network, operated by Bangladesh Telegraph & Telephone Board (BTTB) is unable to meet the demand. Moreover, the distribution of BTTB services is heavily skewed. Under these circumstances, cellular telephony can play a major role in developing the telecommunication infrastructure in the country. The demand for telephones is estimated to be 56 million by the end of 2005. Apparently, it is not possible for BTTB to match this huge demand.

Cellular telephony, in general, is experiencing very rapid growth all over the world, More and more people are using cellular telephones. One reason is that cellular telephone has many appealing advantages compared with fixed-line telephones.

Since 1996 there have been more new cellular connections added each year than fixed-line ones and the gap is growing. Cellular technologies are improving in leaps and boards, to the extent that many predict that mobile telephony will outstrip fixed line telephony by 2010. The number of cellular subscribers worldwide has been doubling every20 months since 1990. During the 1990s it has been the developing world where rates of cellular growth have been fastest. The developing world's share of global cellular subscribers has risen from 5% in 1990 to more than 20% in 1999. This trend is expected to continue in the near future.

5.3.1 Bangladesh Cellular Market, Technologies and the cellular operators

Although the first cellular operation in Bangladesh was launched in 1993, it took almost four years to develop a competitive market in the industry. The real subscriber growth is taking place only in the year 2000. The figure 5.1 shows the EMC Data for the actual cellular subscriber in Bangladesh.

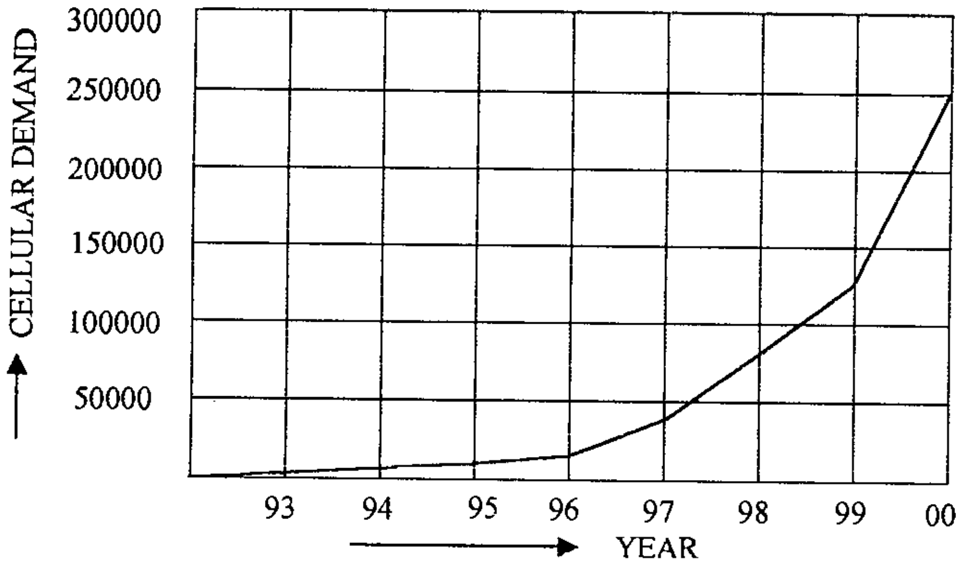


Figure 5.1 Cellular growth in Bangladesh.

Bangladesh started with the leading first generation cellular technology. Later, with the change in time, it has adopted both the two dominating technology of the second-generation cellular standard. The following table describe the technologies and the market standing of the cellular operators in Bangladesh.

Table 5.1 Cellular operators in Bangladesh.

Operator	Brand Name	Technical System	ON AIR	Subscribers upto Nov-00	Subscribers upto DEC-01
Grameen phone	GP	GSM – 900	Mar – 97	170,140	400,000
Pacific Bangladesh telecom limited (PBTL)	City cell	AMPS	Aug – 93	13,400	13,400
	City cell Digital	CDMA	Mar – 99	21,200	52,000
Telecom Malaysia International Bangladesh (TMIB)	AKTEL	GSM – 900	Aug – 99	34,900	55,000
Sheba Telecom	Sheba	GSM – 900	Jun – 98	17,200	25,000
			Total	256,840	545,400

* Source : Proceedings of ICECE, 2001.

5.3.2 The cellular demand in Dhaka city

Traffic demands of a cellular system depends on a number of factors. They are

- Population distribution
- Income level

- Employment status
- Distribution of earners and major occupation
- Initial cost of subscription
- Tariff applied etc.

Traffic calculation of greater Dhaka city depending on above factors is a tedious job but not impossible. Due to the limitation of available spectrum, large number of cell will be need to meet the calculated demand. In a cellular system the capacity is increased by reusing each frequency at several regions of service area. Also cell splitting, sectoring and Micro cell zone approaches are used to expand the capacity of cellular systems. Consideration must be taken into account to keep the interferences at acceptable limit. The recorded cellular demand and population for the year 1993-2000 is given in table 5.2.

Table 5.2 Recorded cellular demands and population for the years 1993 – 2000.

Year	Cellular Demand	Population	Population per mobile	Population Growth rate	AGR
1993	1000	7260125	7260.125	-	
1994	3000	7419847	2473.28	2.1%	
1995	5000	7583084	1516.61	2.2%	
1996	20000	7749912	387.49	2.2%	2.129%
1997	40000	7920410	198.01	2.1%	
1998	70000	8094659	115.63	2.1%	
1999	110000	8272741	75.20	2.1%	
2000	150000	8454000	56.36	2.1%	

* Source: Population census 2001, BBS.

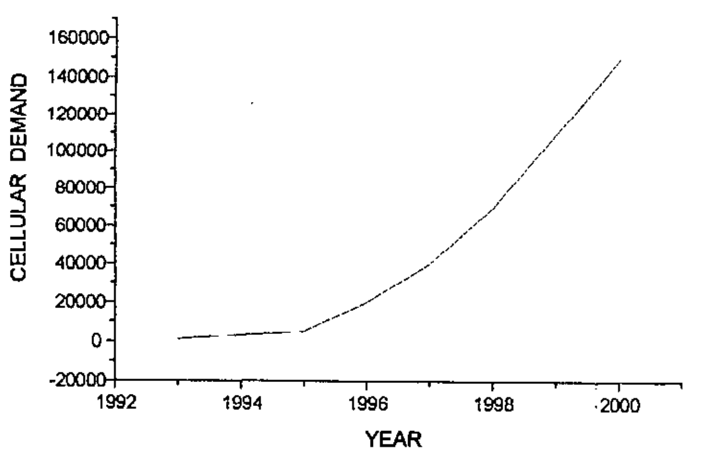


Figure 5.2 Recorded cellular demand in Dhaka city for the year 1993-2000.

5.3.3 Population of Dhaka Metropolitan Areas (DMA).

The population of Dhaka Metropolitan area for the year 2001 to 2010 is shown in table 5.3 which is calculate by assuming AGR 2.129%.

Table 5.3 Calculated population from 2002 to 2010.

Year	Population	Remark
2001	9912908	Recorded data source: Population census BBS. Aug, 2001
2002	10123953	Calculated data. Assume AGR= 2.129%
2003	10339492	
2004	10559620	
2005	10784434	
2006	11014035	
2007	11248524	
2008	11488005	
2009	11732585	
2010	11982371	

5.3.4 (a) Distribution of Monthly Income level, 1991

Distribution of monthly income level is shown in table 5.4a and 5.4b.

Table 5.4a Distribution of monthly income, 1991

Area	Total monthly income (TK)	% of earners
National	20000/- and above	0.59%
	10000/- – 20000/-	3.80%
	below 10000/-	95.61%
Urban	20000/- and above	2.13%
	10000/- – 20000/-	8.83%
	below 10000/-	91.17%
Rural	20000/- and above	0.45%
	10000/- – 20000/-	3.02%
	below 10000/-	96.53%

$$\text{Average \% of earners} = \frac{4.39 + 10.96 + 3.47}{3} = \frac{18.82}{3} = 6.27\%,\ \text{whose total monthly income are } 10000/- \text{ and above.}$$

Table 5.4b Distribution of monthly Income level, 2001.

Area	Total monthly income (Tk)	% of earners	% of House hold
National	20000/- and above	2.53%	1.58%
	10000/- to 20000/-	7.55%	5.22%
	below 10000/-	89.92%	93.2%
Urban	20000/- and above	9.86%	6.5%
	10000/- to 20000/-	18.01%	15.17%
	below 10000/-	72.13%	78.33%
Rural	20000/- and above	0.95%	0.62%
	10000/- to 20000/-	5.30%	3.76%
	below 10000/-	93.75%	95.71%

$$\text{Average\% of house hold's} = \frac{6.8\% + 21.67\% + 4.29\%}{3} = 10.92\%, \text{ whose total monthly income are } 10000/- \text{ and above.}$$

5.3.5 Employment status by monthly house hold Income

Table 5.4c Employment status by monthly house hold income.

Area	Monthly income	Employer	Self employed	Employee	Others
National	20000/- and above	22.25	53.58	23.54	0.82
	10000/- to 20000/-	10.33	56.39	29.80	3.48
Urban	20000/- and above	27.84	38.64	32.67	1.21
	10000/- to 20000/-	10.81	43.60	43.35	2.24
Rural	20000/- and above	11.13	84.73	4.14	--
	10000/- to 20000/-	3.73	69.36	18.84	8.06

$$\text{Average\% of employer} = \frac{16.29 + 19.325 + 7.43}{3} = 14.348\%$$

$$\text{and average\% of self employed} = \frac{54.985 + 41.12 + 77.045}{3} = 57.71\%$$

$$\text{and average\% of employee} = \frac{26.67 + 38.01 + 11.49}{3} = 25.39\%$$

whose monthly income are 10000/– and above.

* Source : House hold expenditure survey, BBS, 1995-96.

5.3.6 Distribution of earners and major occupation by monthly household income.

Table 5.5 Distribution of earners and major occupation by monthly household income 2001.

Monthly income		Professional & Technical	Administrative, executive managerial	Clerical
National	20000/- and above	7.04	1.27	7.14
	10000/- -20000/-	7.70	1.66	9.54
Urban	20000/- and above	8.19	1.84	8.06
	10000/- -20000/-	8.44	3.46	16.14
Rural	20000/- and above	4.48	--	5.09
	10000/- -20000/-	7.00	--	3.43

Monthly income		Trade, Business, sales works	Farmer, Fisherman	Transport Communication	Manufacturing, production worker	Services in sports & Recreation	Construction work
National	20000/- and above	35.79	11.83	2.36	4.93	3.95	1.53
	10000/- -20000/-	20.88	31.26	1.59	4.48	4.48	3.81
Urban	20000/- and above	43.21	2.08	2.10	5.17	4.40	2.21
	10000/- -20000/-	32.87	3.96	2.71	9.18	1.52	3.60
Rural	20000/- and above	19.21	33.64	2.97	4.37	2.94	--
	10000/- -20000/-	9.76	56.37	3.33	4.45	2.32	1.10

Monthly income		Agri. Labour	Electric, Gass, Water	Service	Menial Labour	Others
National	20000/- and above	5.23	--	0.90	15.39	2.64
	10000/- -20000/-	3.43	0.47	0.37	3.27	7.54
Urban	20000/- and above	0.27	--	--	19.79	2.69
	10000/- -20000/-	--	0.98	0.76	6.79	9.60
Rural	20000/- and above	16.31	--	2.90	5.56	2.52
	10000/- -20000/-	6.61	--	--	--	5.63

* Source : Household expenditure survey, BBS, 1995-96.

5.3.7 Cellular demand from 2000 to 2010.

From the recorded data of average population growth rate, income level, employment status and distribution of earning member and major occupation we can take a decision for cellular demand at 2010.

The recorded cellular demand at 2000 is 1,50,000. Also population per mobile is 56.36. From the table 5.4b we see that nationally 6.8% of house hold's, in urban area 21.67% of house hold's and in rural area 4.29% of house hold's monthly income are 1000/- and above. So average is 10.92% which was 6.27% in 1991. So for the year

2001, 10.92% house hold's are capable to take mobile set but from table 5.6 we see that only 2.57% house hold's was taken mobile i.e. population per was 38.87. Which is 4.25 times lower than capable percentage. For the year 2010 this percentage may be increases to 15.10%, whose are capable to take mobile.

From employment status table 5.4c average % of employer, self employed and employee are 14.348%, 57.71% and 25.39% correspondingly, whose income level are 10000/- and above. If we can take an assumption 100% of employer, 80% of self employed and 60% of employee must have a telephone.

Then No. of population, whose must have a telephone

= 100% of 14.348+80% of 57.71+60% of 25.39

= 14.348+46.168+15.234

= 75.75%.

From the major occupation distribution table 5.5 we take an another assumption the population whose are work in Professional & Technical, Administrative, Executive & Managerial, Trade, Business & Sales, Transport & Communication, Construction, Electric, Gass & Water division and their income level are 10000/- and above must have a mobile set for communication.

Then average % of those population = 14.28+4.115+53.9+5.02+4.08+.725=82.12%

So % of population whose must have a mobile set

= 82.12% of 75.75 (Whose must have a telephone)

= 62.20% of those population whose are capable to take a mobile set.

∴ % of total population whose must have a mobile set for the year 2010

= 62.2% of 15.1 (Whose are capable to take a mobile set)

= 9.39%

But for design purpose this percentage is consider at 10% i.e. the population per mobile is 10.

Two common methods of demand forecasting are:

(a) Linear projection

(b) Exponential projection

We plot a linear projection of cellular demand 2000 to 2010. The population at 2010 is determined by assuming average growth rate 2.129% which is shown in Table 5.6. The cellular demand at 2000 is 150000 and at 2010 is 1198237 which is 10% of the total population of Dhaka Statistical Metropolitan Areas (SMA).

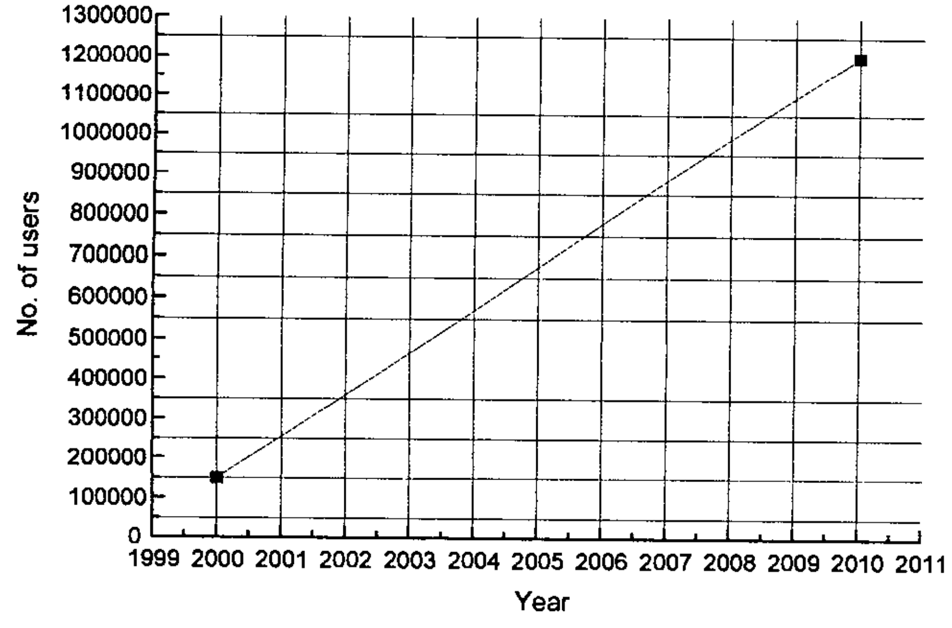


Figure 5.3 Cellular demand from 2000 to 2010

Table 5.6 Cellular demand from 2000 to 2010.

Year	Population	Cellular Demand (from graph)	AGR of Cellular demand	Population per mobile
2000	8454000	1,50,000	-	56.36
2001	9912908	2,55,000	70.00	**38.87**
2002	10123953	3,60,000	41.17	28.12
2003	10339492	4,65,000	22.58	22.23
2004	10559620	5,70,000	18.42	18.52
2005	10784434	6,75,000	15.55	15.97
2006	11014035	7,80,000	13.46	14.12
2007	11248524	8,85,000	11.86	12.71
2008	11488005	9,90,000	10.60	11.60
2009	11732585	10,95,000	9.58	10.71
2010	11982371	12,00,000	8.75	9.98

5.4 TYPICAL CDMA CELLULAR SYSTEM PARAMETER

1.	Number of subscriber	470,000 / BSC
2.	Number of BTS	157 / BSC
3.	Number of subscriber	3000 / BTS
4.	Cell radius	1.5 – 6 km.
5.	Radio frequency	800 MHz band 869 – 894 MHz (Forward link) 824 – 849 MHz (Reverse link)
6.	Multiple access system	CDMA
7.	Modulation	QPSK
8.	Hand off	Available
9.	Concentration ratio	Depend on GOS.
10.	Channel separation	1.25 MHz
11.	Channel number in 5 MHz	3 CH
12.	Number of channel groups	1
13.	Traffic Ch. number per RF channel	20 – 50 Ch.
14.	Frequency separation	45 MHz
15.	Transmission bit rate	1.2288 Mcps.
16.	Voice coding	QCELP – 9.6 kbps
17.	Duplex system	FDD
18.	Secrecy of communication	Available.
19.	Usable channel number per base station with 5 MHz	60 – 150 CH.
20.	GOS	2% - 5%
21.	Handoff	30%
22.	Mobile antenna height	1.5m.
23.	BTS antenna height	30m.
24.	Cell shape	Hexagonal

25. Minimum allowable received power at MS = - 63 to - 104 dBm.
26. Minimum allowable received power at BTS = - 121 dBm
27. BTS transmitter power P_T = 500W (Maximum)
28. MS transmitter power P_T = 0.2W.
29. Transmitter antenna gain G_T = 17 dBi.
30. MS antenna gain G_R = 0 dB.

5.5 AVAILABLE NUMBER OF REVERSE LINK CHANNEL PER SECTOR (WITH OTHER SECTOR INTERFERENCE AND THERMAL NOISE)

Available number of channel per one sector (Reverse link):

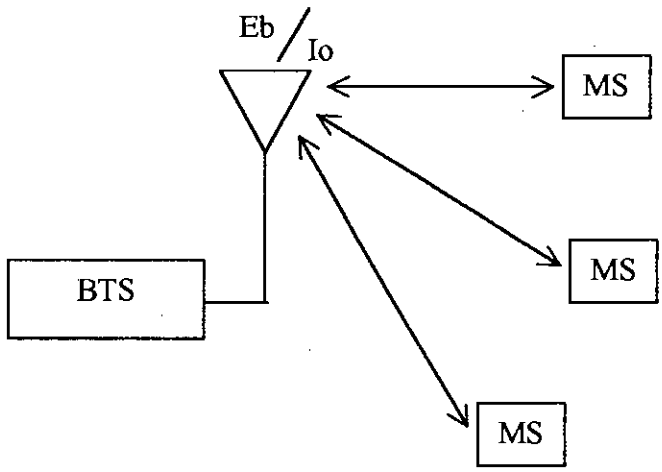


Figure 5.4 MS and BTS communication

Let,

P : Received power from each MS at the BTS

W : Bandwidth of CDMA channel (1.2288 MHz)

R : Maximum bit rate of vocoder (9.6 kbps)

I_{sc}: Own cell interference

I_0 : Thermal noise and total interference

N : Total number of MS communicating with the BTS at the time

f: Other cell interference ratio $(f = \frac{I_{oc}}{I_{sc}})$

N_0 : Thermal noise (N_0 = KTBNF)

η : Ratio of thermal noise density to total interference density including the thermal noise density.

V : Voice activity (Voice activity gain Gv = 1/v)

F : Reduction factor due to imperfect power control

NF : Receiver noise figure.

Received power per channel $E_b = \frac{P}{R}$ (5.1)

Thermal noise and total interference $I_0 = N_0 + I_{SC} + I_{OC}$ (5.2)

Other cell interference ratio $f = \frac{I_{OC}}{I_{SC}}$

$$I_{OC} = f\, I_{SC} \tag{5.3}$$

$$\eta = \frac{N_0}{I_0} = \frac{\text{Thermal noise}}{\text{Thermal noise and total interference}}$$

$$\therefore \quad N_0 = \eta I_0 \tag{5.4}$$

Using eq^n (5.3) and (5.4) in eq^n (5.2) we get

$$I_0 = \eta I_0 + I_{SC} + fI_{SC}$$

$$I_0 = (1+f)I_{SC} + \eta . I_0$$

$$(I_0 - \eta I_0) = (1+f)I_{SC}$$

$$I_0(1-\eta) = (1+f)I_{SC}$$

$$I_0 = \frac{(1+f)I_{SC}}{(1+\eta)} \tag{5.5}$$

Own cell interfereece $I_{SC} = \frac{vp(N-1)}{w}$ (5.6)

Put the value of I_{SC} in eq^n (5.5)

$$I_0 = \frac{(1+f)}{(1-\eta)} \cdot \frac{vp(N-1)}{w} \tag{5.7}$$

$$\eta = \frac{N_0}{I_0} = \frac{E_b / I_0}{E_b / N_0} = \frac{N_0}{E_b} \times \frac{E_b}{I_0}$$

Thermal noise No=KTBNF

$$\eta = \frac{KTBNF}{E_b} \times \frac{E_b}{I_0} \tag{5.8}$$

From eq^n (5.1) and (5.7)

$$\frac{E_b}{I_0} = \frac{P}{R} \cdot \frac{(1-\eta).W}{(1+f)\,VP(N-1)}$$

$$N-1 = \frac{W(1-\eta)}{(E_b/I_0).R.V.(1+f)}$$

$$N-1 = \frac{(W/R).Gv.(1-\eta)}{(E_b/I_0)\,(1+f)}$$

$$N = \frac{(W/R).Gv.(1-\eta)}{(E_b/I_0)\,.\,(1+f)} + 1 \tag{5.9}$$

Due to imperfect power control the reduction factor is F and total number of MS communicating with the BTS at the time per sector

$$N = \frac{(W/R)\,Gv\,.\,(1-\eta)\,.\,F}{(E_b/I_0)\,.\,(1+f)} + 1 \tag{5.10}$$

Number of usable channel per 3 – sector or one cell =N. G_A.

G_A= 2.65 for 3 sector.

Calculation of interference:

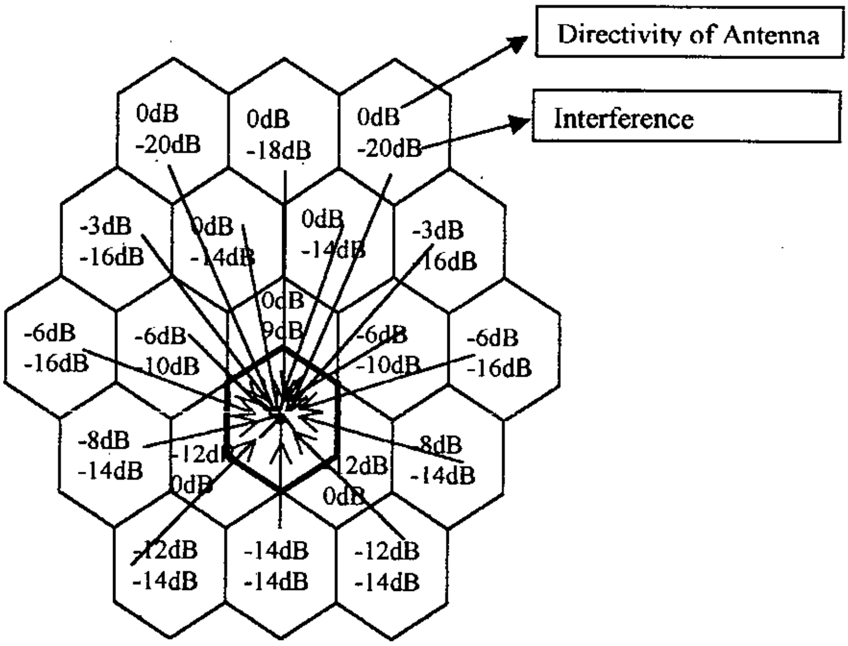


Figure 5.5 Other cell Interference

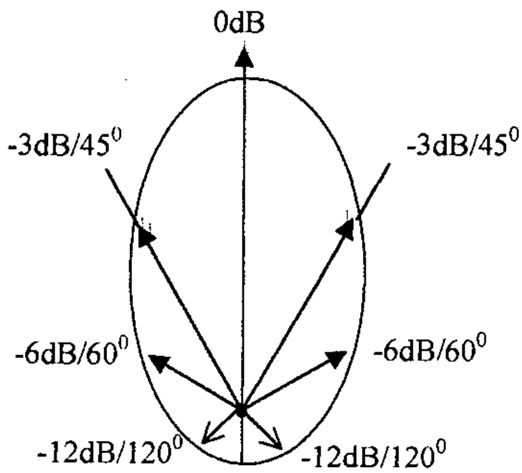


Figure 5.6 Radiation pattern of BTS antenna.

Using O – H model the path loss is expressed as

$$P_L = 69.65 + 26.16 \log_{10} f - 13.82 \log_{10} h_B + (44.9 - 6.55 \log_{10} h_B) \log_{10} d - 1.1\, h_m \log_{10} f + 0.7\, h_m + 1.56 \log_{10} f - 0.8 \text{ dB} \quad (5.11)$$

In CDMA

BTS antenna height $h_B = 30$ m

MS antenna height $h_M = 1.5$ m

Operating frequency $f = 800$ MHz

Path loss $P_L = 125.069 + 35.22 \log_{10} d$

Table 5.7 Cell Interference.

Cell radius d (km)	P_L (dB)	Interference
1.5	131.27	- 10.27
2.0	135.67	- 14.67
2.5	139.08	- 18.08
3.0	141.87	- 20.87

Minimum allowable received power at BTS = 121 dBm.

Desired signal level : 0 dB

Interference from own cell : (-12 dB) + (-12 dB) = 0.125

Interference from neighbor sector: (-16 dB) + (-16 dB) + (-14 dB) + (-14 dB) = 0.129

Interference from next neighbor sector :

(-20dB) + (-18dB) + (-20dB) + (-19dB) + (-19dB) + (-22dB) + (-22dB) + (-22dB) + (-26dB) + (-26dB) + -28dB) = 0.08

Total interference relative level = 0.3348 ≅ 0.34

Calculation of available number of traffic channel of reverse link per sector

If

$$W = 1.2288\,MHz$$

$$R = 9.6\,KHz$$

$$Gv = 9.6\,kbps / (9.6\,kbps \times 0.4 + 1.2\,kbps \times (1 - 0.4))$$

$$= \frac{9.6\,kbps}{4.56\,kbps} = 2.105$$

$$f = 0.34$$

$$F = 0.9$$

$$NF = 4dB = 2.52\ [10\log_{10} 2.52 = 4dB]$$

$$KTB = 1.38 \times 10^{-20} \times 300 \times 9600$$

$$= -134\,dBm.$$

Receive power per channel = - 117 dBm + 3 dB

= - 114 dBm : 3 dB up by SD.

= 3.981×10^{-12}

In CDMA $\frac{E_b}{I_0} = 5.1dB = 3.24$

$$\eta = \frac{KTBNF}{\text{Receive power per CH}} \times \frac{E_b}{I_0}$$

$$= \frac{1.38 \times 10^{-20} \times 300 \times 9600 \times 2.52}{3.981 \times 10^{-12}} \times 3.24$$

$$= 0.0815 = -10.9\,dB$$

From equation (5.10) in section 5.5

$$N = \frac{(W/R)\,.\,Gv\,.\,(1-\eta)\,.\,F}{(E_b/I_0)\,.\,(1+f)} + 1$$

$$= \frac{(1.228800/9600) \times 2.1 \times (1-0.0815) \times 0.9}{3.24(1+0.34)} + 1$$

$$= \frac{128 \times 2.1 \times (09185) \times 0.9}{3.24 \times 1.34} + 1$$

$$= \frac{268.8 \times 0.9185 \times 0.9}{4.3416} + 1$$

$$= 51.18 + 1$$

$$= 52.18$$

$\cong$ 52 No. of MS communicating with BTS at the time.

Since $G_A = 2.65$ for 3 sector

Number of usable channel per 3- sector

= 52×2.65

= 138

If handoff rate is 30%,

No. of usable channel per 3-sector or cell

=138 ÷ 1.3

=106 / 3- sector

= 106 / cell

No. of usable channel per sector

= 106 ÷ 3

= 35.3

we consider 35 channel/sector.

5.6 AVAILABLE NUMBER OF FORWARD LINK CHANNEL PER SECTOR.

Let,

P : Received power from each MS at the BTS

In CDMA 0.76 is power ratio assigned to the traffic channels.

W : Bandwidth of CDMA channel (1.2288 MHZ)

R : Maximum bit rate of vocoder (9.6 kb/s)

I_{sc}: Own cell interference

I_0 : Thermal noise and total interference

N : Total number of MS communicating with the BTS at the time

f: Other cell interference ratio ($f = I_{oc}/I_{sc}$)

N_0 : Thermal noise (No = KTBNF)

η : Ratio of thermal noise density to total interference density including the thermal noise density.

V : Voice activity (Voice Activity Gain $G_V = 1/_V$)

F : Reduction factor due to imperfect power control

NF : Received noise figure

Received power per channel

$$E_b = \frac{0.76 P_{tot}}{NR}$$

$$P_{tot} = p_p + p_s + p_p + NP_{tr} \qquad (5.12)$$

Thermal noise and total interference

$$I_0 = I_{SC} + I_{OC} + N_0$$

$$I_0 = (1 + \frac{I_{OC}}{I_{SC}})\ I_{SC} + N_0$$

Since

$$\frac{I_{OC}}{I_{SC}} = f \qquad \text{and} \qquad \eta = \frac{N_0}{I_0}$$

$$\therefore I_0 = (1+f)\ I_{SC} + \eta . I_0$$

$$I_0 - \eta I_0 = (1+f) I_{SC}$$

$$I_0 = \frac{(1+f) I_{SC}}{(1-\eta)} \qquad (5.13)$$

Own cell interference $I_{SC} = \dfrac{P_{tot}(0.76v + 0.14)}{W}$

∴ From eq^{n} (5.13)

$$I_0 = \frac{P_{tot}(0.76v + 0.14)\,(1+f)}{(1-\eta)\,.\,W} \tag{5.14}$$

Ratio of thermal noise density to total interference density including the thermal noise density

$$\eta = \frac{N_0}{I_0} = \frac{N_0}{E_b} \times \frac{E_b}{I_0}$$

$$\eta = \frac{KTBNF}{\text{Receive power per CH}} \times \frac{E_b}{I_0} \tag{5.15}$$

$$\frac{E_b}{I_0} = \frac{0.76\ P_{tot}\ .\ W\ .\ (1-\eta)}{NR\ .\ P_{tot}\ (0.76v + 0.14)\ (1+f)} \tag{5.16}$$

Using eq^{n} (5.12) and (5.14)

$$\frac{E_b}{I_0} = \frac{W\ .\ 0.76\ .\ (1-\eta)}{NR\ .\ (0.76v + 0.14)\ \left(1+f\right)} \tag{5.17}$$

Total number of MS communicating with the BTS at the time

$$N = \frac{0.76\ (W/R)\ .\ (1-\eta)\ .\ F}{(E_b/I_0)\ .\ (0.76v + 0.14)\ .\ (1+f)} \tag{5.18}$$

Here the term F is including as reduction factor due to imperfect power control.

N (3 – sector) = G_{Λ}. N.

Calculation of available number of traffic channel of forward link per sector:

If $W = 1.2288$ MHz

$R = 9.6$ KHz

$$Gv = \frac{9.6\,\text{kbps}}{9.6\,\text{kbps} \times 0.4 + 1.2\,\text{kbps}(1-0.4)} = 2.1$$

$$v = \frac{1}{Gv} = \frac{1}{2.1} = 0.476$$

$f = 0.34$

$F = 0.9$

$NF = 4$ dB $= 2.52$

$KTB = 1.38 \times 10^{-20} \times 300 \times 9600 = -134$ dBm

Receive power per channel $= -117$ dBm $+ 3$ dB

$= -114$ dBm : 3 dB UP by SD

$E_b/I_0 = 5.1$ dB $= 3.24$

$$\eta = \frac{\text{KTBNF}}{\text{Receive power per CH}} \times \frac{E_b}{I_0}$$

$$= \frac{2.52 \times 1.38 \times 10^{-20} \times 300 \times 9600}{3.981 \times 10^{-12}} \times 3.24$$

$$= 0.0815$$

No. of usable channels per sector

$$N = \frac{0.76.\,(W/R)\,.\,(1-n)\,F}{(E_b/I_0)\,.\,(0.76v + 0.14)\,.\,(1+f)}$$

$$= \frac{0.76 \times (1.228800/9600)\,(1-0.0815) \times 0.9}{3.24(0.76 \times 0.476 + 0.14)\,(1+0.34)}$$

$$= \frac{80.416512}{2.17844}$$

$$= 36.91$$

$= 37$ channels/sector.

5.7 COVERAGE AND TRAFFIC CAPACITY

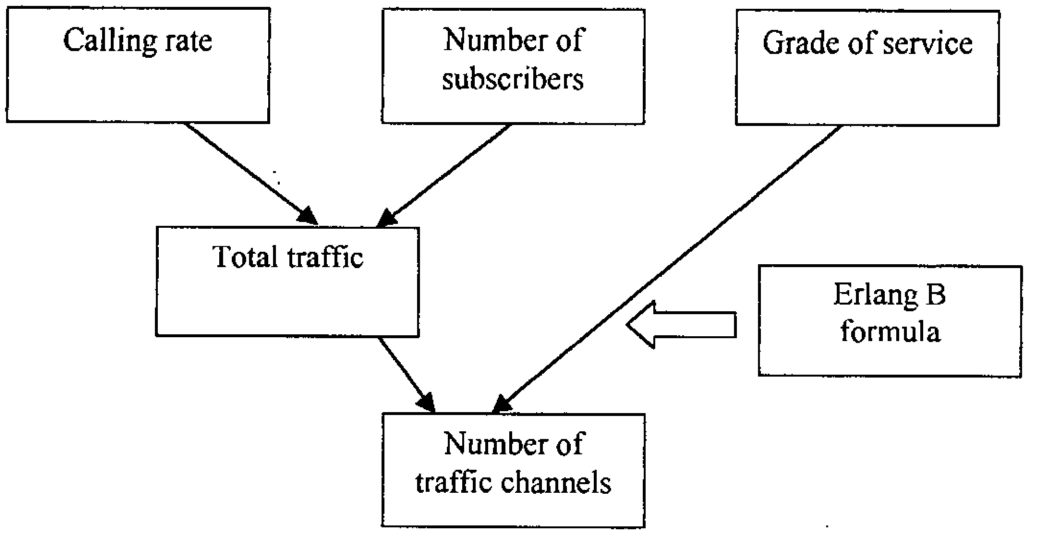


Figure 5.7 Traffic capacity calculation

The reverse link analysis is preferred for calculation of No. of user per cell.

Let, Grade of service (GOS) is 2%

Then from Erlang B chart/table total calling rate or capacity = 26.4 erlangs for 35 channels

If we select the calling rate at busy hour/user

$$= \text{No. of call per hour} \times \text{call duration in hour}$$

$$= \frac{1 \times 2}{60}$$

$$= 0.0333 \text{ Erlangs}$$

$$\text{Number of user / sector} = \frac{26.4}{0.033}$$

$$= 792$$

Number of user/cell = 2376.

If we select the calling rate at busy hour/user

$$= \text{No. of call per hour} \times \text{call duration in hour}$$

$$= \frac{1 \times 1.5}{60}$$

$$= 0.025 \text{ Erlangs.}$$

Number of user/sector $= \frac{26.4}{0.025} = 1056$

Number of user/cell $= 1056 \times 3 = 3168$

The calling rate at busy hour/user and No. of user per cell is given in table 5.8.

Table 5.8 Calling rate at busy hour/user and No. of user per cell

No. of call per hour	Call duration in minute	Calling rate at busy hour per user (erlangs)	Total calling capacity (erlangs)	No. of user per sector	No. of user per cell.
1	1.0	0.0116	26.4	1584	4752
1	1.5	0.025	26.4	1056	3168
1	2.0	0.033	26.4	792	2376
1	2.5	0.0416	26.4	633	1900
1	3.0	0.05	26.4	528	1584
1	3.5	0.058	26.4	452.5	1357

For commercial areas calling rate at busy hour per user is selected 0.033 Erlangs and 0.025 Erlangs for residential, others urban and rural areas.

5.8 CELL PLANNING UPTO 2004

At 2004 the cellular demand will 5,70,000 for greater Dhaka city. So at present time the cell planning is done based on that demand to meet the increasing demand up to 2004. But at 2002 all cells are not active. Since at 2003 & 2004 demand and coverage area will increase and more cell will activate.

5.8.1 Population distribution & cellular demand at 2004

The following table shows the population distribution for different zones from 2001 to 2004.

Table 5.9 Population distribution for different zones.

SL No.	Name of the zone	Recorded	Calculated (AGR=2.129%)		
		2001	2002	2003	2004
1.	Dhaka zone	5784836	5907995	6033776	6162235
2.	Narayangonj zone	230294	235196	240205	245318
3.	Gazipur zone	250429	255760	261205	266766
4.	Other sub-urban and rural area	3647349	3725002	3804306	3885301
	Total	**9912908**	**10123953**	**10339492**	**10559620**

Source : Population census, BBS, Aug 2001.

At 2004 the cellular demand is considered 5,70,000 for 2827 km^2 coverage area.

Table 5.10 Population & cellular demand at 2004.

SL No.	Name of the zone	Population at 2004	Population/ Mobile	Cellular demand
1.	Dhaka zone	6162235	18.52	332632
2.	Narayangonj zone	245318	18.52	13243
3.	Gazipur zone	266766	18.52	14400
4.	Other sub-urban and rural area	3885301	18.52	209725
	Total	**10559320**	--	**5,70,000**

5.8.2 Calculation of number of cell

Calculation of No. of cell depends on cellular demand, busy hour calling rate and traffic available per cell.

Table 5.11 Calculation of number of cell

No.	Name of the zone	Cellular Demand	Busy hour calling rate/ user (E)	Total traffic demand (E)	Traffic available/ cell (E)	Required No. of cell	Actual No. of cell	No. of user/cell	No. of user to be connected
1.	Dhaka	332632	0.0333	11076.65	79.2	139.856	140	2376	332640
2.	Narayangonj sadar	13243	0.025	331.075	79.2	4.180	5	3168	15840
3.	Gazipur sadar	14400	0.025	360.00	79.2	4.545	5	3168	15840
4.	Other sub-urban and rural area	209725	0.025	5243.125	79.2	66.201	67	3168	212256
	Total.	**570000**	--	--	--	--	217	--	**576576**

The considered area is 2827.4 km^2 which is 30 km radius with center at Mohakhali.

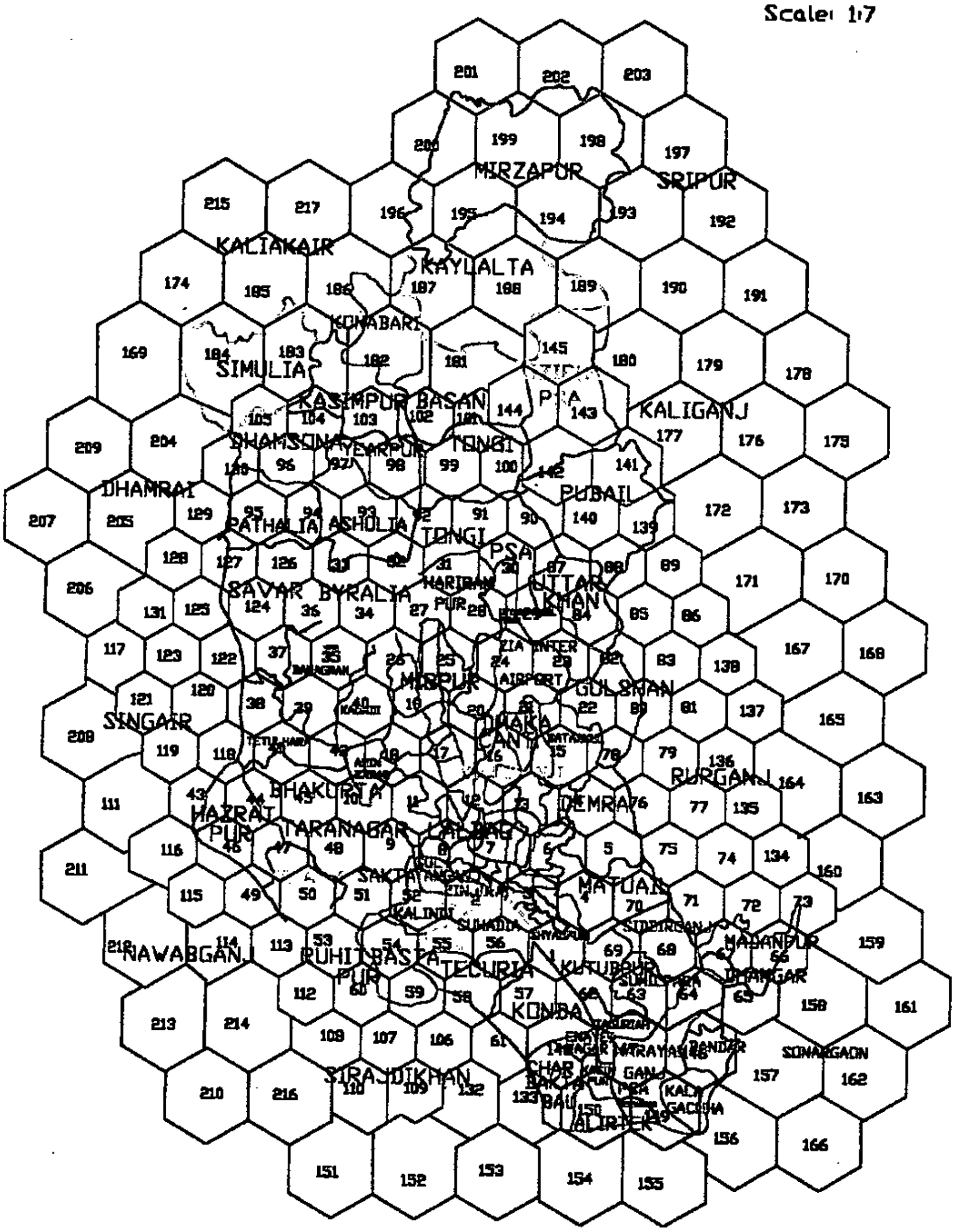
Table 5.12 Calculation of coverage area.

Zone	Cell radius	Cell No.	Coverage area
Dahka	2 km.	140	1450.40
Narayangonj sadar	2.5 km.	5	80.9375
Gazipur sadar	2.5 km.	5	80.9375
Other sub-urban and rural area.	3.0 km.	67	1561.77
		Total cell= 217	**Total coverage area= 3174.045**

Since total coverage area is 3174.045 km^2 which is 31.78 km radius with center at Mohakhali. But the actual coverage area for all zones is (1463.60 + 1741.53 + 759.57) = 3964.7 km^2. So (3964.7 – 3174.045) = 790.655 km^2 rural area is not considered for this design. But those areas will considered by using extra cell and more user to be connected.

5.8.3 Cell plan for Dhaka city from the year 2002 to 2004 is shown in figure 5.8

Scale: 1:7



LEGEND

⬡ for Dhaka zone

⬡ for Urban area

⬡ for Narayanganj zone

Fig. 5.8. Cell plan for Dhaka city from the year 2002 to 2004

5.8.4 Traffic Distribution from the year 2002 to 2004

The number of cell on air for the year 2002 to 2004 is given in table 5.13a.

Table 5.13a Number of cell on air

For the year	Name of zone	No. of population	Cellular demand	Traffic/ user	No. of user to be connected per cell	No. of cell on air
2002	Dhaka	5907995	210100	0.033	2376	89
	Narayangonj	235196	8364	0.025	3168	03
	Gazipur	255760	9095	0.025	3168	03
	Other sub-urban and rural area	3725002	132441	0.025	3168	42
	Total	**10123953**	**360000**			**137**
2003	Dhaka	6033776	271425	0.033	2376	115
	Narayangonj	240205	10805	0.025	3168	04
	Gazipur	261205	11750	0.025	3168	04
	Other sub-urban and rural area	3804306	171020	0.025	3168	54
	Total	**10339492**	**465000**			**177**
2004	Dhaka	6162235	332632	0.033	2376	140
	Narayangonj	245318	13243	0.025	3168	5
	Gazipur	266966	14400	0.025	3168	5
	Other sub-urban and rural area	3885301	209725	0.025	3168	67
	Total	**10559620**	**570000**			**217**

The traffic distribution with coverage area from the year 2002 to 2004 is given in table 5.13b.

Table 5.13b Traffic distribution from the year 2002 to 2004

Cell No.	Location of cell	For the year 2002		For the year 2003		For the year 2004	
		Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity
1	Sham pur	10.36	2376	10.36	2376	10.36	2376
2	Bangla Bazar	10.36	2376	10.36	2376	10.36	2376
3	Jatra Bari	10.36	2376	10.36	2376	10.36	2376
4	Manik Nagar	10.36	2376	10.36	2376	10.36	2376
5	Sabujbagh	10.36	2376	10.36	2376	10.36	2376
6	Motijheel	10.36	2376	10.36	2376	10.36	2376
7	PG Hospital	10.36	2376	10.36	2376	10.36	2376
8	Zigathola	10.36	2376	10.36	2376	10.36	2376
9	Danmondi	10.36	2376	10.36	2376	10.36	2376
10	Mohammedpur	10.36	2376	10.36	2376	10.36	2376
11	Farmgate	10.36	2376	10.36	2376	10.36	2376
12	Mohakhali	10.36	2376	10.36	2376	10.36	2376
		124.32	**28512**	**124.32**	**28512**	**124.32**	**28512**

Cell No.	Location of cell	For the year 2002		For the year 2003		For the year 2004	
		Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity
		124.32	**28512**	**124.32**	**28512**	**124.32**	**28512**
13	Rampura	10.36	2376	10.36	2376	10.36	2376
14	Khilgaon	10.36	2376	10.36	2376	10.36	2376
15	Gulshan-Banani	10.36	2376	10.36	2376	10.36	2376
16	Kafrul	10.36	2376	10.36	2376	10.36	2376
17	Kaylanpur	10.36	2376	10.36	2376	10.36	2376
18	Mirpur-1	10.36	2376	10.36	2376	10.36	2376
19	Mirpur-2	10.36	2376	10.36	2376	10.36	2376
20	Senpara	10.36	2376	10.36	2376	10.36	2376
21	Banni-DOHS	10.36	2376	10.36	2376	10.36	2376
22	Kachukhet	10.36	2376	10.36	2376	10.36	2376
23	Nikuroa	10.36	2376	10.36	2376	10.36	2376
24	Zia Inter. Airport	10.36	2376	10.36	2376	10.36	2376
25	Mirpur	10.36	2376	10.36	2376	10.36	2376
26	Rupnagar-Kaundi	10.36	2376	10.36	2376	10.36	2376
27	Bhasantak-Horirampur	10.36	2376	10.36	2376	10.36	2376
28	Zoar Shahara	10.36	2376	10.36	2376	10.36	2376
29	Khilkhat-Uttara model town	10.36	2376	10.36	2376	10.36	2376
30	Uttara	10.36	2376	10.36	2376	10.36	2376
31	Horirampur	10.36	2376	10.36	2376	10.36	2376
32	Byralia-Asgykua	10.36	2376	10.36	2376	10.36	2376
33	Byralia-Ashulia	10.36	2376	10.36	2376	10.36	2376
34	Byralia	10.36	2376	10.36	2376	10.36	2376
35	Banagram	10.36	2376	10.36	2376	10.36	2376
36	Byralia-saver-Banagram	10.36	2376	10.36	2376	10.36	2376
37	Banagram-Saver	10.36	2376	10.36	2376	10.36	2376
38	Tetulhara	10.36	2376	10.36	2376	10.36	2376
39	Banagram	10.36	2376	10.36	2376	10.36	2376
40	Kaundi	10.36	2376	10.36	2376	10.36	2376
41	Telulhara	10.36	2376	10.36	2376	10.36	2376
42	Telulhara-Kaundi-Aminbazar	10.36	2376	10.36	2376	10.36	2376
43	Singair-Hazatpur	--	--	10.36	2376	10.36	2376
44	Hazatpur	--	--	10.36	2376	10.36	2376
45	Taranagar	10.36	2376	10.36	2376	10.36	2376
46	Hazratpur-Nawabgang	--	--	10.36	2376	10.36	2376
47	Hazratpur-Kalatia	10.36	2376	10.36	2376	10.36	2376
48	Taranagar	10.36	2376	10.36	2376	10.36	2376
49	Nawabganj-Kalatia	--	--	10.36	2376	10.36	2376
50	Kalatia	10.36	2376	10.36	2376	10.36	2376
51	Sakta	10.36	2376	10.36	2376	10.36	2376
52	Sakta-Kalindi	10.36	2376	10.36	2376	10.36	2376
		497.28	**114048**	**538.72**	**123552**	**538.72**	**123552**

Cell No.	Location of cell	For the year 2002		For the year 2003		For the year 2004	
		Coverage area (km²)	Installed Traffic Capacity	Coverage area (km²)	Installed Traffic Capacity	Coverage area (km²)	Installed Traffic Capacity
		497.28	**114048**	**538.72**	**123552**	**538.72**	**123552**
53	Ruhitpur	10.36	2376	10.36	2376	10.36	2376
54	Basta	10.36	2376	10.36	2376	10.36	2376
55	Basta-Kalindi-suhadya	10.36	2376	10.36	2376	10.36	2376
56	Suhadya-Tecuria	10.36	2376	10.36	2376	10.36	2376
57	Suhadya-Shyaupur-Konda	10.36	2376	10.36	2376	10.36	2376
58	Tecuria	10.36	2376	10.36	2376	10.36	2376
59	Basta	10.36	2376	10.36	2376	10.36	2376
60	Ruhitpur-Nawabgang	10.36	2376	10.36	2376	10.36	2376
61	Konda-Sirajdikhan	10.36	2376	10.36	2376	10.36	2376
62	Kutubpur-Konda	10.36	2376	10.36	2376	10.36	2376
63	Taguriah-Kutubpur-Sumilpara	10.36	2376	10.36	2376	10.36	2376
64	Narayanganj PSA	10.36	2376	10.36	2376	10.36	2376
65	Masapur	10.36	2376	10.36	2376	10.36	2376
66	Dhamgar-Madanpur	--	--	10.36	2376	10.36	2376
67	Madanpur	10.36	2376	10.36	2376	10.36	2376
68	Siddirganj	10.36	2376	10.36	2376	10.36	2376
69	Siddirganj-Kutubpur	10.36	2376	10.36	2376	10.36	2376
70	Matuail Siddirganj	10.36	2376	10.36	2376	10.36	2376
71	Rupganj	10.36	2376	10.36	2376	10.36	2376
72	Madanpur-Rupganj	--	--	10.36	2376	10.36	2376
73	Madanpur-Rupganj	--	--	10.36	2376	10.36	2376
74	Rupganj	--	--	10.36	2376	10.36	2376
75	Rupganj-Matuail	10.36	2376	10.36	2376	10.36	2376
76	Demra-Rupganj	10.36	2376	10.36	2376	10.36	2376
77	Rupganj	--	--	10.36	2376	10.36	2376
78	Satarkul-Gulshan Demra-Rupganj	10.36	2376	10.36	2376	10.36	2376
79	Rupganj	10.36	2376	10.36	2376	10.36	2376
80	Gulshan-Rupganj	10.36	2376	10.36	2376	10.36	2376
81	Rupganj	10.36	2376	10.36	2376	10.36	2376
82	Dakhinkhan-Gulshan	10.36	2376	10.36	2376	10.36	2376
83	Rupganj	10.36	2376	10.36	2376	10.36	2376
84	Uttarkhan	10.36	2376	10.36	2376	10.36	2376
85	Uttarkhan-Rupganj	10.36	2376	10.36	2376	10.36	2376
86	Rupganj	--	--	10.36	2376	10.36	2376
87	Tongi PSA-Uttarkhan	10.36	2376	10.36	2376	10.36	2376
88	Uttarkhan	10.36	2376	10.36	2376	10.36	2376
89	Pubail	--	--	10.36	2376	10.36	2376
90	Tongi PSA	10.36	2376	10.36	2376	10.36	2376
91	Tongi PSA	10.36	2376	10.36	2376	10.36	2376
92	Tongi PSA-Ashulia	10.36	2376	10.36	2376	10.36	2376
93	Ashulia	10.36	2376	10.36	2376	10.36	2376
		849.52	**194832**	**963.48**	**220968**	**963.48**	**220968**

Cell No.	Location of cell	For the year 2002		For the year 2003		For the year 2004	
		Coverage area (km²)	Installed Traffic Capacity	Coverage area (km²)	Installed Traffic Capacity	Coverage area (km²)	Installed Traffic Capacity
		849.52	**194832**	**963.48**	**220968**	**963.48**	**220968**
94	Ashulia-Pathalia	10.36	2376	10.36	2376	10.36	2376
95	Pathalia	--	--	10.36	2376	10.36	2376
96	Dhamsona	--	--	10.36	2376	10.36	2376
97	Dhamsona-Yearpor Ashulia	--	--	10.36	2376	10.36	2376
98	Yearpur	10.36	2376	10.36	2376	10.36	2376
99	Tongi	10.36	2376	10.36	2376	10.36	2376
100	Tongi	10.36	2376	10.36	2376	10.36	2376
101	Basan	--	--	10.36	2376	10.36	2376
102	Basan	--	--	10.36	2376	10.36	2376
103	Kasimpur	--	--	10.36	2376	10.36	2376
104	Kasimpur-Dhamsiba	--	--	--	--	10.36	2376
105	Simulia	--	--	--	--	10.36	2376
106	Sirajdikhan	10.36	3168	10.36	3168	10.36	3168
107	Sirajdikhan	10.36	3168	10.36	3168	10.36	3168
108	Sirajdikhan	--	--	10.36	3168	10.36	3168
109	Sirajdikhan	10.36	3168	10.36	3168	10.36	3168
110	Sirajdikhan	--	--	10.36	3168	10.36	3168
111	Nawabgang	--	--	--	--	10.36	2376
112	Sirajdikhan	--	--	--	--	10.36	2376
113	Nawabganj-Kalatia	10.36	3168	10.36	3168	10.36	3168
114	Nawabgang	10.36	3168	10.36	3168	10.36	3168
115	Nawabgang	10.36	3168	10.36	3168	10.36	3168
116	Nawabganj	10.36	3168	10.36	3168	10.36	3168
117	Singair	--	--	--	--	10.36	2376
118	Telulhara-Singair	10.36	3168	10.36	3168	10.36	3168
119	Singair	10.36	3168	10.36	3168	10.36	3168
120	Singair	10.36	3168	10.36	3168	10.36	3168
121	Singair	10.36	3168	10.36	3168	10.36	3168
122	Savar-Singair	10.36	3168	10.36	3168	10.36	3168
123	Singair	10.36	3168	10.36	3168	10.36	3168
124	Savar	10.36	3168	10.36	3168	10.36	3168
125	Savar-Damrai	10.36	3168	10.36	3168	10.36	3168
126	Pathalia	10.36	3168	10.36	3168	10.36	3168
127	Pathalia-Damrai	10.36	3168	10.36	3168	10.36	3168
128	Damrai	10.36	3168	10.36	3168	10.36	3168
129	Damrai	10.36	3168	10.36	3168	10.36	3168
130	Damrai-Dhamsona	10.36	3168	10.36	3168	10.36	3168
131	Singair-Damrai	--	--	--	--	10.36	2376
132	Sirajdikhan	--	--	10.36	2376	10.36	2376
133	Sirajdikhan-Charbaktabau	--	--	--	--	10.36	2376
134	Rupganj	--	--	--	--	10.36	2376
135	Rupganj	--	--	10.36	2376	10.36	2376
136	Rupganj	--	--	10.36	2376	10.36	2376
		1098.16	**267696**	**1326.06**	**319968**	**1408.96**	**338976**

Cell No.	Location of cell	For the year 2002		For the year 2003		For the year 2004	
		Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity
		1098.16	**267696**	**1326.06**	**319968**	**1408.96**	**338976**
137	Rupganj	--	--	10.36	2376	10.36	2376
138	Rupganj	--	--	--	--	10.36	2376
139	Pubail	10.36	2376	10.36	2376	10.36	2376
140	Pubail	10.36	2376	10.36	2376	10.36	2376
141	Pubail-Gazipur PSA	--	--	16.1875	3168	16.1875	3168
142	Gazipur PSA	16.1875	3168	16.1875	3168	16.1875	3168
143	Gazipur PSA	16.1875	3168	16.1875	3168	16.1875	3168
144	Gazipur PSA-Basan	16.1875	3168	16.1875	3168	16.1875	3168
145	Gazipur PSA-Kaylalta	--	--	--	--	16.1875	3168
146	Bandar-Narayanganj	--	--	16.1875	2376	16.1875	2376
147	Narayanganj PSA	16.1875	3168	16.1875	3168	16.1875	3168
148	Narayanganj PSA-Taguriah	16.1875	3168	16.1875	3168	16.1875	3168
149	Narayanganj PSA-Kalagachhia	16.1875	3168	16.1875	3168	16.1875	3168
150	Nar. PSA-Aliatek-Kasimpur	--	--	--	--	16.1875	3168
151	Sirajdikhan	--	--	--	--	23.31	3168
152	Sirajdikhan	--	--	--	--	23.31	3168
153	Sirajdikhan	--	--	--	--	23.31	2376
154	Alirtek-Sirajdikhan	--	--	--	--	23.31	2376
155	Gognagar	--	--	--	--	23.31	2376
156	Kalagachhia	--	--	--	--	23.31	2376
157	Sonargaon	23.31	2376	23.31	2376	23.31	2376
158	Sonargaon	23.31	3168	23.31	3168	23.31	3168
159	Sonargaon	23.31	3168	23.31	3168	23.31	3168
160	Madanpur-Sonargaon	--	--	--	--	23.31	2376
161	Sonargaon	23.31	3168	23.31	3168	23.31	3168
162	Sonargaon	23.31	3168	23.31	3168	23.31	3168
163	Rupganj	--	--	--	--	23.31	3168
164	Rupganj	23.31	3168	23.31	3168	23.31	3168
165	Rupganj	--	--	--	--	23.31	3168
166	Sonargaon	23.31	3168	23.31	3168	23.31	3168
167	Rupganj	--	--	--	--	23.31	3168
168	Rupganj	--	--	--	--	23.31	3168
169	Simulia	--	--	--	--	23.31	3168
170	Kaliganj	23.31	3168	23.31	3168	23.31	3168
171	Kaliganj-Rupganj	--	--	--	--	23.31	2376
172	Pubail	23.31	3168	23.31	3168	23.31	3168
173	Kaliganj	--	--	23.31	2376	23.31	2376
174	Kaliakair	23.31	3168	23.31	3168	23.31	3168
175	Kaliganj	--	--	--	--	23.31	3168
176	Kaliganj	23.31	3168	23.31	3168	23.31	3168
177	Kaliganj-Pubail	23.31	3168	23.31	3168	23.31	3168
178	Kaliganj	--	--	--	--	23.31	3168
		1495.725	**328680**	**1765.67**	**391248**	**2264.955**	**461736**

Cell No.	Location of cell	For the year 2002		For the year 2003		For the year 2004	
		Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity	Coverage area (km^2)	Installed Traffic Capacity
		1495.725	**328680**	**1765.67**	**391248**	**2264.955**	**461736**
179	Kaliganj	23.31	3168	23.31	3168	23.31	3168
180	Gazipur PSA-Kaliganj	23.31	3168	23.31	3168	23.31	3168
181	Basan	--	--	23.31	3168	23.31	3168
182	Konabari	--	--	23.31	3168	23.31	3168
183	Simulia-Kasimpur	23.31	3168	23.31	3168	23.31	3168
184	Simulia	23.31	3168	23.31	3168	23.31	3168
185	Kaliakair	23.31	3168	23.31	3168	23.31	3168
186	Kaliakair-Konabari	23.31	3168	23.31	3168	23.31	3168
187	Kaylalta	--	--	--	--	23.31	2376
188	Kaylalta	--	--	--	--	23.31	2376
189	Kaylalta-Gazipu PSA	--	--	--	--	23.31	2376
190	Sripur	23.31	3168	23.31	3168	23.31	3168
191	Sripur	--	--	--	--	23.31	3168
192	Sripur	--	--	23.31	3168	23.31	3168
193	Sripur-Mirzapur	--	--	23.31	3168	23.31	3168
194	Mirzapur-Kaylalta	--	--	23.31	2376	23.31	2376
195	Mirzapur	--	--	23.31	3168	23.31	3168
196	Mirzapur-Kaliakair	--	--	--	--	23.31	2376
197	Sripur	--	--	23.31	3168	23.31	3168
198	Sripur-Mirzapur	--	--	23.31	3168	23.31	3168
199	Mirzapur	--	--	23.31	3168	23.31	3168
200	Mirzapur-Kaliakair	--	--	--	--	23.31	2376
201	Mirzapur	--	--	--	--	23.31	3168
202	Mirzapur	--	--	--	--	23.31	2376
203	Mirzapur	--	--	--	--	23.31	3168
204	Damrai	23.31	3168	23.31	3168	23.31	3168
205	Damrai	23.31	3168	23.31	3168	23.31	3168
206	Singair-Damrai	--	--	--	--	23.31	2376
207	Damrai	--	--	--	--	23.31	2376
208	Singair	--	--	--	--	23.31	2376
209	Damrai	--	--	23.31	3168	23.31	3168
210	Nawabgang-Sirajdikhan	--	--	--	--	23.31	3168
211	Nawabganj	--	--	23.31	3168	23.31	3168
212	Nawabganj	--	--	23.31	3168	23.31	3168
213	Nawabganj	--	--	23.31	3168	23.31	3168
214	Sirajdikhan-Nawabganj	--	--	23.31	3168	23.31	3168
215	Kaliakair	23.31	3168	23.31	3168	23.31	3168
216	Sirajdikhan	--	--	--	--	23.31	2376
217	Kaliakair	23.31	3168	23.31	3168	23.31	3168
	Total	**1752.135**	**363528**	**2348.42**	**469656**	**3174.045**	**576576**

So at 2002 the No. of BTS on air is 137, a total of 363528 users to be connected and coverage area is 1736.595 km^2. At 2003 THE No. of BTS on air is 177, a total of 469656 users to be connected and coverage area is 2358.195 km^2. At 2004 the No. of BTS on air increases to 217, a total of 576576 users to be connected and coverage area is 3174.045 km^2.

5.9 CELL PLAN FOR DHAKA CITY FROM THE YEAR 2005 TO 2007

To meet increasing cellular demand within same coverage area from 2005 to 2007 the following assumption will be taken and cell planning will change based on cellular demand 2007.

Assumptions:

1. The population are uniformly distributed over the considered area.
2. Users are uniformly distributed.
3. Cell radius is same all over the considered area.
4. Busy hour calling rate/ user is consider as same erlangs for considered area.
5. Coverage area is unchanged.

The population at 2007 are 1,12,48524 and cellular demands are 885000 (population per mobile is 12.71).

So, design inputs are

Cellular demand = 885000
No. of call per hour = 1
Call duration in minute = 1.75
Population per mobile = 11.86
Traffic available / cell = 79.2 E
Total Coverage area = 3174 km^2

$$\text{Busy hour calling rate/user} = \frac{\text{No. of call per hour} \times \text{Call duration in minute}}{60} \text{E}$$

$$= 0.03\text{E}$$

Total traffic needed $= \text{Cellular demand} \times \text{busy hour calling rate/user}$

$= 885000 \times 0.03 \text{ E}$

$= 26550\text{E}$

No. of cell required $= \dfrac{\text{Total traffic needed}}{\text{Traffic available/cell}}$

$= \dfrac{26550}{79.2}$

$= 335.22 \text{ Nos.}$

Coverage/cell $= \dfrac{\text{Total coverage area}}{\text{No. of cell required}}$

$= \dfrac{3174}{335.22}$

$= 9.468 \text{km}^2$

If cell shape is hexagonal

$$\therefore \quad 2.59r^2 = 9.468\,km^2$$

$$\text{Cell radius} \quad r = \sqrt{\frac{9.468}{2.59}}$$

$$= 1.91\,km.$$

Let,

Cell radius = 2 km.

Area/cell = $2.5/9 \times 2^2 = 10.36$

Total No. of cell = 336

Total coverage area $= 336 \times 10.36$

$= 3481 \text{ km}^2$

Total traffic available $= 336 \times 79.2 \text{ E}$

$= 26611.2 \text{ E}$

No. of user to be connected $= \dfrac{26611.2}{0.03}$

$= 887040$

But calculated demand at 2007 is 8,85,000.

Cell plan for Dhaka city from the year 2005 to 2007 is shown in figure in 5.9

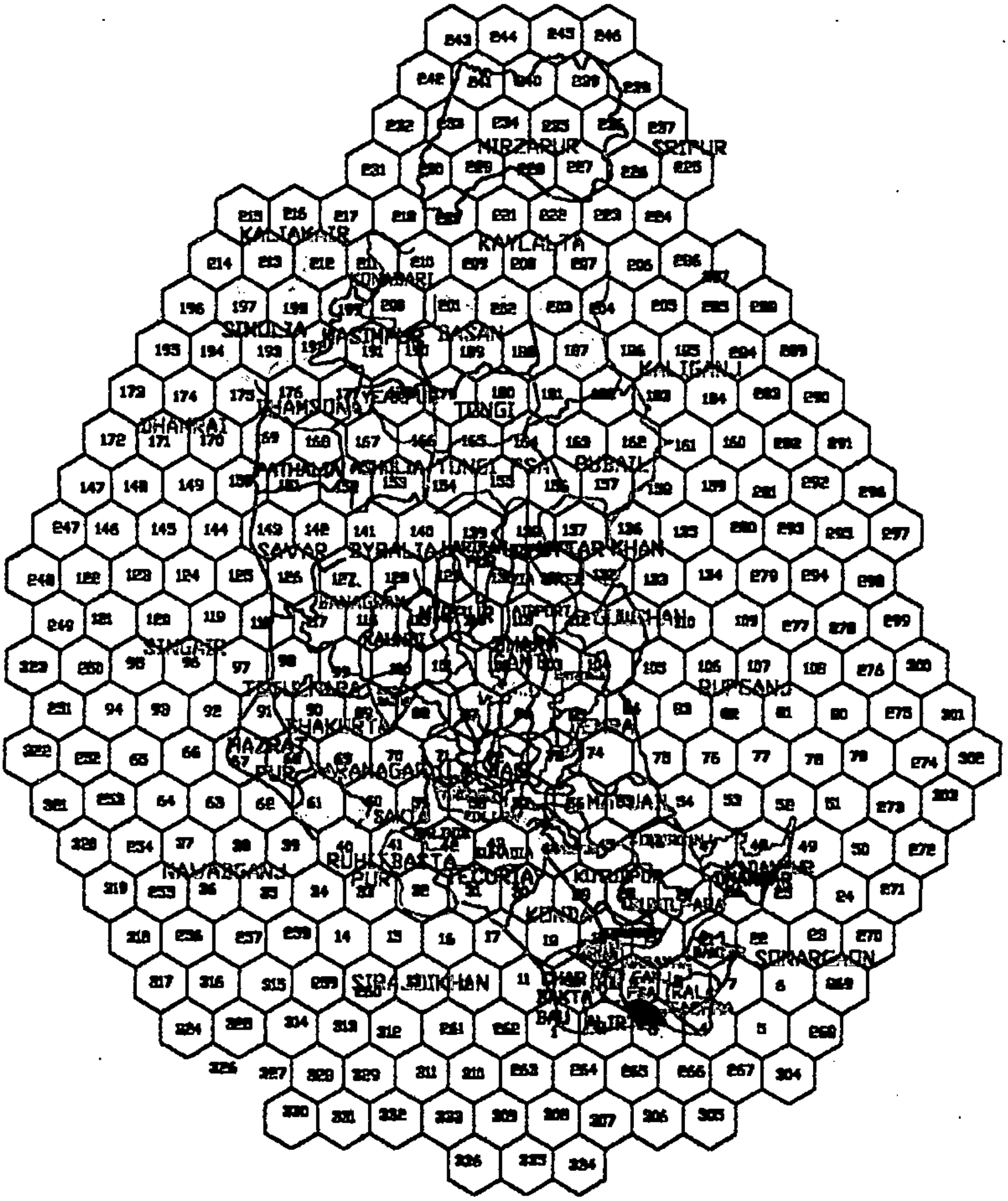


Fig. 5.9 Cell plan for Dhaka city from the year 2005 to 2007

5.10 CELL PLAN FOR DHAKA CITY FROM THE YEAR 2008 TO 2010

To meet increasing cellular demand for same coverage area from 2008 to 2010 the cell planning will change based on cellular demand at 2010.

So, design inputs are

Cellular demand = 12,00000
No. of call per hour = 1
Call duration in minute = 1.75
Traffic available / cell = 79.2 E
Population per mobile = 9.98

$$\text{Busy hour calling rate / user} = \frac{\text{No. of call per hour} \times \text{Call duration in min.}}{60}$$

$$= 0.03 \text{ E}$$

Total traffic needed = Cellular demand × busy hour calling rate/user
= 12,00000 × 0.03 E
= 36000 E.

$$\text{No. of cell required} = \frac{\text{Total traffic needed}}{\text{Traffic available/cell}}$$

$$= \frac{36000}{79.2}$$

$$= 454.5 \cong 455$$

$$\text{Total coverage area} = 3174 \text{ km}^2$$

$$\text{Coverage area/cell} = \frac{\text{Total coverage area}}{\text{No. of cell required}}$$

$$= \frac{3174}{455} = 6.975 \text{ km}^2$$

If Cell shape is hexagonal

$\therefore 2.59r^2 = 6.975$

$\therefore$ Cell radius $\quad r = \sqrt{\dfrac{\text{Coverage area per cell}}{2.59}}$

$$= \sqrt{\frac{6.975}{2.59}}$$

$$= 1.641 \text{ km.}$$

Let,

Cell radius = 1.65 km.

Coverage area per cell = $2.59r^2 = 2.59 \times (1.65)^2 = 7.051275 \text{ km}^2$

Total No. of cell = 455

Total coverage area = $455 \times 7.051275 = 3208.33 \text{ km}^2$

Total traffic available = 455×79.2 E = 36036 E

No. of user to be connected $= \dfrac{36036 \text{ E}}{\text{Busy hour calling rate/user}}$

$$= \frac{36036 \text{ E}}{0.03 \text{ E}}$$

$$= 1201200$$

But actual demand at 2010 is 12,00000.

Cell Plan for Dhaka city from the year 2008 to 2010 is shown in figure 5.10

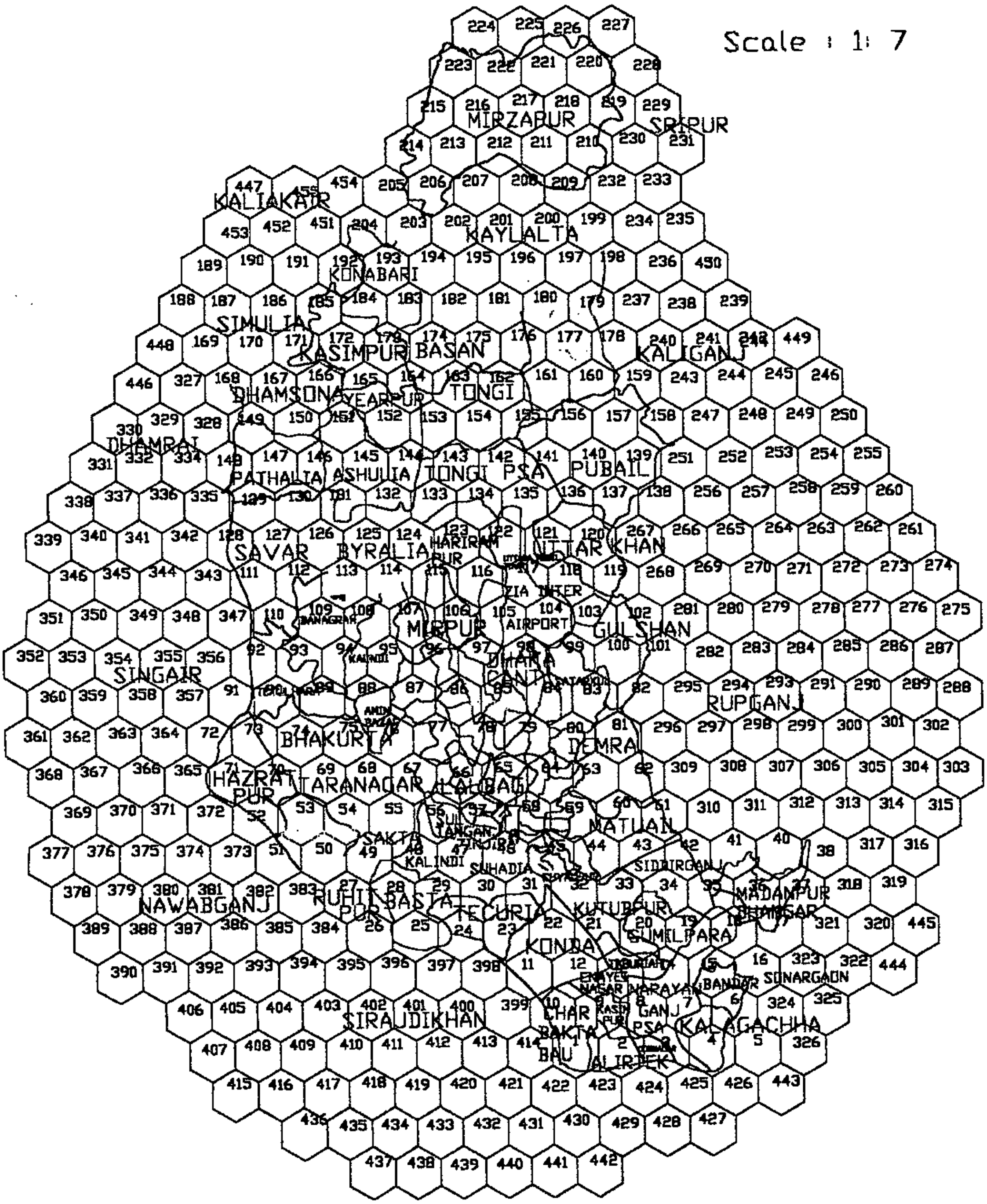


Fig. 5.10 Cell Plan for Dhaka city from the year 2008 to 2010

5.11 BTS ANTENNA HEIGHT CALCULATION

In CDMA standard electrical tilt angle of antenna is used from 0^0 to 10^0, which is shown in figure 5.11 and denoted by Ψ

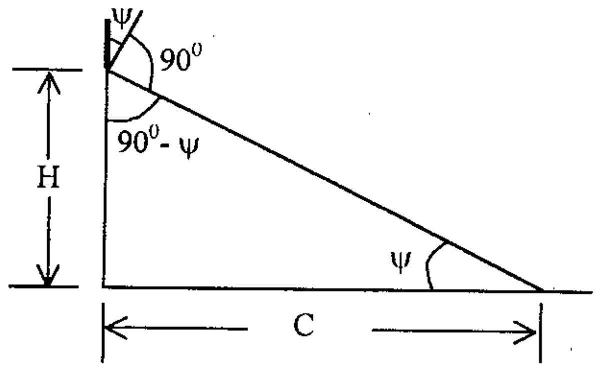


Figure 5.11 BTS antenna height calculation

Let,

H = Antenna height in meter

C = Coverage or sector radius in meter

Ψ = Electrical tilt angle of antenna in degree

From figure 5.11 we can write

$$\frac{H}{C} = \tan \psi$$

$$\therefore \quad H = C \tan \psi \tag{5.19}$$

For different values of electrical tilt angle and sector radius, the necessary antenna height is shown in table 5.14.

Table 5.14 BTS antenna height

Electrical tilt angle (Ψ) of antenna in degree	Coverage or sector radius C in meter	BTS antenna height in meter H = C tan Ψ
0.5	1650	14.40
	2000	17.45
	2500	21.81
	3000	26.18
0.75	1650	21.60
	2000	26.18
	2500	32.77
	3000	39.27
1.00	1650	28.80
	2000	34.91
	2500	43.63
	3000	52.36
1.25	1650	36.00
	2000	43.60
	2500	54.55
	3000	65.46

For a certain amount of coverage area, the amount of electrical tilt angle and corresponding antenna height are selected by considering height and location of man made structures such as buildings, street width and orientation and terrain irregularities.

5.12 FREE SPACE PATH LOSS

Path loss occurs when the received signal becomes weaker and weaker due to increasing distance between mobile station and base station, even if there are no obstacles between the transmitting (Tx) and receiving (Rx) antenna. For free space and for a given antenna the received power density is inversely proportional to the square of the distance, d between the Tx and Rx antennas. In practice more complex models like Okumura's Walfisc's, Xia's and Okumura-Hata's are used. The path loss problem seldom arises in a cellular radio system because before we loose contact due to path loss, a new transmission path is established via another base station. Path loss depends on a number of factors. They are,

- Distance between Tx and Rx antenna
- Height of Tx and Rx antenna
- Operating frequency
- Height and location of man made structures such as buildings
- Terrain irregularities.

Let,

P : Radiated power from dipole antenna located at sphere centre.

p : Power density received by an isotropic antenna located at paint p

$\frac{\lambda^2}{4\pi}$: Antenna effective area of the isotropic antenna.

f_c : Frequency in MHz ($f_c \geq 800$ MHz)

h_b : Antenna height of base station in meter

h_m : Antenna height of mobile station in meter

d : Distance between BTS and MS in km

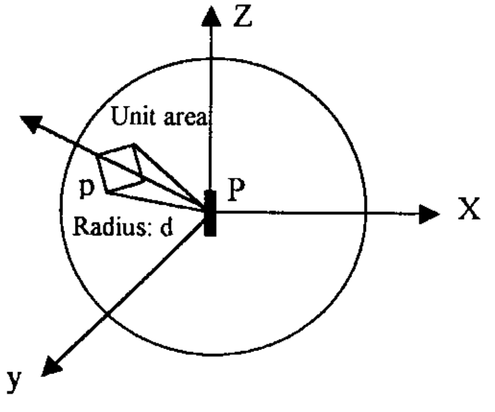


Figure 5.12 Free space path loss

$$p = \left(\frac{P}{4\pi d^2}\right) \times \left(\frac{\lambda^2}{4\pi}\right)$$

$$= \frac{P\lambda^2}{(4\pi d)^2}$$

$$\text{Free space propagation loss} = \frac{p}{P} = \frac{\lambda^2}{(4\pi d)^2}$$

$$P_L = 10 \log[\lambda / (4\pi d)]^2 \text{ in dB}$$

$$P_L = 20 \log[\lambda / 4\pi d)] \text{ in dB} \qquad (5.20)$$

According to Hata model for urban area the path loss is expressed as,

$P_L = 69.55 + 26.16 \log f_c - 13.82 \log h_b - a(h_m) + (44.9 - 6.55 \log h_b) \log d$
Where, $a(h_m) = (1.1 \log f_c - 0.7) h_m - (1.56 \log f_c - 0.8)$ (5.21)

$P_L = 69.55 + 26.16 \log f_c - 13.82 \log h_b - (1.1 \log f_c - 0.7) h_m +$
$(1.56 \log f_c - 0.8) + (44.9 - 6.55 \log h_b) \log d$ (5.22)

Modification for large city.
$P_L = 69.55 + 26.16 \log f_c - 13.82 \log h_b - a(h_m) +$
$(44.9 - 6.55 \log h_b) \log d$
where, $a(h_m) = 3.2 (\log 11.75 h_b)^2 - 4.97$ dB (5.23)

Modification for suburban city

$$P_L = P_L(Urban) - 2[\log(fc/28)]^2 - 5.4 \quad (5.24)$$

There are four factors which are involved in equation 5.22, where transmission frequency (f_c) and mobile station antenna height are constant in CDMA transmission. The antenna height of BTS and distance between BTS and MS are related. But those values are depend on electrical tilt angle of BTS antenna.

Let,

$f_c = 800$ MHz
$h_b = 1.5$ m

The HATA's equation for path loss of urban area is

$P_L = 69.55 + 26.16 \log f_c - 13.82 \log h_b - (1.1 \log f_c - 0.7) h_m +$
$(1.56 \log f_c - 0.8) + (44.9 - 6.55 \log h_b) \log d$
$\therefore P_L = 145.483556 - 13.82 \log h_b + (44.9 - 6.55 \log h_b) \log d$ (5.25)

Then path loss is calculated for different values of electrical tilt angle of antenna, coverage and antenna height, which are shown in table 5.15.

Table 5.15 Free space path loss

Electrical tilt angle of antenna in degree	Coverage or sector radius in Km	BTS Antenna height, h_b in meter	Path loss, P_L in dB
0.5	1.65	14.40	137.589
	2.00	17.45	139.389
	2.50	21.81	141.361
	3.00	26.18	142.878
0.75	1.65	21.60	134.905
	2.00	26.18	136.607
	2.50	32.77	138.457
	3.00	39.27	139.894
1.0	1.65	28.80	133.000
	2.00	34.91	134.633
	2.50	43.63	136.415
	3.00	52.36	137.776
1.25	1.65	36.00	131.523
	2.00	43.60	133.100
	2.50	54.55	134.820
	3.00	65.46	136.134

5.13 BTS ANTENNA TYPE SELECTION

A cell is normally partitioned into three 120^0 sectors or six 60^0 sectors. But three 120^0 sectors is used in this design. So ANDREW sector antenna is used whose data sheet is given in table 5.16 and also azimuth radiation pattern is shown in figure 5.13.

Table 5.16 Data sheet of ANDREW (sector) antenna.

Antenna Type: CTSD08-06515-0D

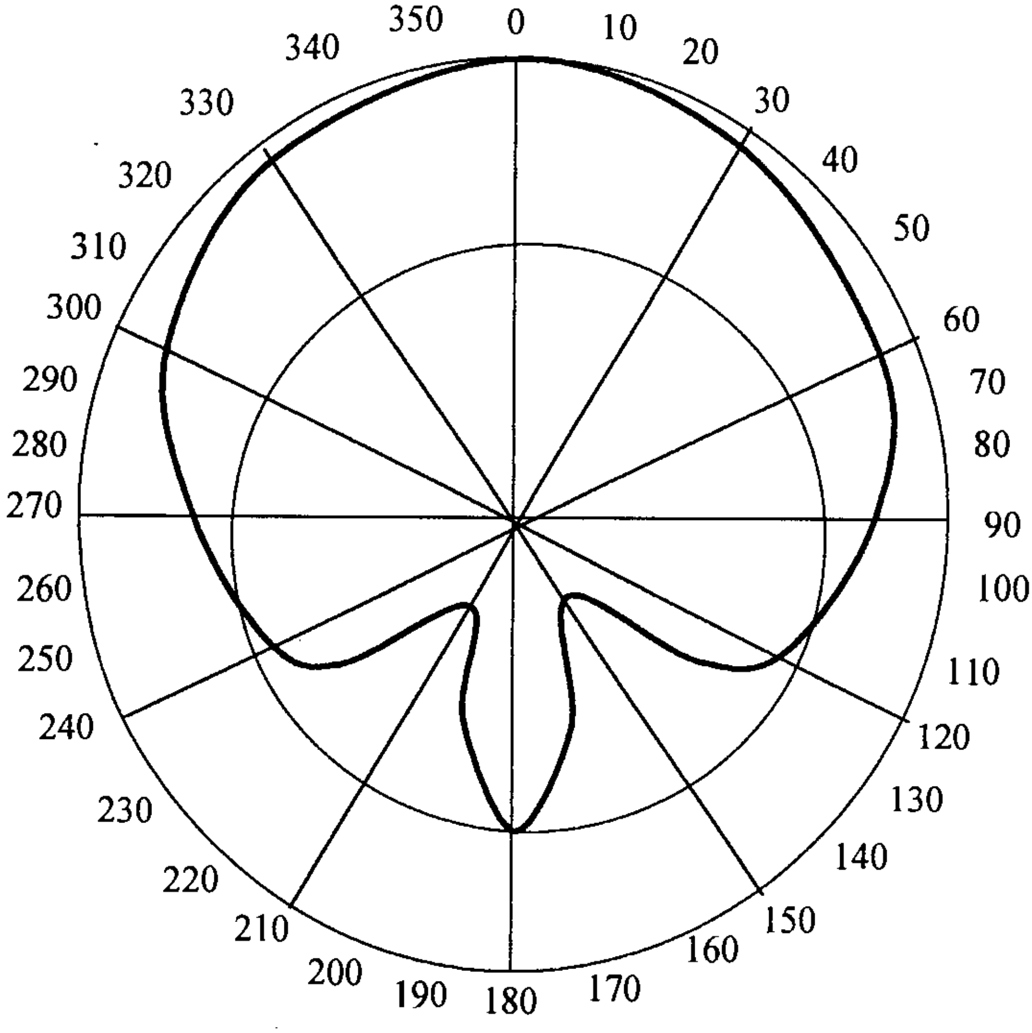
Description: 65 deg., 17 dBi, No downtilt, 7-16 DIN Female, Dual Pol.

Frequency band : 806-896 MHz

Gain (dBi)	17.0
Gain (dBd)	15.0
Azimuth beamwidth (deg)	65
Polarization type	Dual/Slant
Intermodulation	<-150 dBc
Down tilt (deg)	0
Impedance (ohms)	50
Return Loss, dB (VSWR)	>14.0 (<1.5)
Front to back ratio (dB)	25
Maximum input power (watts)	500
Lightning protection	DC Ground
Input connector type	7-16 DIN Female
Dimensions, L x W x D, mm (inches)	2450 (96.5) x 350 (13.8) x 80 (3.1)
Weight, kg (lb)	12 (26.4)
Radome material	FIBERGLASS
Radome color	Gray
Survival wind speed, km/h (mph)	200 (125)
Wind load, frontal, N (lbf)	1420 (319)
Wind load, lateral, N (lbf)	279 (63)
Wind load, back, N (lbf)	1432 (323)
Temperature range, C, (F)	-40/+70 (-40/+158)
Humidity	Up to 100%
Traditional weatherproofing kit	221213
Tilt mount part number	600899A
Connector type	1
Pattern type	1
Polarization	1
Elevation beamwidth (deg)	8.0

The following figure 5.13 shows the azimuth radiation pattern of sector antenna.

Type:	CTSD08-06515-0D	
	dBi	dBd
Gain:	17.0	15.0
Beamwidth:	65	
Polarization:	Dual/Slant	



5.13 Sector antenna radiation pattern.

5.14 PHYSICAL TILT ANGLE OF BTS ANTENNA

Some sector antennas are electrically pre-tilted. In this case, if electrically pre-tilted angle is greater than required electrical angle, then antenna must be tilted physically. So physical tilt angle depends on required electrical tilt angle. From tables 5.14 and 5.15 electrical tilt angle 1^0 is suitable by considering antenna height and the amount of path loss.

5.15 BTS AND MS TRANSMITTER POWER LEVEL

In CDMA the mobile station transmitter power 23 dBm is used. But the BTS transmitter power depends on transmitting antenna gain, receiving antenna gain, path loss and minimum allowable received power of MS in CDMA.

Since,

MS transmitter antenna gain $G_R = 0$ dB

BTS sector antenna gain $G_T = 17$ dB (From data sheet)

Minimum allowable received power at MS (In CDMA) $P_R = -104$ dBm

Path loss is a variable factor which depends on coverage and BTS antenna height. For 1^0 electrically tilt antenna it ranges from 133 dBm to 138 dBm. But for BTS transmitter power calculation, 137 dBm path loss is considered.

Minimum allowable received power at MS

$$P_R = P_T + G_T + G_R - P_L$$

$$\therefore \quad P_T = P_R + P_L - G_T - G_R$$

If $P_R = -104$ dBm.

Then, $P_T = -104 + 137 - 17 - 0$

$= 16$ dBm.

If $P_R = -63$ dBm

Then $P_T = P_R + P_L - G_T - G_R$

$= -63 + 137 - 17 - 0$

$= 57$ dBm.

From the above discussion we conclude the BTS transmitting power 57 dBm is needed for better reception quality. But we select 20w (43 power level which is used in CDMA system.

Then received power at the cell boundary

$$P_R = P_T + G_T + G_R - P_L$$
$$= 43 + 17 + 0 - 137$$
$$= -77 \text{ dBm.}$$

So 20w BTS transmitting power level is selected for this design.

5.16 POSITION OF MSC AND NUMBER OF TRUNK LINE FROM PSTN

The position of MSC is selected at Mohakhali. Because the cell plan is done for 3000 km^2 which is 30 km radius with centre at Mohakhali. For PSTN call attend the MSC must be connected with local exchanges. Since the position of MSC is seclected at Mohakhali, so Gulshan and Sere-Bangla Nager exchange are suitable for local exchange.

The calculation process of the number of trunk lines necessary to accommodate peak traffic is given below.

Let,

Total No. of subscriber = x
No. of busy hour call attend to PSTN = y
Busy hour holding time in minute = z

$$\text{Busy hour erlang by subscribers to PSTN} = \frac{xyz}{60}$$
$$= K \text{ erlang}$$

If Grade of service (GOS) is 2%.

Then calculate the required channel number (K_1) for K earlangs using Erlangs B chart.

$$\text{So required number of trunk lines} = \frac{K_1}{30}$$

Here, 30 is the voice channel per trunk line.

If, total subscriber = 570,000 and 1.5% of 570000 = 8550 subscriber call attend to PSTN.

No. of busy hour call attend to PSTN = 1

Busy hour holding time = 1.5 min.

Then busy hour Erlang by subscribe to PSTN $= \frac{8550 \times 1 \times 1.5}{60}$ *erlangs*

$= 213.75$ *erlangs.*

If GOS is 2%, then from Erlang B chart required channel is 228 to accommodate 213.75 erlangs.

$\therefore$ Required number of trunk lincs $= \frac{228}{30}$

$= 7.6$

So required number of trunk line is 8.

5.17 FIELD STRENGTH IN VARIOUS CELLS OF THE COVERAGE AREA

According to Hata's model for urban area the path loss in expressed as

$$P_L = 69.55 + 26.16 \log f_c - 13.82 \log h_b - (1.1 \log f_c - 0.7)\, h_m + (1.56 \log f_c - 0.8) + (44.9 - 6.55 \log h_b) \log d$$

Reverse link (MS to BTS) path loss is

$$P_L = 69.55 + 76.28 - 13.82 \log h_b - 3.7612 + 3.7488 + (44.9 - 6.55 \log h_b) \log d$$
$$= 145.8176 - 13.82 \log h_b + (44.9 - 6.55 \log h_b) \log d. \quad (5.26)$$

where, fc = 824 MHz

hm = 1.5 m

For a constant value of electrical antenna tilt angle, antenna heights are different for different coverage which is shown in table 5.14.

By calculating the path losses for different antenna height and coverage, the reverse link received field strength is shown in table 5.17.

Table 5.17 MS to BTS received field strength.

d(km)	h_b(m)	P_L(dB)	P_T (dBm)	G_T (dB)	G_R (dB)	$P_R=P_T+G_T+G_R-P_L$(dBm)	Minimum allowable received field strength of CDMA at BTS (dBm)
1.65	28.8	133.334	23	17	0	-93.334	-121
2.0	34.91	134.967	23	17	0	-94.967	
2.5	43.63	136.749	23	17	0	-96.749	
3.0	52.36	138.110	23	17	0	-98.110	

So the reverse link received field strength is greater than minimum allowable received field strength at BTS.

Forward link (BTS to MS) path loss is

$$P_L = 69.55 + 26.16 \log f_c - 13.82 \log h_b - (1.1 \log f_c - 0.7)\, h_m + (1.56 \log f_c - 0.8) + (44.9 - 6.55 \log h_b) \log d$$

$$P_L = 69.55 + 76.884 - 13.82 \log h_b - 3.799 + 3.784 + (44.9 - 6.55 \log h_b) \log d$$
$$= 146.419 - 13.82 \log h_b + (44.9 - 6.55 \log h_b) \log d. \quad (5.27)$$

Where, fc = 869 MHz

hm = 1.5 m

For a constant value of electrical antenna tilt angle, antenna heights are different for different coverage which is shown in table 5.14. By calculating the path losses for different antenna height and coverage, the forward link received field strength is shown in table 5.18.

Table 5.18 **BTS to MS received field strength.**

d(km)	h_b(m)	P_L(dB)	P_T (dBm)	G_T (dB)	G_R (dB)	$P_R=P_T+G_T+G_R-P_L$(dBm)	Minimum allowable received field strength of CDMA at MS (dBm)
1.65	28.8	133.935	43	17	0	-73.935	-63 to -104
2.0	34.91	135.568	43	17	0	-75.568	
2.5	43.63	137.350	43	17	0	-77.35	
3.0	52.36	138.711	43	17	0	-78.711	

So the forward link received field strength is greater than lower limit of the minimum requirement field strength of CDMA at MS. The reverse and forward receive field strength is shown in figure 5.14.

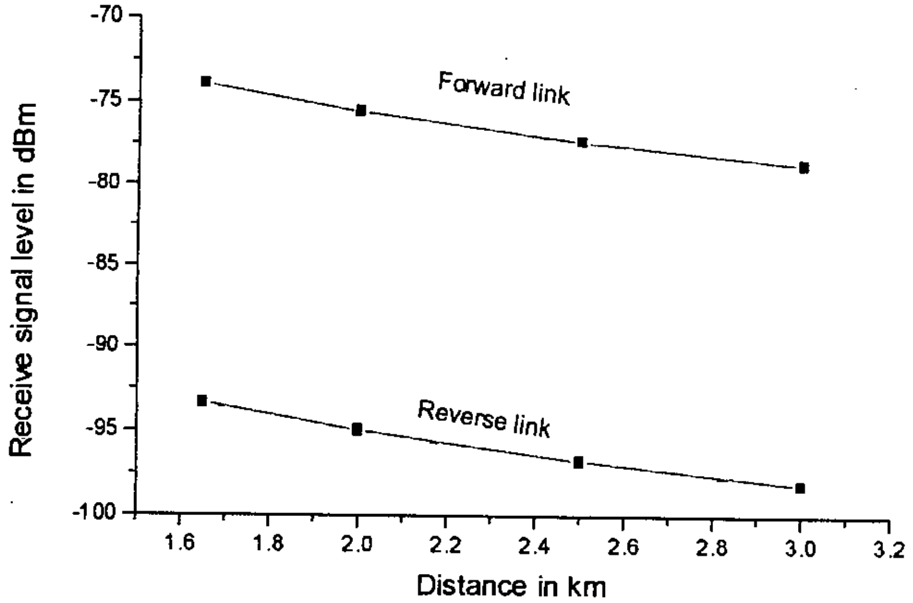


Figure 5.14 Receive signal level in urban area.

5.18 IN BUILDING SIGNAL STRENGTH

Due to the building penetration loss, the signal received inside a building is lower than that just at the outside. The penetration loss depends on the construction materials. It also depends on the height at which the user is using the mobile.

The N^{th} floor signal gain with respect to outside signal is expressed as,

$$G_B = 2.5n - 16.5 \qquad n < 13$$
$$= 23.25 \log_{10} n - 10.9 \qquad n \geq 13$$

Signal strength at different floor of a high rise building is given in below.

Let,

Distance from the base station Tx=d=3 km

Path loss = P_L = 138.711 (From table 5.18)

BTS Tx power = P_T = 20w = 43 dBm

BTS Tx gain = G_T = 17 dbi

MS antenna gain G_R = 0 dB

∴ Signal strength at points outside of the building $P_R = P_T + G_T + G_R - P_L$

$= -78.711$ dBm

Signal strength at N^{th} floor $= P_N = G_B + P_R$

$= G_B - 78.711$ dBm

The received signal strength at different floor is shown in table 5.19.

Table 5.19 Received signal strength at different floor

Floor number (N)	N^{th} floor signal gain (dBm)	Signal strength at points outside of the building, P_R (dBm)	Signal strength at N^{th} floor, P_N (dBm)
1	-14.0	-78.711	-92.71
3	-9.0	-78.711	-87.71
5	-4.0	-78.711	-82.71
7	1.0	-78.711	-77.71
9	6.0	-78.711	-72.71
11	11.0	-78.711	-67.71
13	14.9	-78.711	-63.71
15	16.44	-78.711	-62.26
17	17.7	-78.711	-61.00
19	18.83	-78.711	-59.88
21	19.84	-78.711	-58.87
23	20.76	-78.711	-57.95
25	21.60	-78.711	-57.10

From the above table we conclude the signal strength above the 15^{th} floor is greater than higher limit signal strength (-63 dBm), which is adjusted by power control process. But below the 15^{th} floor, signals strength are well above the minimum requirement of MS receiver.

5.19 DISCUSSION ON RESULTS

The existing CDMA based cellular network for Dhaka city covers only Dhaka municipal corporation but the proposed cellular network covers greater Dhaka city approximately 30 km radius with centre at Mohakhali. The considered area is approximately 3000 km^2, which covers the whole area of Dhaka city and Narayangonj and partial area of Gazipur district.

There is no demand forecasting in the existing CDMA based cellular network of city cell digital and TDMA based cellular network of other operator. But a tedious job is done for cellular demand forecasting of greater Dhaka city upto 2010 considering the number of population, income level, employment status, distribution of earner and major occupation.

At present the cellular traffic capacity of citycell digital (CDMA based cellular mobile company) is only 65000. But if we install the 1^{st} plan (sec 5.8), 570000 users will be connected. In the suggested network, the base stations are established at equal spacing which is an another difference from existing CDMA system. So signal strength all over the coverage area lies within the required range of signal level. But in existing CDMA system the base stations are in unequal spacing, so the signal strength in some points of the coverage area are below the minimum requirement of signal level. The channel capacity of CDMA based cellular network is greater than other systems e.g. GSM and AMPS. In CDMA, approximately 3000 users can be connected by one base station but in GSM only 600 users can be connected. So in CDMA less number of base stations is needed to connect same number of users. In densely populated area (DMC), 0.033 erlangs busy hour traffic is assigned for one user but existing CDMA system assigns 0.03 erlangs.

Also in densely populated area, 2 km cell radius is used to connect large number of user. Another important difference exists from GSM system in the point of view of handoff procedure. In CDMA, only one carrier is used for all the users where each user is identified by a specific code, therefore handoff is softer. But in other systems different carrier is used for different base station, so between the base station handoff is hard. In CDMA, usually sector antenna is used but in the other system omnidirectional antenna is used. Hence in CDMA system interference is less than other systems (Section 5.5).

In this chapter various factors are discussed to calculate the antenna height, path loss, transmitting power level and to select the type of antenna and position of MSC. Also calculation of the physical tilt angle of BTS antenna, transmitter power level and number of trunks necessary to accommodate peak traffic are described.

Lastly the field strength at cell boundary and different floor of a high rise building are calculated. In both cases the signal strength lies between the minimum requirement at BTS and MS. Interference from own cell and neighbor sector are found –9.03 dB and –8.9 dB respectively. The next neighbor sector interference is also within CDMA limit. So the reception quality is expected to be good enough.

CHAPTER- 6

CDMA PERFORMANCE ENGINEERING

6.1 INTRODUCTION

The mobile radio channel places fundamental limitations on the performance of wireless communication systems. The transmission path between the transmitter and receiver can very from simple direct line-of-sight to one that is severely obstructed by building and foliage.

The meachanism behind electromagnetic wave propagation are diverse but can generally be attributed to reflection, diffraction and scattering. Capacity of CDMA becomes maximum when receiving power from communicating MS are controlled to equal level. Handoff process in used for improvement of voice quality, reduction of MS interference and reduction of call dropping probability. When a mobile moves into a different cell with a conversation is in progress, the MSC must automatically transfer the call to a new channel belonging to the new base station. In the mobile station idle state, the mobile station continuously searches for the strongest pilot channel signal on the current CDMA frequency assignment whenever it monitors the paging channel. Also the performance of the mobile network depends on the signal received by the MS.

6.2 POWER CONTROL

The key to the high capacity of commercial CDMA is extremely simple. If, rather than using constant power, the transmitters can be controlled in such a way that the received powers from all users are roughly equal, then the benefits of spreading are realized. If the received power is controlled, then the subscribers can occupy the same spectrum, and the hoped-for benefits of interference averaging accrue.

Power control is necessary to maintain all mobile stations signals exactly at the same and adequate power level. In this way interference from one unit to another is held to a minimum.

6.2.1 Advantages of power control

- An analog cellular phone always transmits enough power to overcome fade, even though a fade does not exist most of the time.
- The CDMA mobile station transmits only enough power to maintain the link. The average transmitted power is much lower than that required for analogue system.
- Transmitting with lower power in a CDMA mobile station extends battery life and requires a smaller battery.
- CDMA mobile station output power amplifiers cost less.

6.2.2 Importance of Transmit power control

- Capacity of CDMA becomes maximum when receiving power from communicating MS/SU are controlled to equal level.

- In CDMA system, Radio frequency assigned is commonly used by all channels and receiving power from other channels increases interference that is they will decrease E_b/No.
- In CDMA system, to control receiving power from all.
- Receiving level changes by following three modes:
  1. Caused by variation of average propagation loss depend on variation of propagation path length.
  2. Caused by shadowing by obstacles such as buildings, tunnels. This variation change is very rapid.
  3. Caused by multi-path fading. This variation change is also very rapid.

6.2.3 Transmit power control

a. Transmit power control of MS/SU
   - Open loop control (Low Speed Control)
   - Closed Loop Control (High Speed Control)
   - Outer Loop Control

b. Transmit power control of BTS
   - Individual Traffic Channel Power Control
   - Pilot Channel Power Control.

a. Transmit power control of MS/SU

Open loop power control:

- Assumes loss is similar on forward and reverse paths.
- Receive power + transmit power = -73 dBm
- Example:
  mobile receive power = -85 dBm
  transmit power = (-73) – (-85) = 12 dBm.

The figure 6.1 shows the open loop transmit power control of MS/SU.

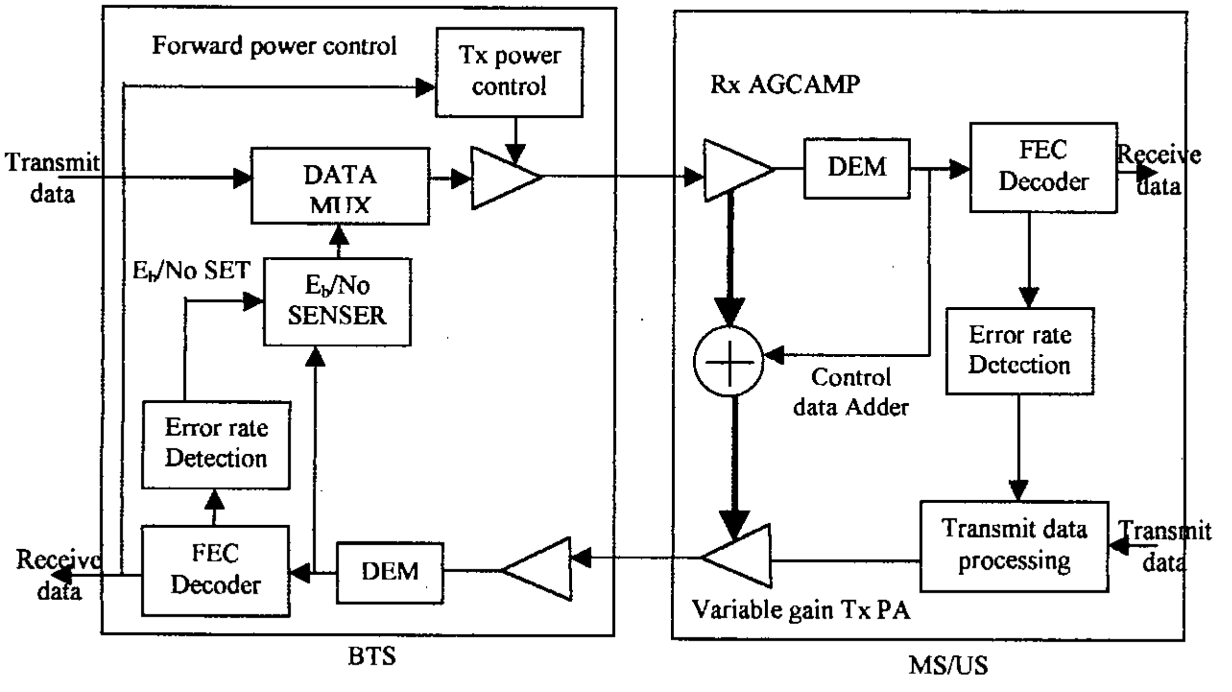


Figure 6.1 Open loop (Low speed) transmit power control.

Closed loop power control:

- The base station monitors power reveived from each mobile station and commands the mobile to either raise or lower power by fixed 1 dB steps.
- This process is repeated 800 times (1.25 msec intervals).
- Closed loop power control corrects open loop power estimate.

The figure 6.2 shows the close loop transmit power control of BTS.

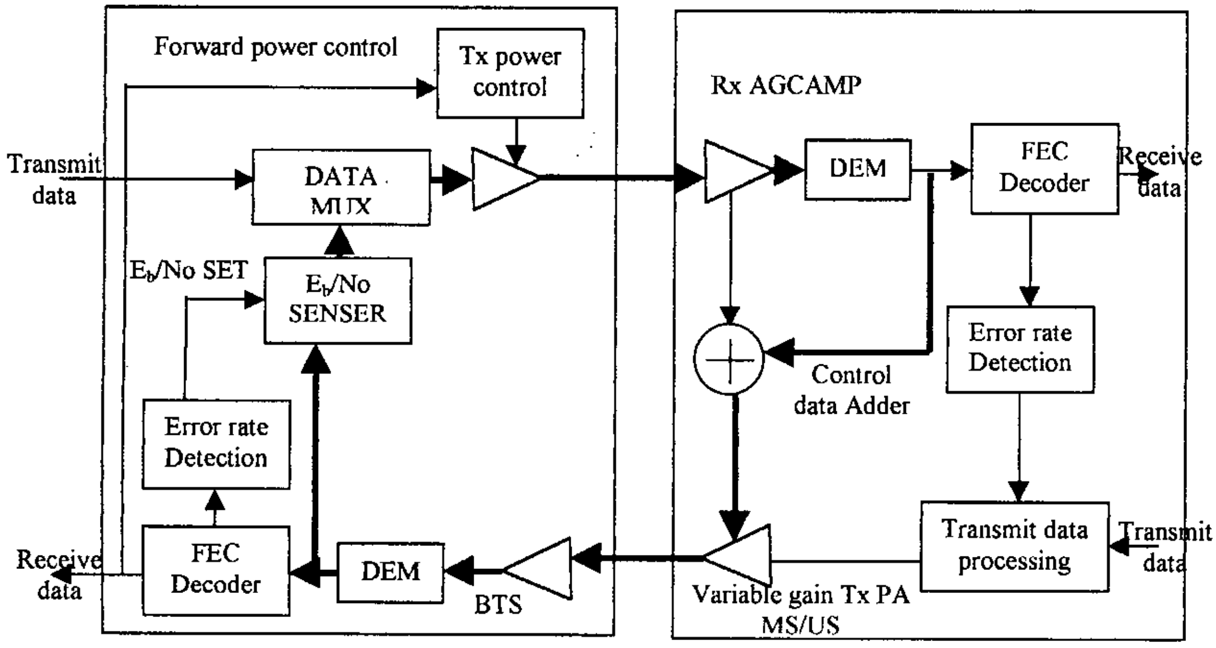


Figure 6.2 Close loop (high speed) power control.

b. Transmit power control of BTS

i) Pilot channel power control (Blossoming): When one BTS starts to service, it increases the pilot channel transmit power level slowly. By this operation, BTS sector size increases up to the normal size slowly without increasing the interference to other sector. This operation is called "Blossoming".

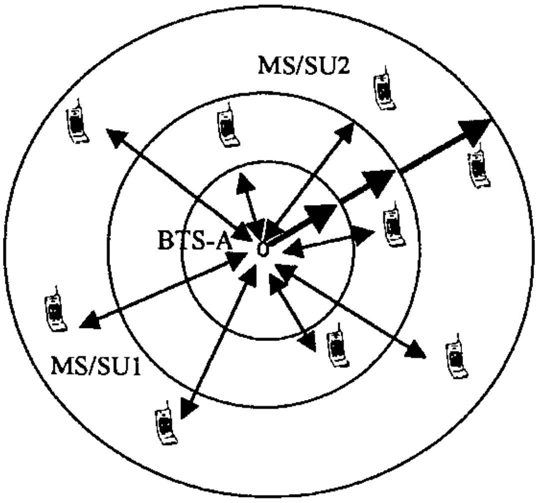


Figure 6.3a. Pilot channel power control (Blossoming)

ii) Pilot channel power control (Wilting): When one BTS stops the service without the service interruption, the BTS rejects new call connections and checks its communicating MSs/Sus, so as not to disturb the communication. If communicating MSs / Sus, are not existing, the BTS decreases its output power level slowly. If communicating MSs/Sus are existing, the BTS waits until it is confirmed that the MSs/Sus complete the communication or are handoffed to neighbor sector, then the BTS decreases its output power level slowly and finally it stops its service.

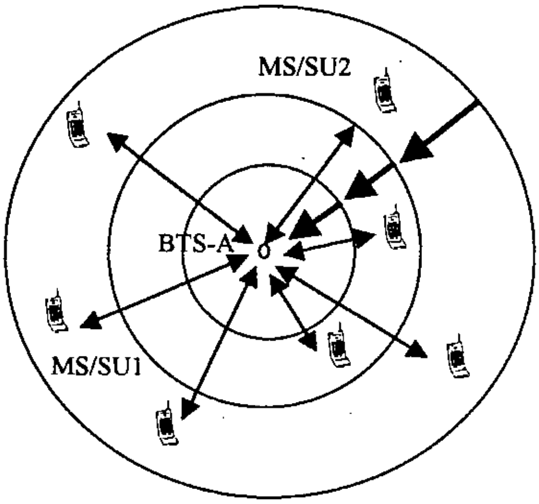


Figure 6.3b. Pilot channel power control (Wilting)

iii) Designated Traffic channel power control : Forward link traffic power control against CORNER PROBLEM. When MS/SU 3 is linking with BTS-B at duplicated service area zone where BTS A, B and C can serve, the forward link signals from BTS-A and BTS-C are recognized as only noise for MS/SU3. The location of MS/SU3 is not near from these three BTSs. This means the link performance is no good in comparison with other MSs / SUs, MS / SU1, MS / SU2, MS / SU4 and MS / SU5.

In this case, even if the MS / SU3 requests handoff, the link performance cannot be improved by handoff, because this situation does not change for BTS-A and C.

This problem is called as "CORNER PROBLEM". Every MS / SU always check the link performance, and periodically sends the check result to BTS.

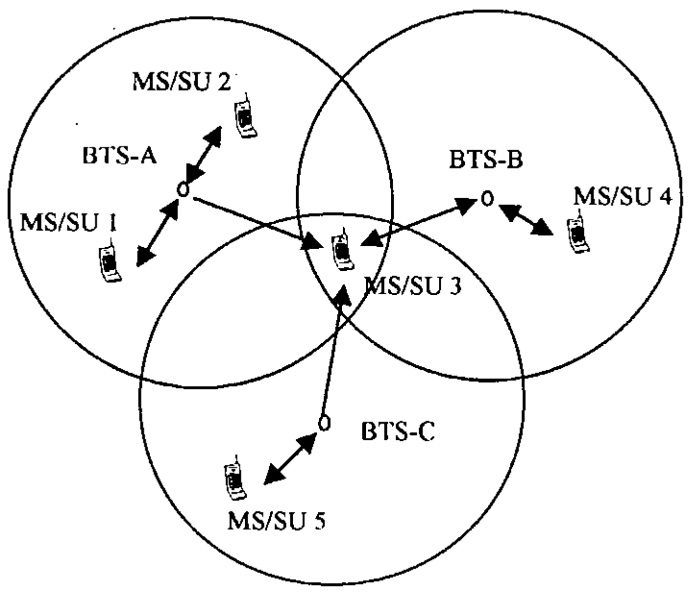


Figure 6.4 Traffic channel power control.

If the reported link performance data is over the lower limit of the threshold level, BTS increases the traffic channel transmit power to maintain the link performance.

6.3 HAND-OFF STRATEGIES

When a mobile moves into a different cell with a conversation is in progress, the MSC must automatically transfer the call to a new channel belonging to the new base station. This hand-off operation not only involves identifying a new base station, but also requires that the voice and control signals be allocated to channels associated with the new base station.

To choose the best target cell, the mobile station and the BTS takes measurements on its own cell and on neighboring cell. The active role that a mobile station plays is called Mobile Assisted Handover (MAHO). The results from the measurements are sent to the BSC for analysis. BSC inturn decided if a handover is necessary. The evaluation algorithm is called locating. If the algorithm finds that another cell is better, the BSC initiates a request to handover the call to the better cell.

Every hand-off must be performed successfully, should happen as infrequently as possible, and must be imperceptible by the user. In order to meet these requirements, system designers must specify an optimum signal level at which to initiate a hand-off. Once a particular signal level specified as the minimum usable signal for acceptable voice quality at the base station receive (normally taken as between-63 dBm and –106 dBm), a slightly stronger signal is used as a threshold at which a hand-off is made.

The margin, say Δ, given by $\Delta = P_r$-handoff – P_r-minimum usable, can't be too large or too small. If Δ is too large, unnecessary hand-offs which burden the MSC may occur and if Δ is too small, there may be insufficient time to complete a handoff before a call is lost due to weak signal condition. Therefore, Δ is chosen carefully to meet these conflicting requirement.

6.3.1 Handoff in CDMA

1. Improvement of voice quality
2. Reduction of MS / SU interference
3. Reduction of call dropping probability
4. Increase of capacity and coverage.

6.3.2 Handoff operation

1. Idle state Handoff
2. Softer Handoff between two sectors of the same BTS
3. Soft Handoff between two BTSs
4. Hard Handoff caused of lack of resources
5. Hard Handoff caused of operating RF switching
6. Hard Handoff between two BSC
7. Hard Handoff between two systems (CDMA to Analogue System)

6.3.3 Handoff operation sequence

1. Pilot strength exceeds T-ADD. MS / SU sends pilot strength measurement message to the BTS.
2. Base station sends Handoff direction message to the MS / SU.
3. The MS / SU transfers the pilot signal to active set and sends Handoff completion Messages to the BTS.

4. Pilot strength decreases than T-DROP, the MS / SU turns on the time out the Handoff drop timer, then the MS / SU sends pilot strength measurement message to the BTS.
5. The BTS sends Handoff direction message.
6. The MS / SU changes the pilot signal to neighbor set and sends Handoff completion messages to theBTS.
7. The MS / SU communicate through one Tch.

a. Softer handoff

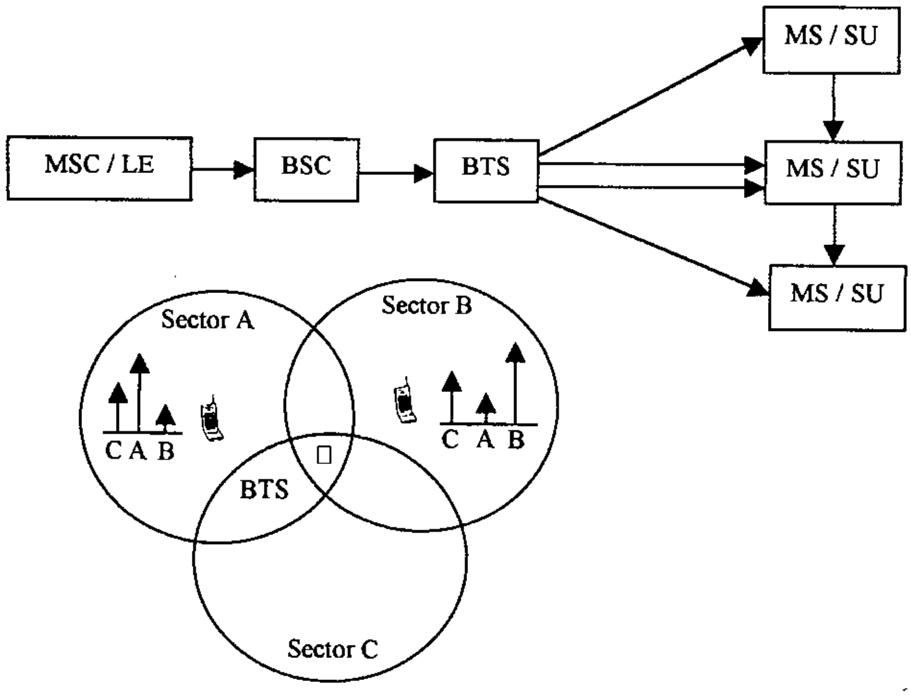


Figure 6.5 Softer handoff.

In case of softer handoff, BSC does not establish duplicated T-ch path between BSC and BTS.

b. Soft Handoff

A handoff in which a new base station commences communications with the mobile station without interrupting the communications with the old base station. The base station can direct the mobile station to perform a soft handoff only when all forward traffic channels assigned to the mobile station have identical frequency assignments.

Soft handoff provides diversity of forward traffic channels and reverse traffic channel paths on the boundaries between base stations.

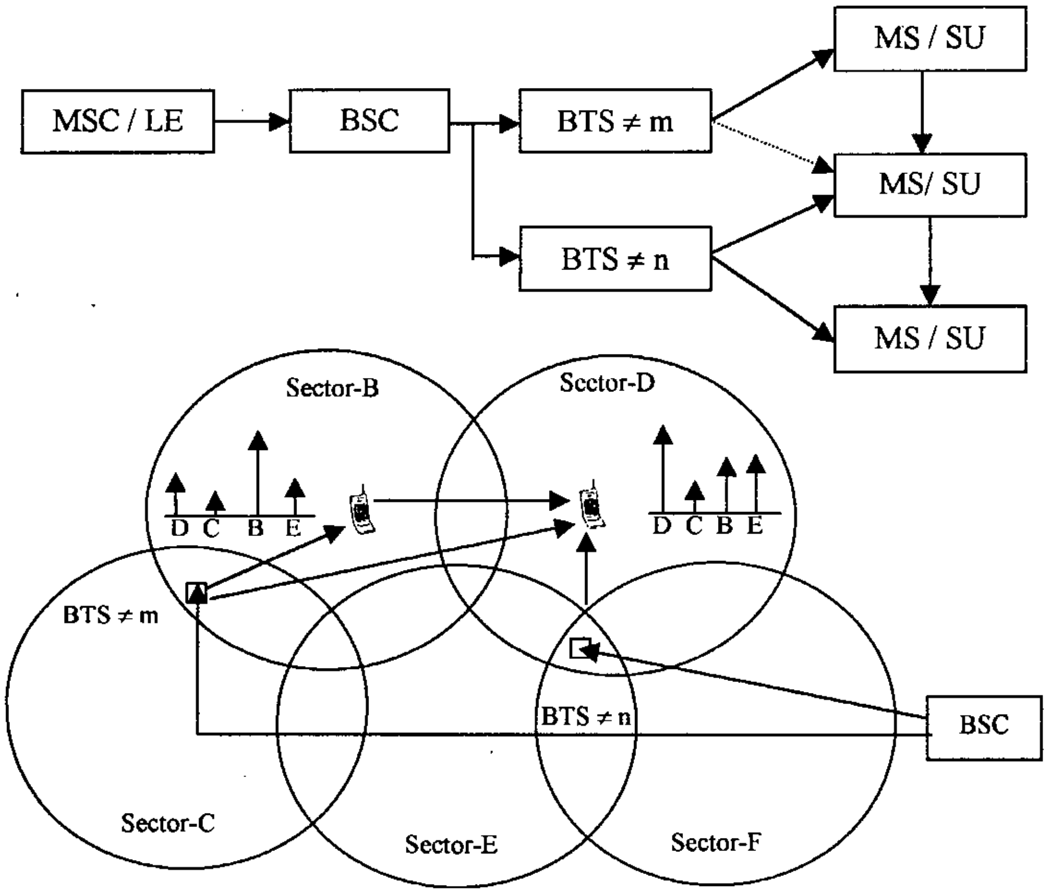


Figure 6.6 Soft handoff

1. Receiving during soft handoff: Each base station in the active set demodulates the reverse traffic channel. The base station should provide diversity combining of the demodulated signals obtained by each base station in the active set.
2. Transmitting during soft handoff: The base station begins transmitting identical modulation symbols on all forward traffic channels specified in a handoff direction message by the action time of the message.

   The base station transmits identical power control symbols on all identical power control sub channels that were identified as such in the lost handoff direction message.

The base station uses the same long code mask on the reverse traffic channel and on all forward traffic channels whose associated pilots are in the active set.

Table 6.1 Soft handoff procedure.

MS / SU		Base station
User conversation using A		User conversation using A
1. Pilot B strength exceeds T-ADD.		
2. Sends pilot strength measurement message.	→	1. A receives
3. Receives handoff direction message.		2. B begins transmitting traffic on the forward traffic channel and acquires the reverse traffic.
	←	3. A and B send handoff direction message to use A and B.
4. Acquires B; begins using active set {A,B}. 5. Sends handoff completion message.	→	4. A and B receive handoff completion message.
6. Handoff drop timer of pilot A expires. 7. Sends pilot strength measurement message.	→	5. A and B receive pilot strength measurement message.
	←	6. A and B sends handoff direction message to use B only.
8. Receive handoff direction message.	→	7. A and B receive handoff completion message.
9. Stops diversity combining: begins using active set {B}. 10. Sends handoff completion message.		8. A stops transmitting on the forward traffic channel and receiving on the reverse traffic channel.
User conversation using B		User conversation using B

c. CDMA to CDMA hard handoff

A handoff in which the base station directs the mobile station to transition between disjoint sets of base stations, different frequency assignments, or different frame offsets.

d. CDMA to analogue handoff

A handoff in which the base station directs the mobile station from a forward traffic channel to an analogue voice channel.

Reference: Dr. Man Young Rhee, "CDMA Cellular Mobile Communications and Network Security." Prentice Hall PTR, PP. 344-348, 1998.

6.4 SEARCH WINDOW SIZES

In the mobile station idle state, the mobile station continuously searches for the strongest pilot channel signal on the current CDMA frequency assignment whenever it monitors the paging channel.

The pilot search should be governed by the following sets:

- Active Set
  The search window size for the pilot in the active set should be the number of PN chips specified in table 6.2 corresponding to the search window size for the active set (SRCH – WIN-A). The mobile station should centre the search window for the pilot of the active set around the earliest arriving usable multipath component of the pilot. If the mobile station receives a value greater than or equal to 13 for SRCH-WIN-A, it may store and use the value 13 in SRCH-WIN-A.
- Neighbor Set
  The search window size for each pilot in the neighbor set should be the number of PN chips specified in table 6.2 corresponding to the search window size for the neighbor set (SRCH-WIN-N). The mobile station should centre the search window for each pilot in the neighbor set around the pilot's PN sequence offset using timing defined by the mobile station's time reference.

- Remaining Set
  The search window size for each pilot in the remaining set should be the number of PN chips specified in table 6.2 corresponding to the search window size for the remaining set (SRCH-WIN-R). The mobile station should centre the search window for each pilot in the remaining set around the pilot's PN sequence offset using timing defined by the mobile station's time reference. The mobile station

should only search for remaining set pilots whose pilot PN sequence offset indices are equal to integer multiples of the pilot offset index increment.

Table 6.2 Search window sizes

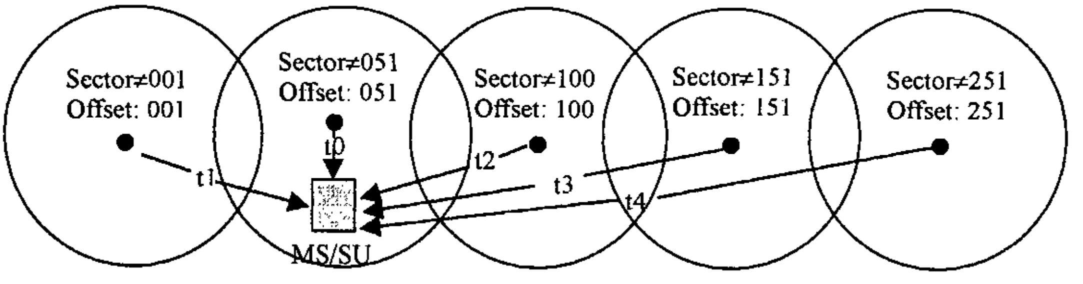
SL No.	SRCH-WIN-A SRCH-WIN-N SRCH-WIN-R (Searcher Window)	Window Size (PN chips)
1	0	2 or search window centre ± 1 chip
2	1	4 or search window centre ± 2 chips
3	2	6 or search window centre ± 3 chips
4	3	8 or search window centre ± 4 chips
5	4	10 or search window centre ± 5 chips
6	5	14 or search window centre ± 7 chips
7	6	20 or search window centre ± 10 chips
8	7	28 or search window centre ± 14 chips
9	8	40 or search window centre ± 20 chips
10	9	56 or search window centre ± 28 chips
11	10	80 or search window centre ± 40 chips
12	11	114 or search window centre ± 57 chips
13	12	160 or search window centre ± 80 chips
14	13	226 or search window centre ± 113 chips
15	14	320 or search window centre ± 160 chips
16	15	452 or search window centre ± 226 chips

WIN-A is applied for Active Set and/or Candidate Set

WIN-N is applied for Neighbor Set

WIN-R is applied for Remaining Set

If the mobile station determines that one of the neighbor set or remaining set pilot channel signals is sufficiently stronger than the active set pilot channel, the mobile station should perform an idle handoff.



to, t1, t2, t3, t4 show propagation time between BTS and MS/SU.

Figure 6.7a. Pilot PN offset search.

When end user of MS / SU located in sector #051 turns on the POW SW, the MS / SU starts initial Pilot PN search, that is, the MS / SU searches all of the Pilot Offsets.

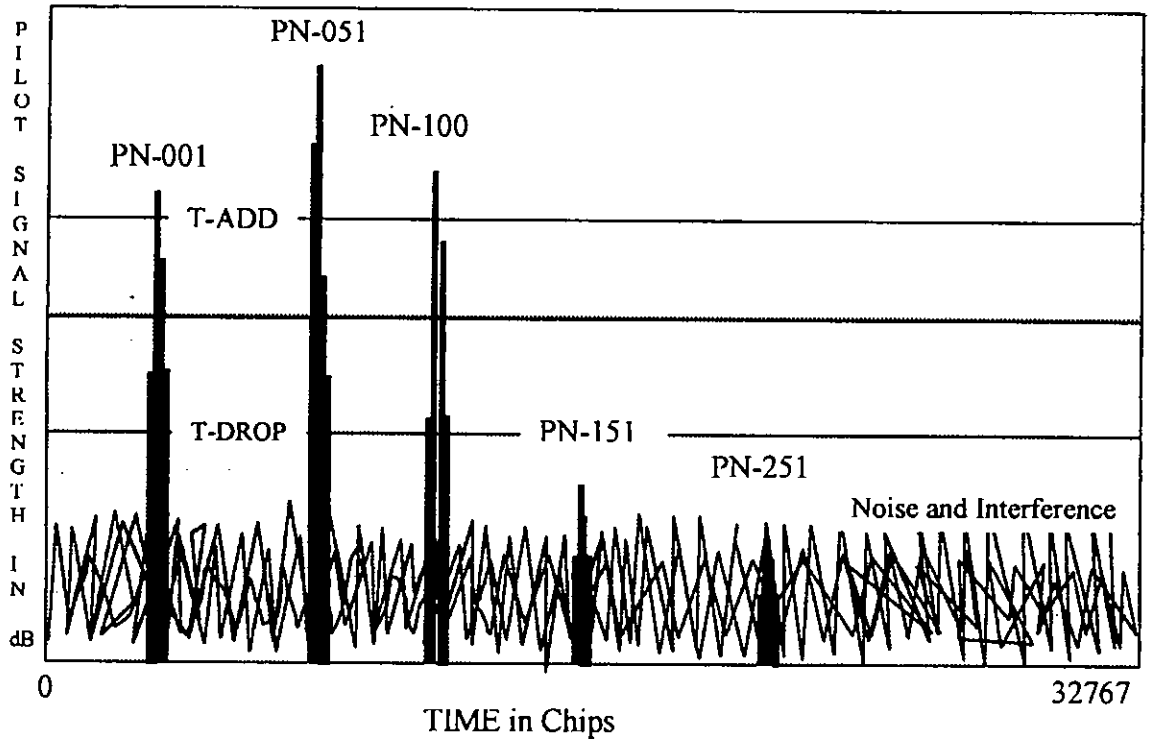


Figure 6.7b Initial state pilot search.

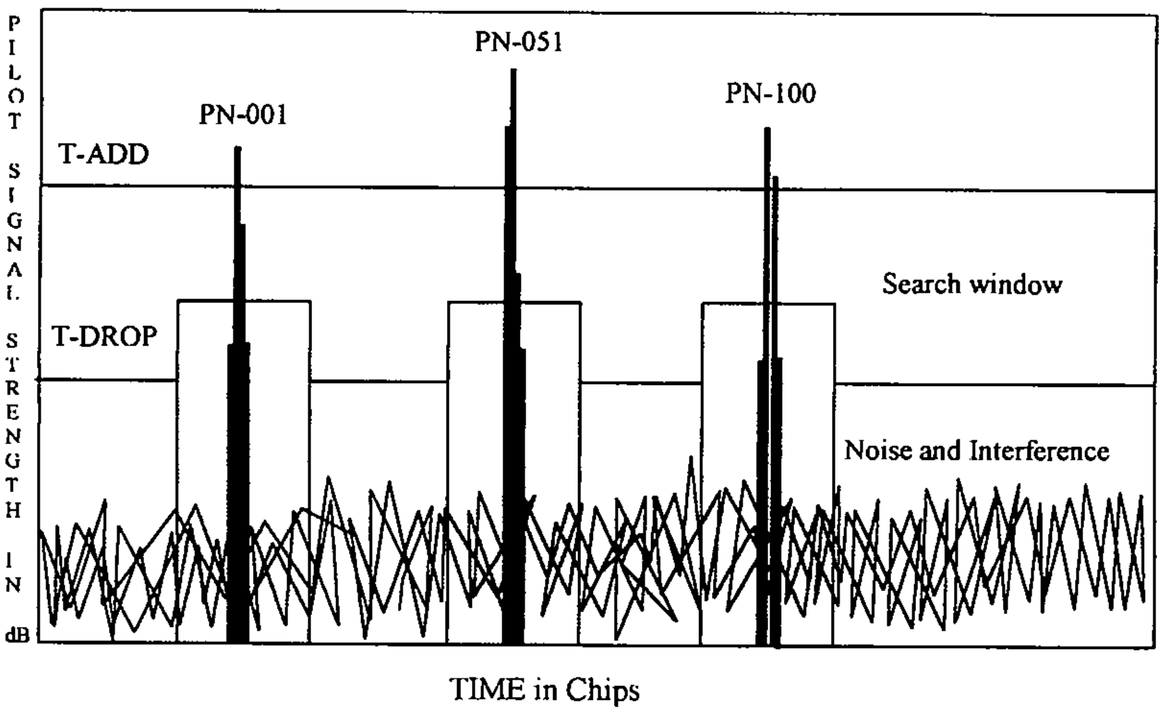


Figure 6.7c Idle state pilot search.

6.5 IMPROVING CAPACITY IN CELLULAR SYSTEMS.

As the demand for cellular service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users. At this point, cellular design techniques are needed to provide more channels per unit area. Techniques such as cell splitting, sectoring, and coverage zone approaches are used to expand the capacity of cellular systems. Cell splitting allows an orderly growth of the cellular system. Sectoring uses directional antennas to further control the frequency reuse of channels. The zone microcell concept distributes the coverage of a cell and extends the cell boundary to hard-to-reach places. While cell splitting increases the number of base stations in order to increase capacity, sectoring and zone microcells rely on base station antenna placements to improve capacity by reducing co-channel interference.

6.5.1 Cell Splitting.

Cell splitting is the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power. Cell splitting increases the capacity of the system since it increases the number of times that channels are reused. By defining new cells which have a smaller radius than the original cells, and installing these smaller cells (called microcells) between the existing cells, capacity increases due to the additional number of channels per unit area.

Imagine if every cell in Figure 6.8 were reduced in such a way that the radius of every cell was cut in half. In order to cover the entire service area with smaller cells, approximately four times as many cells would be required. This can be easily shown by considering a circle with radius R. The area covered by such a circle is four times as large as the area covered by a circle with radius R/2.

The increased number of cells would lead to an increase in the number of channels and thus capacity in the coverage area. Cell splitting allows a system to grow by replacing large cells with smaller cells, while not upsetting the channel allocation scheme required to maintain the minimum reuse distance ratio between co-channel cells. An example of cell splitting is shown in Figure 6.8.

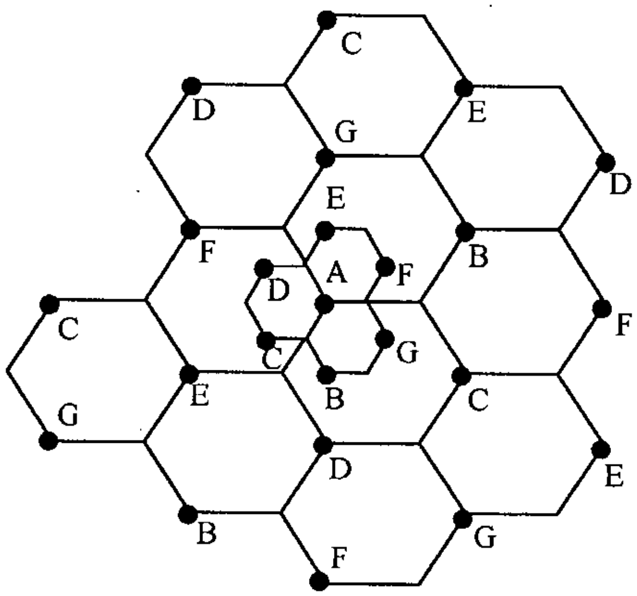


Figure 6.8 Illustration of cell splitting

In Figure 6.8 the base stations are placed at corners of the cells and the area served by base station A could no longer be served effectively by the number of allotted channels. Thus, new base stations were added in the region to reduce the area served by a single base station. Note in the figure that the original base station A has been surrounded by three new microcell base stations. The three smaller cells were added in such a way to preserve the frequency reuse plan of the system. For example, the microcell base station labeled G was placed half way between two larger stations utilizing the same channel set G. This is also the case for the other microcells in the figure. Cell splitting merely scales the geometry of the cluster. In this case, the radius of each new microcells is half that of the original cell.

For the new cells to be smaller in size, the transmit power of these cells must be reduced. The transmit power of the new cells with radius half that of the original cells can be found by examining the received power at the new and old cell boundaries, and setting them equal to each other. This ensures that the frequency reuse plan for the new microcells behaves exactly as for the original cells.

$$P_r(\text{at old cell boundary}) \ \alpha \ Pt_1 R^{-n} \tag{6.1}$$

And

$$P_r(\text{at new cell boundary}) \ \alpha \ Pt_2 (R/2)^{-n} \tag{6.2}$$

where P_{t1} an P_{t2} are the transmit powers of the larger and smaller cell base stations, respectively, and n is the path loss exponent. If we take $n = 4$ and set the received powers equal to each other, then

$$P_{t2} = \frac{P_{t1}}{16} \tag{6.3}$$

In other words, the transmit power must be reduced by 12 dB in order to fill in the original coverage area with microcells, while maintaining the S/I required as more microcells are installed throughout the system.

In practice, not all cells are split at the same time. It is often difficult for service providers to find real estate that is perfectly situated for cell splitting base stations. Therefore, different cell sizes will exist simultaneously. In such situations, special care needs to be taken to keep the distance between co-channel cells at the required minimum, and hence channel assignment becomes more complicated. When there are two cell sizes in the same region as shown in Figure 6.8, equation (6.3) shows that one cannot simply use the original transmit power for all new cells, or the new transmit power for all the cells. If the larger transmit power is used for all cells, some channels used by the smaller cells would not be sufficiently separated from co-channel cells. On the other hand, if the smaller transmit power is used for all the cells, portions of the larger cells left will be unserved. For this reason, channels in the old cell must be broken down into two channel groups, one that corresponds to the smaller cell reuse requirements and the other that corresponds to the larger cell reuse requirements.

The two channel group sizes depend on the stage of the splitting process. At the beginning of the cell splitting process, there will be fewer channels in the small power groups. However, as demand grows, more channels will be required and thus the smaller groups will require more channels. This splitting process continues until all the channels in an area are used in the lower power group, at which point cell splitting is complete within the region. Antenna downtilting is often used to limit the radio coverage of cells, as well. By causing the antenna beam to point down towards the ground, the cell coverage is further reduced in small cells.

Advantages:

1. Cell splitting allows an orderly growth of the cellular system.
2. By decreasing the cell radius R, and keeping the co-channel reuse ratio D/R unchanged, cell splitting increases the number of channels per unit area.

Disadvantages:

1. Different cell sizes will exist, so special care needs to be taken to keep the distance between co-channel cells at the required minimum, and hence channel assignment becomes more complicated.
2. Fast moving mobile users require many more handoffs, which burden the MSC.
3. No. of base stations increases.

6.5.2 Sectoring

Cell splitting achieves capacity improvement by essentially rescaling the system. By decreasing the cell radius R, and keeping the co-channel reuse ratio D/R unchanged, cell splitting increases the number of channels per unit area. However, another way to increase capacity is to keep the cell radius unchanged and seek methods to decrease the D/R ratio. In this approach, capacity improvement is achieved by reducing the number of cells in a cluster and thus increasing the frequency reuse. However, in order to do this, it is necessary to reduce the relative interference without decreasing the transmit power.

The co-channel interference in a cellular system may be decreased by replacing a single omni-directional antenna at the base station by several directional antennas, each radiating within a specified sector. By using directional antennas, a given cell will interfere only with a fraction of the co-channel cells. This technique for decreasing co-channel interference, and thus increasing system capacity is called sectoring. The factor by which the co-channel interference is reduced depends on the amount of sectoring used. A cell is normally partitioned into three 120^0 sectors or six 60^0 sectors as shown in Figures 6.9a And 6.9b.

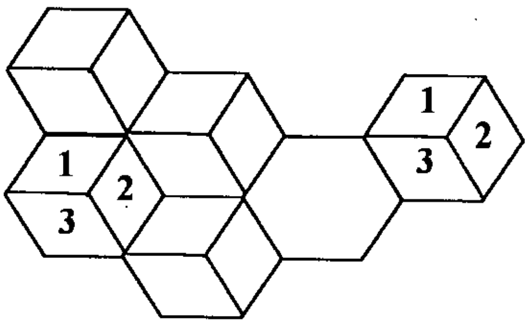


Figure 6.9a 120 degree sectoring.

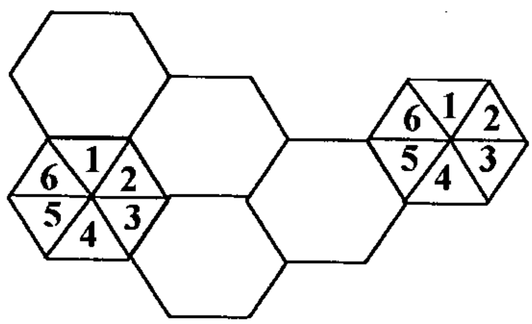


Figure 6.9b 60 degree sectoring.

When sectoring is employed, the channels used in a particular cell are broken down into sectored groups and are used only within a particular sector, as illustrated in Figures 6.9a and 6.9b. Assuming seven cell reuse, for the case of 120 degree sectors, the number of interferers in the first level is reduced from six to two. This is because only two of the six co-channel cells receive interference with a particular channel group in the cell under study.

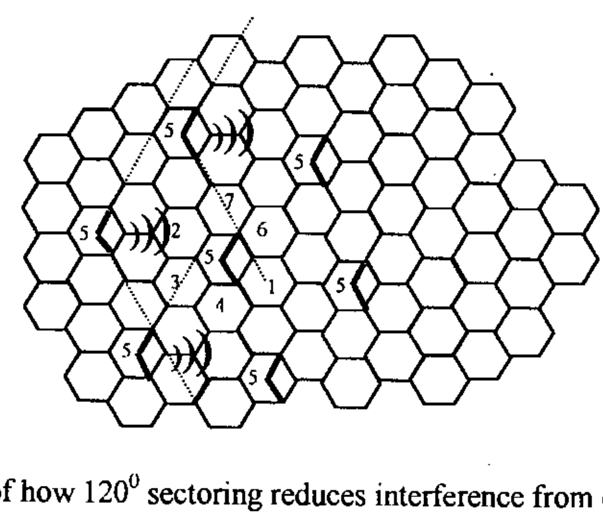


Figure 6.9c Illustration of how 120^0 sectoring reduces interference from co-channel cells

Consider, for example, the interference experienced by a mobile in the center cell labeled 5 in Figure 6.9c. There are three cells labeled 5 to the right of the center cell and three to the left of the center cell which use the same channels. Out of these, only two have antenna patterns which radiate into the center cell, and hence a mobile in the center cell 5 will experience interference on the forward link due to these two cells only. The resulting S/I for this case can be found 24.2 dB. This is a significant improvement over the omni-directional case, where the worst case S/I was found to be 17 dB. In practical systems, further improvement in S/I is achieved by downtilting the antennas so that the radiation pattern in the horizontal (elevation) plane has a notch at the co-channel cell distance.

The improvement in S/I implies that with 120 degree sectoring, the minimum required S/I of 18 dB can be easily achieved with 7 cell reuse, as compared to 12 cell reuse for the worst possible situation in the unsectored case. Thus, sectoring provides much better frequency reuse, giving an increase in capacity by a factor of 12/7, or 1.714. The penalty paid for this capacity increase is an increased number of antennas at each base station, as well as an increased number of hand-offs as mobiles pass between sectors of the same cell. Further, the trunking efficiency of the systems is decreased since the channels at a base station are partitioned in a fixed manner to serve each sector. That is, each sectored group of channels is treated as a separate trunk group. For a given number of channels serving a coverage area, sectorization does not take full advantage of the flexibility offered by trunking.

Advantages :

1. Co-channel interference may be decreased by replacing a single omni-directional antenna at the base station.
2. S/I is significantly improved over omni-directional case.

Disadvantages :

1. The penalty paid for this capacity increase is an increased number of antennas at each base station.
2. As well as an increased number of hand-offs required as mobiles pass between sectors of the same cell.

6.5.3 A Novel Microcell Zone Concept

The increased number of hand-offs required when employing sectoring leads to an increase in load on the switching and control link elements of the system. A solution to this problem was presented by Less. This proposal is based on a microcell concept for 7 cell reuse, as illustrated in Figure 6.10.

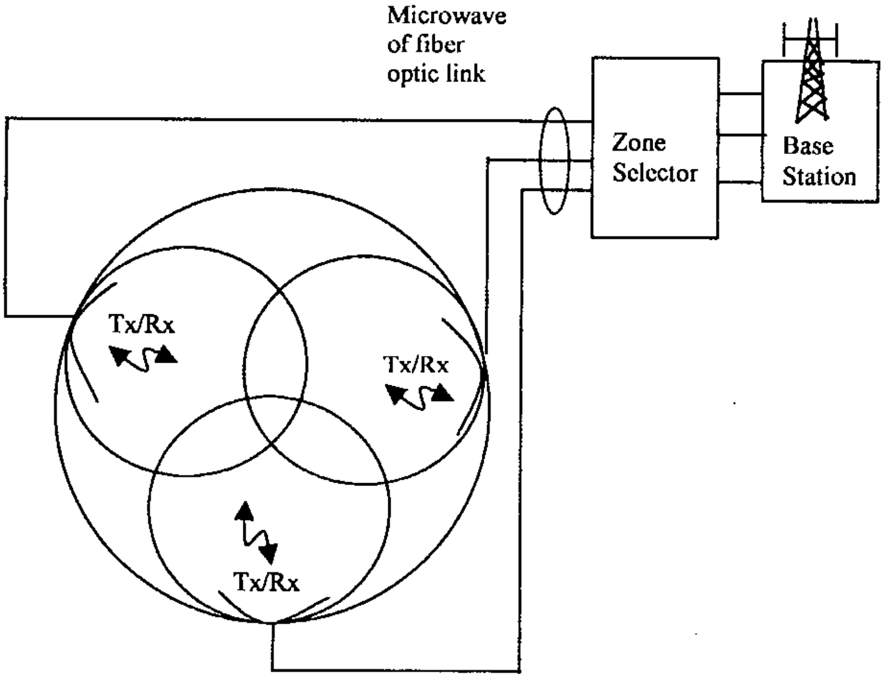


Figure 6.10 The Microcell concept.

In this set-up, each of the three (or possibly more) zone sites (represented as Tx/Rx in Figure 6.10) are connected to a single base station and share the same radio equipment. These multiple zones and single base station make up a cell. As a mobile travels within the cell, it is served by the zone with the strongest signal. This approach is superior to sectoring since antennas are now placed at the outer edges of the cell, and any channel may be assigned to any zone by the base station. Additionally, as a mobile travels from one zone to another within the cell, it retains the same channel. Thus unlike in sectoring, a hand-off is not required at the MSC when the mobile travels between zones within the cell. The base station simply switches the channel to a different antenna or zone site. In this way, a given channel is active only in the particular zone in which the mobile is traveling, and hence the interference is largely reduced. The channels are distributed in time and space by all three zones as well as reused in co-channel cells in the normal fashion.

Advantages:

1. The co-channel interference in the cellular system is reduced since a large central base station is replaced by several lower powered transmitters on the edges of the cell.
2. Decreased co-channel interference improves the signal quality and also leads to an increase in capacity.

Disadvantages:

Several low powered transmitters are need.

Conclusion for further improvement of cellular capacity:

In GSM system each cell is divided into sectors in order to reduce interference. As a result the trunking efficiency of dividing channels in each sector decreases.

In CDMA sectorization is used to increase capacity in a way that introduces three radios in three sectors and therefore obtains three times the capacity as compared with the theoretical one radio in a cell.

Also the coverage area is increasing by using repeater station. or establish new base station.

By decreasing cell radius or using double carrier or using 6 sector per cell the cellular capacity will improve.

But in CDMA double carrier and 6 sectorization method the problem arises due to hand-off procedure.

So after using 3 –sector per cell, cell splitting is better than other method for further improvement of cellular capacity for designed network.

CHAPTER – 7
CONCLUSIONS

7.1 CONCLUSIONS

A CDMA based Cellular Network is designed for Dhaka city. This will cover more than 3000 km^2 which is 30 km radius with centre at Mohakhali. This area includes Dhaka Narayangonj and Gazipur District. A tedious job is done for demand forecasting for Dhaka city which includes population distribution, Income level, employment status etc. Cell planning is done up to 2010. At 2002 the population per mobile is 28.12 but considering all the factors, that may increase to 10 at 2010. Cell planning is done to meet the increasing cellular demand. From the 1st plan a total of 5,70,000 subscriber can be connected which fulfil the increasing cellular demand up to 2004. From the second plan 885000 subscriber can be connected which fulfil the increasing demand up to 2007 and a total of 1200000 subscriber can be connected which fulfil increasing demand up to 2010. But in changing the cell plan the previous BTS position remain unchanged. To meet the growing cellular capacity within a cell, cell splitting is better than other methods from the point of view of soft hand off.

For commercial area the busy hour calling rate is considered 0.033 erlangs and 0.025 erlangs for residential, Other urban and rural areas. For CDMA system 2% to 5% GOS is considered to be suitable. But 2% GOS is considered for this design.

Interference from own cell and neighbor sector are found –9.03 dB and –8.9 dB. The next neighbor sector interference is also within CDMA limit. The reception quality is expected to be good enough, since the signal strength at some boundary points of a cell is well above the minimum requirement of CDMA. So the design is considered suitable for practical implementation.

7.2 FUTURE WORKS

The result of this design may also be extended for other cities such as Chittagong, Rajshahi & Khulna in Bangladesh. The work can be extended all over the Bangladesh. System capacity of current design can be improved by using cell splitting, sectoring etc. techniques. The CDMA based design can be extended for emerging wideband CDMA technology in future.

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APPENDIX - A

Blocked-Calls-Cleared

(Erlang B) [1]

A, erlangs													
B													
N	1.0%	1.2%	1.5%	2%	3%	5%	7%	10%	15%	20%	30%	40%	50%
1	.0101	0.121	.0152	.0204	.0309	.0526	.0753	.111	.176	.250	.429	.667	1.00
2	.153	.168	.190	.223	.282	.381	.470	.595	.796	1.00	1.45	2.00	2.73
3	.455	.489	.535	.602	.715	.899	1.06	1.27	1.60	1.93	2.63	3.48	4.59
4	.869	.922	.992	1.09	1.26	1.52	1.75	2.05	2.50	2.95	3.39	5.02	6.50
5	1.36	1.43	1.52	1.66	1.88	2.22	2.50	2.88	3.45	4.01	5.19	6.60	8.44
6	1.91	2.00	2.11	2.28	2.54	2.96	3.30	3.76	4.44	5.11	6.51	8.19	10.4
7	2.50	2.60	2.74	2.94	3.25	3.74	4.14	4.67	5.46	6.23	7.86	9.80	12.4
8	3.03	3.25	3.40	3.63	3.99	4.54	5.00	5.60	6.50	7.37	9.21	11.4	14.3
9	3.78	3.92	4.09	4.34	4.75	5.37	5.88	6.55	7.55	8.52	10.6	13.0	16.3
10	4.46	4.61	4.81	5.08	5.53	6.22	6.78	7.51	8.62	9.68	12.0	14.7	18.3
11	5.16	5.32	5.54	5.84	6.33	7.08	7.69	8.49	9.69	10.9	13.3	16.3	20.3
12	5.88	6.05	6.29	6.61	7.14	7.95	8.61	9.47	10.8	12.0	14.7	18.0	22.2
13	6.61	6.80	7.05	7.40	7.97	8.83	9.54	10.5	11.9	13.2	16.1	19.6	24.2
14	7.35	7.56	7.82	8.20	8.80	9.73	10.5	11.5	13.0	14.4	17.5	21.2	26.2
15	8.11	8.33	8.61	9.01	9.65	10.6	11.4	12.5	14.1	15.6	18.9	22.9	28.2
16	8.88	9.11	9.41	9.83	10.5	11.5	12.4	13.5	15.2	16.8	20.3	24.5	30.2
17	9.65	9.89	10.2	10.7	11.4	12.5	13.4	14.5	16.3	18.0	21.7	26.2	32.2
18	10.4	10.7	11.0	11.5	12.2	13.4	14.3	15.5	17.4	19.2	23.1	27.8	34.2
19	11.2	11.5	11.8	12.3	13.1	14.3	15.3	16.6	18.5	20.4	24.5	29.5	36.2
20	12.0	12.3	12.7	13.2	14.0	15.2	16.3	17.6	19.6	21.6	25.9	31.2	38.2
21	12.8	13.1	13.5	14.0	14.9	16.2	17.3	18.7	20.8	22.8	27.3	32.8	40.2
22	13.7	14.0	14.3	14.9	15.8	17.1	18.2	19.7	21.9	24.1	28.7	34.5	42.1
23	14.5	14.8	15.2	15.8	16.7	18.1	19.2	20.7	23.0	25.3	30.1	36.1	44.1
24	15.3	15.6	16.0	16.6	17.6	19.0	20.2	21.8	24.2	26.5	31.6	37.8	46.1
25	16.1	16.5	16.9	17.5	18.5	20.0	21.2	22.8	25.3	27.7	33.0	39.4	48.1
26	17.0	17.3	17.8	18.4	19.4	20.9	22.2	23.9	26.4	28.9	34.4	41.1	50.1
27	17.8	18.2	18.6	19.3	20.3	21.9	23.2	24.9	27.6	30.2	35.8	42.8	52.1
28	18.6	19.0	19.5	20.2	21.2	22.9	24.2	26.0	28.7	31.4	37.2	44.4	54.1
29	19.5	19.9	20.4	21.0	22.1	23.8	25.2	27.1	29.9	32.6	38.6	46.1	56.1
30	20.3	20.7	21.2	21.9	23.1	24.8	26.2	28.1	31.0	33.8	40.0	47.7	58.1
31	21.2	21.6	22.1	22.8	24.0	25.8	27.2	29.2	32.1	35.1	41.5	49.4	60.1
32	22.0	22.5	23.0	23.7	24.9	26.7	28.2	30.2	33.3	36.3	42.9	51.1	62.1
33	22.9	23.3	23.9	24.6	25.8	27.7	29.3	31.3	34.4	37.5	44.3	52.7	64.1
34	23.8	24.2	24.8	25.5	26.8	28.7	30.3	32.4	35.6	38.8	45.7	54.4	66.1
35	24.6	25.1	25.6	26.4	27.7	29.7	31.3	33.4	36.7	40.0	47.1	56.0	68.1
36	25.5	26.0	26.5	27.3	28.6	30.7	32.3	34.5	37.9	41.2	48.6	57.7	70.1
37	26.4	26.8	27.4	28.3	29.6	31.6	33.3	35.6	39.0	42.4	50.0	59.4	72.1
38	27.3	27.7	28.3	29.2	30.5	32.6	34.4	36.6	40.2	43.7	51.4	61.0	74.1
39	28.1	28.6	29.2	30.1	31.5	33.6	35.4	37.7	41.3	44.9	52.8	62.7	76.1
40	29.0	29.5	30.1	31.0	32.4	34.6	36.4	38.8	42.5	46.1	54.2	64.4	78.1
41	29.9	30.4	31.0	31.9	33.4	35.6	37.4	39.9	43.6	47.4	55.7	66.0	80.1
42	30.8	31.3	31.9	32.8	34.3	36.6	38.4	40.9	44.8	48.6	57.1	67.7	82.1
43	31.7	32.2	32.8	33.8	35.3	37.6	39.5	42.0	45.9	49.9	58.5	69.3	84.1
44	32.5	33.1	33.7	34.7	36.2	38.6	40.5	43.1	47.1	51.1	59.9	71.0	86.1
45	33.4	34.0	34.6	35.6	37.2	39.6	41.5	44.2	48.2	52.3	61.3	72.7	88.1
46	34.3	34.9	35.6	36.5	38.1	40.5	42.6	45.2	49.4	53.6	62.8	74.1	90.1
47	35.2	35.8	36.5	37.5	39.1	41.5	43.6	46.3	51.6	54.8	64.2	76.0	92.1
48	36.1	36.7	37.4	38.4	40.1	42.5	44.6	47.4	51.7	56.0	65.6	77.7	94.1
49	37.0	37.6	38.3	39.3	41.0	43.5	45.7	48.5	52.9	57.3	67.0	79.3	96.1
50	37.9	38.5	39.2	40.3	41.9	44.5	46.7	49.6	54.0	58.5	68.5	81.0	98.1

APPENDIX - A

Blocked-Calls-Cleared

(Erlang B) [*Continued*]

A, erlangs													
B													
N	1.0%	1.2%	1.5%	2%	3%	5%	7%	10%	15%	20%	30%	40%	50%
51	38.8	39.4	40.1	41.2	44.9	45.5	47.7	50.6	55.2	59.7	69.9	82.7	100.1
52	39.7	40.3	41.0	42.1	43.9	46.5	48.8	51.7	56.3	61.0	71.3	84.3	102.1
53	40.6	41.2	42.0	43.1	44.8	47.5	49.8	52.8	57.5	62.2	72.7	86.0	104.1
54	41.5	42.1	42.9	44.0	45.8	48.5	50.8	53.9	58.7	63.5	74.2	87.6	106.1
55	42.4	43.0	43.8	44.9	46.7	49.5	51.9	55.0	59.8	64.7	75.6	89.3	108.1
56	43.3	43.9	44.7	45.9	47.7	50.5	52.9	56.1	61.0	65.9	77.0	91.0	110.1
57	44.2	44.8	45.7	46.8	48.7	51.5	53.9	57.1	62.1	67.2	78.4	92.6	112.1
58	45.1	45.8	46.6	47.8	49.6	52.6	55.0	58.2	63.3	68.4	79.8	94.3	114.1
59	46.0	46.7	47.5	48.7	50.6	53.6	56.0	59.3	64.5	69.7	81.3	96.0	116.1
60	46.9	47.6	48.4	49.6	51.6	54.6	57.1	61.4	65.6	70.9	82.7	97.6	118.1
61	47.9	48.5	49.4	50.6	52.5	55.6	58.1	61.5	66.8	72.1	84.1	99.3	120.1
62	48.8	49.4	50.3	51.5	53.5	56.6	59.1	62.6	68.0	73.4	85.5	101.0	122.1
63	49.7	50.4	51.2	52.5	54.5	57.6	60.2	63.7	69.1	74.6	87.0	102.6	124.1
64	50.6	51.3	52.2	53.4	55.4	58.6	61.2	64.8	70.3	75.9	88.4	104.3	126.1
65	51.5	52.2	53.1	54.4	56.4	59.6	62.3	65.8	71.4	77.1	89.8	106.0	128.1
66	52.4	53.1	54.0	55.3	57.4	60.6	63.3	66.9	72.6	78.3	91.2	107.6	130.1
67	53.4	54.1	55.0	56.3	58.4	61.6	64.4	68.0	73.8	79.6	82.7	109.3	132.1
68	54.3	55.0	55.9	57.2	59.3	62.6	65.4	69.1	74.9	80.8	94.1	111.0	134.1
69	55.2	55.9	56.9	58.2	60.3	63.7	66.4	70.2	76.1	82.1	95.5	112.6	136.1
70	56.1	56.8	57.8	59.1	61.3	64.7	67.5	71.3	77.3	83.3	96.9	114.3	138.1
71	57.0	57.8	58.7	60.1	62.3	65.7	68.5	72.4	78.4	84.6	98.4	115.9	140.1
72	58.0	58.7	59.7	61.0	63.2	66.7	69.6	73.5	79.6	85.8	99.8	117.6	142.1
73	58.9	59.6	60.6	62.0	64.2	67.7	70.6	74.6	80.8	87.0	101.2	119.3	144.1
74	59.8	60.6	61.6	62.9	65.2	68.7	71.7	75.6	81.9	88.3	102.7	120.9	146.1
75	60.7	61.5	62.5	63.9	66.2	69.7	72.7	76.7	83.1	89.5	104.1	122.6	148.0
76	61.7	62.4	63.4	64.9	67.2	70.8	73.8	77.8	84.2	90.8	105.5	124.3	150.0
77	62.6	63.4	64.4	65.8	68.1	71.8	74.8	78.9	85.4	92.0	106.9	125.9	152.0
78	63.5	64.3	65.3	66.8	69.1	72.8	75.9	80.0	86.6	93.3	108.4	127.6	154.0
79	64.4	65.2	66.3	67.7	70.1	73.8	76.9	81.1	87.7	94.5	109.8	129.3	156.0
80	65.4	66.2	67.2	68.7	71.1	74.8	78.0	82.2	88.9	95.1	111.2	130.9	158.0
81	66.3	67.1	68.2	69.6	72.1	75.8	79.0	83.3	90.1	97.0	112.6	132.6	160.0
82	67.2	68.0	69.1	70.6	73.0	76.9	80.1	84.4	91.2	98.2	114.1	134.3	162.0
83	68.2	69.0	70.1	71.6	74.0	77.9	81.1	85.5	92.4	99.5	115.5	135.9	164.0
84	69.1	69.9	71.0	72.5	75.0	78.9	82.2	86.6	93.6	100.7	116.9	137.6	166.0
85	70.0	70.9	71.9	73.5	76.0	79.9	83.2	87.7	94.7	102.0	118.3	139.3	168.0
86	70.9	71.8	72.9	74.5	77.0	80.9	84.3	88.8	95.9	103.2	119.8	140.9	170.0
87	71.9	72.7	73.8	75.4	78.0	82.0	85.3	89.9	97.1	104.5	121.2	142.6	172.0
88	72.8	73.7	74.8	76.4	78.9	83.0	86.4	91.0	98.2	105.7	122.6	144.3	174.0
89	73.7	74.6	75.7	77.3	79.9	84.0	87.4	92.1	99.4	106.9	124.0	145.9	176.0
90	74.7	75.6	76.7	78.3	80.9	85.0	88.5	93.1	100.6	108.2	125.5	147.6	178.0
91	75.6	76.5	77.6	79.3	81.9	86.0	89.5	94.2	101.7	109.4	126.9	149.3	180.0
92	76.6	77.4	78.6	80.2	82.9	87.1	90.6	95.3	102.9	110.7	128.3	150.9	182.0
93	77.5	78.4	79.6	81.2	83.9	88.1	91.6	96.4	104.1	111.9	129.7	152.6	184.0
94	78.4	79.3	80.5	82.2	84.9	89.1	92.7	97.5	105.3	113.2	131.2	154.3	186.0
95	79.4	80.3	81.5	83.1	85.8	90.1	93.7	98.6	106.4	114.4	132.6	155.9	188.0
96	80.3	81.2	82.4	84.1	86.8	91.1	94.8	99.7	107.6	115.7	134.0	157.6	190.0
97	81.2	82.2	83.4	85.1	87.8	92.2	95.8	100.8	108.8	116.9	135.5	159.3	192.0
98	82.2	83.1	84.3	86.0	88.8	93.2	96.9	101.9	109.9	118.2	136.9	160.9	194.0
99	83.1	84.1	85.3	87.0	89.8	94.2	97.9	103.0	111.1	119.4	138.3	162.6	196.0
100	84.1	85.0	86.2	88.0	90.8	95.2	99.0	104.1	112.3	120.6	139.7	164.3	198.0
102	85.9	86.9	88.1	89.9	92.8	97.3	101.1	106.3	114.6	123.1	142.6	167.6	202.2
104	87.8	88.8	90.1	91.9	94.8	99.2	103.2	106.5	116.9	125.6	145.4	170.9	206.0
106	89.7	90.7	92.0	93.8	96.7	101.4	105.3	110.7	119.3	128.1	148.3	174.2	210.0

APPENDIX - A

Blocked-Calls-Cleared

(Erlang B) [*Continued*]

A, erlangs													
						B							
N	1.0%	1.2%	1.5%	2%	3%	5%	7%	10%	15%	20%	30%	40%	50%
108	91.6	92.6	93.9	95.7	98.7	103.4	107.4	112.9	121.6	130.6	151.1	177.6	214.0
110	93.5	94.5	95.8	97.7	100.7	105.5	109.5	115.1	124.0	133.1	154.0	180.9	218.0
112	95.4	96.4	97.7	99.6	102.7	107.5	111.7	117.3	126.3	135.6	156.9	184.2	222.0
114	97.3	98.3	99.7	101.6	104.7	109.6	113.8	119.5	128.6	138.1	159.7	187.6	226.0
116	99.2	100.2	101.6	103.5	106.7	111.7	115.9	121.7	131.0	140.6	162.6	190.9	230.0
118	101.1	102.1	103.5	105.5	108.7	113.7	118.0	123.9	133.3	143.1	165.4	194.2	234.0
120	103.0	104.0	105.4	107.4	110.7	115.8	120.1	126.1	135.7	145.6	168.3	197.6	238.0
122	104.9	105.9	107.4	109.4	112.6	117.8	122.2	128.3	138.0	148.1	171.1	200.9	242.0
124	106.8	107.9	109.3	111.3	114.6	119.9	124.4	130.5	140.3	150.6	174.0	204.2	246.0
126	108.7	109.8	111.2	113.3	116.6	121.9	126.5	132.7	142.7	153.0	176.8	207.6	250.0
128	110.6	111.7	113.2	115.2	118.3	124.0	128.6	134.9	145.0	155.5	179.7	210.9	254.0
130	112.5	113.6	115.1	117.2	120.6	126.1	130.7	137.1	147.4	158.0	182.5	214.2	258.0
132	114.4	115.5	117.0	119.1	122.6	128.1	132.8	139.3	149.7	160.5	185.4	217.6	262.0
134	116.3	117.4	119.0	121.1	124.6	130.2	134.9	141.5	152.0	163.0	188.3	220.9	266.0
136	118.2	119.4	120.9	123.1	126.6	132.3	137.1	143.7	154.4	165.5	191.1	224.2	270.0
138	120.1	121.3	122.8	125.0	128.6	134.3	139.2	145.9	156.7	168.0	194.0	227.6	274.0
140	122.0	123.2	124.8	127.0	130.6	136.4	141.3	148.1	159.1	170.5	196.8	230.9	278.0
142	123.9	125.1	126.7	128.9	132.6	138.4	143.4	150.3	161.4	173.0	199.7	234.2	282.0
144	125.8	127.0	128.6	130.9	134.6	140.5	145.6	152.5	163.8	175.5	202.5	237.6	286.0
146	127.7	129.0	130.6	132.9	136.6	142.6	147.7	154.7	166.1	178.0	205.4	240.9	290.0
148	129.7	130.9	132.5	134.8	138.6	144.6	149.8	156.9	168.5	180.5	208.2	244.2	294.0
150	131.6	132.8	134.5	136.8	140.6	146.7	151.9	159.1	170.8	183.0	211.1	247.6	298.0
152	133.5	134.8	136.4	138.8	142.6	148.8	154.0	161.3	173.1	185.5	214.0	250.9	302.0
154	135.4	136.7	138.4	140.7	144.6	150.8	156.2	163.5	175.5	188.0	216.8	254.2	306.0
156	137.7	138.6	140.3	142.7	146.6	152.9	158.3	165.7	177.8	190.5	219.7	257.6	310.0
158	139.2	140.5	142.3	144.7	148.6	155.0	160.4	167.9	180.2	193.0	222.5	260.9	314.0
160	141.2	142.5	144.2	146.6	150.6	157.0	162.5	170.2	182.5	195.5	225.4	264.2	318.0
162	143.1	144.4	146.1	148.6	152.7	159.1	164.7	172.4	184.9	198.0	228.2	267.6	322.0
164	145.0	146.3	148.1	150.6	154.7	161.2	166.8	174.6	187.2	200.4	231.1	270.9	326.0
166	146.9	148.3	150.0	152.6	156.7	163.3	168.9	176.8	189.6	202.9	233.9	274.2	330.0
168	148.9	150.2	152.0	154.5	158.7	165.3	171.0	179.0	191.9	205.4	236.8	277.6	334.0
170	150.8	152.1	153.9	156.5	160.7	167.4	173.2	181.2	194.2	207.9	239.7	280.9	338.0
172	152.7	154.1	155.9	158.5	162.7	169.5	175.3	183.4	196.6	210.4	242.5	284.2	342.0
174	154.6	156.0	157.8	160.4	164.7	171.5	177.4	185.6	198.9	212.9	245.4	287.6	346.0
176	156.6	158.0	159.8	162.4	166.7	173.6	179.6	187.8	201.3	215.4	248.2	290.9	350.0
178	158.5	159.9	161.8	164.4	168.7	175.7	181.7	190.0	203.6	217.9	251.1	294.2	354.0
180	160.4	161.8	163.7	166.4	170.7	177.8	183.8	192.2	206.0	220.4	253.9	297.5	358.0
182	162.3	163.8	165.7	168.3	172.8	179.8	185.9	194.4	208.3	222.9	256.8	300.9	362.0
184	164.3	165.7	167.6	170.3	174.8	181.9	188.1	196.6	210.7	225.4	259.6	304.2	366.0
186	166.2	167.7	169.6	172.3	176.8	184.0	190.2	198.9	213.0	227.9	262.5	307.5	370.0
188	168.1	169.6	171.5	174.3	178.8	186.1	192.3	201.1	215.4	230.4	265.4	310.9	374.0
190	170.1	171.5	173.5	176.3	180.8	188.1	194.5	203.3	217.1	232.9	268.2	314.2	378.0
192	172.0	173.5	175.4	178.2	182.8	190.2	196.6	205.5	220.1	235.4	271.1	317.5	382.0
194	173.9	175.4	177.4	180.2	184.8	192.3	198.7	207.7	222.4	237.9	273.9	320.9	386.0
196	175.9	177.4	179.4	182.2	186.9	194.4	200.8	209.9	224.8	240.4	276.8	324.2	390.0
198	177.8	179.3	181.3	184.2	188.9	196.4	203.0	212.1	227.1	242.9	279.6	327.5	394.0
200	179.7	181.3	183.3	186.2	190.9	198.5	205.1	214.3	229.4	245.4	284.5	330.9	398.0
202	181.7	183.2	185.2	188.1	192.9	200.6	207.2	216.5	231.8	247.9	285.4	334.2	402.0
204	183.6	185.2	187.2	190.1	194.9	202.7	209.4	218.7	234.1	250.4	288.2	337.5	406.0
206	185.5	187.1	189.2	192.1	196.9	204.7	211.5	221.0	236.5	252.9	291.1	340.9	410.0
208	187.5	189.1	191.1	194.1	199.0	206.8	213.6	223.2	238.8	255.4	293.9	344.2	414.0
210	189.4	191.0	193.1	196.1	201.0	208.9	215.8	225.4	241.2	257.9	296.8	347.5	418.0
212	191.4	193.0	195.1	198.1	203.0	211.0	217.9	227.6	243.5	260.4	299.6	350.0	422.0

APPENDIX - A

Blocked-Calls-Cleared

(Erlang B) [*Continued*]

A, erlangs													
B													
N	1.0%	1.2%	1.5%	2%	3%	5%	7%	10%	15%	20%	30%	40%	50%
214	193.3	194.9	197.0	200.0	205.0	213.0	220.0	229.8	245.9	262.9	302.5	354.2	426.0
216	195.2	196.9	199.0	202.0	207.0	215.1	222.2	232.0	248.2	265.4	305.3	357.5	430.0
218	197.2	198.8	201.0	204.0	209.1	217.1	224.3	234.2	250.6	267.9	308.2	360.9	434.0
220	199.1	200.8	202.9	206.0	211.1	219.3	226.4	236.4	252.9	270.4	311.1	364.2	438.0
222	201.1	202.7	204.9	208.0	213.1	221.4	228.6	238.6	255.3	272.9	313.9	367.5	442.0
224	203.0	204.7	206.8	210.0	215.1	223.4	230.7	240.9	257.6	275.4	316.8	370.9	446.0
226	204.9	206.6	208.8	212.0	217.1	225.5	232.8	243.1	260.0	277.8	319.6	374.2	450.0
228	206.9	208.6	210.8	213.9	219.2	227.6	235.0	245.3	262.3	280.3	322.5	377.5	454.0
230	208.8	210.5	212.8	215.9	221.2	229.7	237.1	247.5	264.7	282.8	325.3	380.9	458.0
232	210.8	212.5	214.7	217.9	223.2	231.8	239.2	249.7	267.0	285.3	328.2	384.2	462.0
234	212.7	214.4	216.7	219.9	225.2	233.8	241.4	251.9	269.4	287.8	331.1	387.5	466.0
236	214.7	216.4	218.7	221.9	227.2	235.9	243.5	254.1	271.7	290.3	333.9	390.9	470.0
238	216.6	218.3	220.6	223.9	229.3	238.0	245.6	256.3	274.1	292.8	336.8	394.2	474.0
240	218.6	220.3	222.6	225.9	231.3	240.1	247.8	258.6	276.4	295.3	339.6	397.5	478.0
242	220.5	222.3	224.6	227.9	233.3	242.2	249.9	260.8	278.8	297.8	342.5	400.9	482.0
244	222.5	224.2	226.5	229.9	235.3	244.3	252.0	263.0	281.1	300.3	345.3	404.2	486.0
246	224.4	226.2	228.5	231.8	237.4	246.3	254.2	265.2	283.4	302.8	348.2	407.5	490.0
248	226.3	228.1	230.5	233.8	239.4	248.4	256.3	267.4	285.8	305.3	351.0	410.9	494.0
250	228.3	230.1	232.5	235.8	241.4	250.5	258.4	269.6	288.1	307.8	353.9	414.2	498.0

APPENDIX - B

64- ary Orthogonal Symbol Set

[1]

Walsh Chip within Symbol

MODULATIO SYMBO INDE

	0123	4567	11 8901	1111 2345	1111 6789	2222 0123	2222 4567	2233 8901	3333 2345	3333 6789	4444 0123	4444 4567	4455 8901	5555 2345	5555 6789	6666 0123
0	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101
2	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011
3	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110
4	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111
5	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010
6	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100
7	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001
8	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111
9	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010
10	001	0011	1100	1100	0011	0011	1100	1100	001	0011	1100	1100	0011	0011	1100	1100
11	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001
12	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000
13	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101
14	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011
15	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110
16	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111
17	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010
18	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100
19	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001
20	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111
21	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010
22	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100
23	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001
24	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000
25	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101
26	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011
27	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110
28	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111
29	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010
30	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100
31	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001

APPENDIX - B

64- ary Orthogonal Symbol Set

[Continued]

Walsh Chip within Symbol

	0123	4567	11 8901	1111 2345	1111 6789	2222 0123	2222 4567	2233 8901	3333 2345	3333 6789	4444 0123	4444 4567	4455 8901	5555 2345	5555 6789	6666 0123
32	0000	0000	0000	0000	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111
33	0101	0101	0101	0101	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010
34	0011	0011	0011	0011	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100
35	0110	0110	0110	0110	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001
36	0000	1111	0000	1111	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000
37	0101	1010	0101	1010	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101
38	0011	1100	0011	1100	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011
39	0110	1001	0110	1001	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110
40	0000	0000	1111	1111	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000
41	0101	0101	1010	1010	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101
42	0011	0011	1100	1100	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011
43	0110	0110	1001	1001	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110
44	0000	1111	1111	0000	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111
45	0101	1010	1010	0101	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010
46	0011	1100	1100	0011	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100
47	0110	1001	1001	0110	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001
48	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111	0000	0000	0000	0000
49	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010	0101	0101	0101	0101
50	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100	0011	0011	0011	0011
51	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001	0110	0110	0110	0110
52	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000	0000	1111	0000	1111
53	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101	0101	1010	0101	1010
54	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011	0011	1100	0011	1100
55	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110	0110	1001	0110	1001
56	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000	0000	0000	1111	1111
57	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101	0101	0101	1010	1010
58	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011	0011	0011	1100	1100
59	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110	0110	0110	1001	1001
60	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111	0000	1111	1111	0000
61	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010	0101	1010	1010	0101
62	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100	0011	1100	1100	0011
63	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001	0110	1001	1001	0110

APPENDIX – C

Equipment of BSC & BTS

[1]

TYPICAL BSC FNE WITH 4 XCDR FRAMES & 1 MM		
	QTY	DESCRIPTION
1	4	TRANSCODER FRAME -48VDC
2	8	TRANSCODER CAGE COMMON EQUIP
3	38	NTW MULTI SERIAL INTERFACE 2
4	61	NTW HXCDR TRIMODE
5	50	ENHANCED GENERAL PROCESSOR
6	6	DOUBLE KILOPORT SWITCH CARD
7	72	DOUBLE KILOPORT SWITCH EXTENDR
8	24	PWR SUPPLY DIGITAL SHELF -48V
9	6	PWR CNVTR XCDR -48VDC
10	230	FIB OPT CBL 15M ST M
11	8	V.35 MODEM CARD
12	2	DATA SHLF 23SEG DC 19IN
13	1	PUMA MM R12000 W/2-WAY SMP
14	1	R10K TO R12K W/SMP UPG
15	1	PUMA MM HW/SW MANUAL CD
16	56	TYP 43 INTERCONNECT
17	4	SUN ULTRA MEMORY 256
18	2	CLOCK EXT CLKX
BSC ANE		
	QTY	DESCRIPTION
1	1	SYSTEM PKG 48V 600A CAB
2	4	ISH41A V.35M-DB25M 50FT
3	4	10M FIBER OPTIC CBL ST
4	7	XC ALARM TO TERMIN CABLE
5	3000	3002 CBL HS PER METER
6	300	BNC MALE FOR BT3002 CABLE
7	1	NULL MODEM ADAPTOR F-F
8	1	10BASE2 MAU BNC + SCREW
9	1	LTX-2 MAU THIN COAX XCVR
10	5	BNC T CONNECTOR F-M-F
11	5	ETHERNET TERMIN 50OHM
12	1	FIBER OPTIC MODEM
13	2	FIBER OPT CBL 430MM ST M
14	10	RECTIFIER 48V 50A ASCOM
15	1	DUAL FEED GMT FUSE PNL 19
16	2	EXPANSION RECTIFIER SHELF
17	8	CKT BKR 100A
18	4	CKT BKR 10A
19	300	#2 AWG BLACK PER FT
20	300	#2 AWG REDPER
21	280	2/0 BLACK MTW PER FT
22	280	2/0 RD MTW PER FT
23	150	500 MCM WELD BLK FT
24	70	#14 AWG BLK PER FT
25	70	#14 AWG RD PER FT
26	200	#6AWG RD PER FT
27	200	#6AWG BLK PER FT
28	25	LUG COMP #2 1HOLE 3/8

APPENDIX – C

Equipment of BSC & BTS

[Continued]

29	20	LUG COMP #6 2HOLE 1/4X5/8
30	21	LUG COMP 2/0 2HOLE 3/8X1
31	5	LUG COMP 500 2HOLE 1/2X175
32	3	LUG SAU70 14-4 W/HDWR PKG
33	200	#2AWG GRN PER FT
34	5	INSUL GND BAR W/#2 TAIL
35	25	3/8X1-1/4 STAINLESS N&B PK
36	10	CABLE TRAY GROUNDING CBL
37	20	WASHER FLAT NO. 10
38	20	NUT
39	20	SCREW COMBO HD 10-32X3/4
40	20	LOCKING WASHER
41	2	NO-OX-10 GREASE
42	75	3/8IN BOLT +ANCHOR PKG
43	75	3/8IN FLAT WASHR
44	0	EQ RK BLT 19X1.75X7F6IN DB
45	0	RK GND BAR 19INX1/4X1 COPR
46	0	INSULATOR PAD 19IN RACK
47	4	EQUIP SHELF 19IN FRNT MT
48	1	SCREW 12-24X5/8IN 100 PKG
49	1	MISC HARDWARE PER SITE
50	8	HARDWARE PKG
51	8	HARDWARE PKG FOR 1 GSM RCK
52	35	INSULATING BUSHING 3/8IN
53	7	CABLE TIES 5.6IN 100/WHITE
54	9	CABLE TIES 11.5IN 100/BLK
55	7	CABLE TIES 14.5 100/BLACK
56	18	HEAT SHRINK FOR #4 TO 3/0
57	7	LABEL ASSY RL154BR I154WH
58	6	SLOTTED WIRING DUCT 1X1X72
59	10	COVER FOR E SLOTTED TRAY-6
60	600	3002 SOCKET T43
61	200	U LINKS
62	200	BNC MALE FOR BT3002 CABLE
63	32	MINI DSX W/PANL & BALUNS
64	192	BNC CONNCTR MALE 75 OHM
TYPICAL BTS FNE FOR AN SC4812T 1C WITH 4xMCC24		
	QTY	DESCRIPTION
1	1	SC4812T 800/3 SEC BTS
2	3	800MHZ DBP BBX
3	2	SC4812T 800 LPA SET
4	3	DBPF
5	3	DPLXR DIR CPLR 800MHZ
6	1	4812 FRAME PACKAGING WOOD
7	1	HIGH STABILITY OSC
8	1	UNIVERSAL MTG BRACKET DDC
9	1	DOORS
10	4	MCC 24
11	1	GPS ANT 7/8IN LDF5 CBL
12		REQUIRED SOFTWARE LICENSES

APPENDIX – C

Equipment of BSC & BTS

[Continued]

BTS ANE		
	QTY	DESCRIPTION
1	1	SYSTEM PKG 24V 400A CAB
2	1	1055 AH Battery
3	109	2/0 BLK PER FT
4	109	2/0 RD PER FT
5	69	500 MCM BLK PER FT
6	7	LUG COMP 2/0 2HOLE 3/8X1
7	5	LUG COMP 500 2HOLE 1/2X175
8	100	#2AWG GRN PER FT
9	2	INSUL GND BAR W/#2 TAIL
10	25	3/8X1-1/4 STAINLESS N&B PK
11	24	LUG COMP #2 1HOLE 3/8
12	10	LUG COMP 6 1 HOLE 10-32
13	5	CABLE TRAY GROUNDING CBL
14	12	WASHER FLAT NO. 10
15	12	NUT
16	12	SCREW COMBO HD 10-32X3/4
17	12	LOCKING WASHER
18	1	NO-OX-10 GREASE
19	20	10 PAIR HINGED LABEL
20	2	10 PR DISC MODULE BX OF 10
21	4	5 MODULE POSITIONS
22	10	SUPPORT BARS
23	2	60WIRE SHLD HDR JCK 25FT
24	2	SPRCEL SPAN CABL 25FT W/CO
25	1	XCON WIRE 1PR #24 1000FT
26	1	CABLE TIES 14.5 100/BLACK
27	2	CABLE TIES 11.5IN 100/BLK
28	2	CABLE TIES 5.6IN 100/WHITE
29	14	INSULATING BUSHING 3/8IN
30	4	HARDWARE PKG FOR 1 GSM RCK
31	8	HARDWARE PKG
32	1	MISC HARDWARE PER SITE
33	16	3/8IN FLAT WASHR
34	16	3/8IN MNTG LAG BOLT PKG
35	1	UNIVERSAL THERMOSTAT GUARD
36	1	ATTIC FAN THERMOSTAT
37	2	LABEL ASSY RL154BR I154WH
38	1	MARKERS SOLID NUMBER 19MM
39	1	MARKERS SOLID NUMBER 19MM
40	1	MARKERS SOLID NUMBER 19MM
41	1	MARKERS SOLID NUMBER 19MM
42	1	MARKERS SOLID NUMBER 19MM
43	1	MARKERS SOLID NUMBER 19MM
44	1	MARKERS SOLID NUMBER 19MM
45	1	MARKERS SOLID NUMBER 19MM
46	1	MARKERS SOLID NUMBER 19MM
47	1	MARKERS SOLID NUMBER 19MM
48	1	INSULATOR PAD 19 RACK PKG

APPENDIX – C

Equipment of BSC & BTS
[Continued]

49	1	INSULATOR PAD 23IN PCK PKG
50	1	EQ RK BLT 19X1.75X7F6IN DB
51	1	VINYL CLOTH LABELS LETTERS
52	1	NUMBER VINYL LABELS
53	6	15DB 64 DG 820-960 DF
54	2	WAVEGUIDE ENTRY 12 PORT
55	12	WAVEGUIDE BOOT 4IN 7/8IN
56	90	1/2 IN SUPRFLEX COAX CBL
57	6	CON DM CPTV SS PLTE FSJ4
58	22	CON NM SLDR BS PLATE FSJ4
59	6	ARR QTRWAVE 806 1990 DF
60	500	7/8 IN FOAM COAX CABLE
61	8	HANGER PKG 7/8 IN TXLINE
62	8	ANGLE ADPTR IN METRIC SYS
63	8	HANGER HDW PKG 1IN LG
64	6	7/8IN LDF TX LINE 7/16
65	6	CONNECTOR WEATHERPROOFING
66	2	CABLE TIE 14.25IN 50/BLK
67	1	GPS ANT AND PRE AMP MODULE
68	1	MCXNCABLE W NPLUG MCX CONN
69	100	USE CGDSLDF450A
70	2	HANGER 1/2IN BOLT IN 10PK
71	2	HANGER HDW PKG 1IN LG
72	2	BOOT 4IN DIA 1/2IN AIR CBL
73	2	CONNECTOR WEATHERPROOFING
74	2	ANGLE ADPTR KIT 1/2"