بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Signal Fading in mobile Communication (CDMA)

خفوت الإشارة في الاتصالات النقالة لنظام التقسيم التشفيري لتعدد الوصولية

A Research Submitted in Partial fulfillment for the Requirements of the Degree of M.Sc. in Communication Engineering

Prepared By:

Mustafa Burai Mustafa

Supervised By:

Dr. Abdelrasool Gabar Elzibaidy

December 2010

بسم الله الرحمن الرحيم

قال تعالى :

{ قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي وَلَوْ جِئْنَا بِمِثْلِهِ مَدَدًا }

صدق الله العظيم
الكهف الآيات (108-109)

Dedication

TO:

MY FATHER

MY MOTHER

MY SISTERS

MY BROTHERS

MY TEACHERS

Acknowledgments

I pay my thanks for help, support and encouragement, to god firstly, who bless me in each step of my life.

To my father, who didn’t keep effort in pushing me toward successful.

To my teacher DR. Abdelrasoul Gabar, who kept on guiding and supervising, till the last step in my research.

At the last and not the least to every person who surround and help me, by words, deeds and even thoughts, to my friends and colleagues.

Abstract

In today's knowledge-based world, wireless communication plays an important role in economic growth and well-being of people. However, because of the undesirable effects of fading on wireless channel, the information transmission is being impaired. Hence, in order to achieve reliable and effective information transfer, an effective means of reducing the fading effect on wireless channel must be found. Signals can take different paths to the receiver. These multipaths thus take different amounts of time to get at the receiver and can cause problems at the receiver. Also large-scale path loss is a function of distance fading can be caused by a variety of circumstances, such as distance from the transmitter or shadowing from large objects like mountains.

This research discussed fading effects and the solutions of these effects in CDMA. Diversity technology has been observed as an effective means of mitigating the effect of fading. In this research, space transmission diversity technique and power control were studied and showed how these technique were applied to combat fading effect on wireless channel of CDMA technology.

مستخلص

في عالم اليوم ال قائم على المعرفة ، تلعب الاتصالات اللاسلكية دورا هاما في النمو الا قتصادي للمجتمع. ونسبة للآثار غير المرغوب بها للخفوت في ال قنوات اللاسلكية يحدث خلل في ن قل الصوت والمعلومات، وبالتالي من أجل تح قيق ن قل المعلومات بصورة موثو قة وفعالة لا بد من العثور على وسيلة فعالة لخفض أثر الخفوت على ال قناة اللاسلكية. الإشارات يمكن أن تتخذ مسارات مختلفة إلى المست قبل. هذه المسارات المتعددة تأخذ فترات مختلفة من الو قت للوصول الى المست قبل ويمكن أن يسبب هذا الاختلاف بعض المشاكل في المست قبل. أيضا ف قد المسار الواسع ينتج خفوت المسافة التي يمكن أن تسببها مجموعة متنوعة من الظروف ، مثل المسافة من جهاز الإرسال أو الحجب بواسطة الأجسام الكبيرة مثل الجبال.

هذا البحث ينا قش الآثار المترتبة على خفوت الإشارة في نظام الت قسيم التشفيري لتعدد الوصولية. فتعتبر ت قنية تعدد الوسط وسيلة فعالة لمعالجة مشكلة الخفوت في الإشارة. في هذا البحث تمت دراسة ت قنية تعدد وسط الانت قال و التحكم في الطا قة باعتبارها وسائل فعالة للتخفيف من تأثير الخفوت على ال قنوات اللاسلكية لنظام الت قسيم التشفيري لتعدد الوصولية.

Table of Contents

Content	Page No.
3.2.2 Frequency Diversity ……………………………………………...	(47)
3.2.3 Space Diversity ………………………………………………...	(48)
3.2.4 Rake Receiver ………………………………………………….	(50)
3.4 Power Control …………………………………………………….	(54)
3.4.1 Forward Power Control …………………………………………..	(54)
3.4.2 Reverse Power Control …………………………………………...	(55)
Chapter four: Simulation ……………………………………………….	(60)
Chapter five: Results and Discussion …………………………………..	(64)
Chapter six: Conclusion and Recommendation …………………………...	(66)
References ……………………………………………………………...	(69)
Appendices ……………………………………………………………..	(70)

List of Figures

List of Tables

Abbreviations

Abbreviation	Full Name
1G	First Generation Mobile Communications
2G	Second Generation Mobile Communications
3G	Third Generation Mobile Communications
4G	Fourth Generation Mobile Communications
A/D	Analog to Digital
Ac	Traffic carried
Al	Traffic lost
Ao	Traffic offered
AMPS	Advanced Mobile Phone System in the United States
AMTS	Advanced Mobile Telephone System
APGW	Access Point Gateway
ARP	Autoradiopuhelin, Car Radio Phone
ATM	Asynchronous Transfer Mode
BER	Bit Error Ratio
BPSK	Binary Phase Shift Keying
BS	Base Station
BSC	Base Station Controller
BSS	Base Station System
BTS	Base Transceiver Station
C/I	Carrier-to-Interference Ratio
CDMA	Code Division Multiple Access
CRC	Cyclic redundancy check
CSM	Center Switch Module
DSSS	Direct-Sequence Spread Spectrum

Abbreviation	Full Name
EDGE	Enhanced Data rates for GSM Evolution
EFR	Enhance Full Rate
EIRP	Effective Isotropic Radiation Power
EV-DO	Evolution Data Only
EVRC	Extended Variable Rate Coding
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple Access
FER	Frame Error Rate
FHSS	Frequency Hopping Spread Spectrum
FOMA	Freedom of Mobile Multimedia Access
FSL	Free Space Loss
FSPL	Free Space Pass Loss
GMSK	Gaussian Minimum Shift Keying
GoS	Grade of Service
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
HCMTS	High Capacity Mobile Telephone System
HDLC	High level data link control
HSDPA	High-Speed Downlink Packet Access
HSUPA	High-Speed Uplink Packet Access
I/O	Input / Output
IMSI	International Mobile Subscriber Identity
IMTS	Improved Mobile Telephone Service
IS-95	Industries Standared-95
Kbps	kilo-bits per second
LAWN	Local Area Walkup & Wireless Network
LTE	Long Term Evolution
LMSD	Legacy Mobile Station Domain
LOS	Line-of-Sight

Abbreviation	Full Name
MDN	Mobile Data Number
MIN	Mobile Station Identify Number
MS	Mobile Station
MSC	Mobile Switching Centre
MSS	Mobile Switching System
MTS	Mobile Telephone Switching
MTSO	Mobile Telephone System Office
NGN	Next Generation Network
NLOS	Non-Line of Sight
NMT	Nordic Mobile Telephone in Europe
PALM	Public Automated Land Mobile
PN	Pseudorandom Noise Code
PSN	Packet Switch Network
PSTN	Public Switched Telephone Network
PTT	Push-To-Talk
RF	Radio Frequency
SIM	Subscriber Identity Module
SMS	Short Message Service
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
T-R	Trans-Receive
UIM	User Identity Module
UMB	Ultra Mobile Broadband

Abbreviation	Full Name
UMTS	Universal Mobile Telecommunications System
VPN	Virtual Private Network
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WIDEN	Wideband Integrated Dispatch Enhanced Network
WIN	Wireless Intelligent Network

CHAPTER ONE

Introduction

Preface 1-1

The mobile radio channel places fundamental limitation on the performance of wireless communication systems. The transmission path between the transmitter and receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, mountains, and trees. Unlike wired channels that are stationary and predictable, radio channels are extremely random and do not offer easy analysis. Even the speed of motion impacts how rapidly the signal level fades as a mobile terminal moves in space.

Radio-wave propagation through wireless channels is a complicated phenomenon characterized by various effects, such as multipath and shadowing. A precise mathematical description of this phenomenon is either unknown or too complex for tractable communications systems analyses. Modeling the radio channel has historically been one of the most difficult parts of mobile radio system design. However, considerable efforts have been devoted to the statistical modeling and characterization of these different effects. The result is a range of relatively simple and accurate statistical models for fading channels which depend on the particular propagation environment and the underlying communication scenario.

The fading could be defined as rapid fluctuations of the amplitude of a radio signal over a short period of time or travel distance. Fading is caused by interference between two or more versions of transmitted signal, which arrives at the receiver at slightly different times. These multipath waves combine at the receiver antenna to give a resultant signal, which can vary in delay, in amplitude and phase.

Propagation in free space always like light (straight line).

Receiving power additionally influenced by:

- fading (frequency dependent)
- shadowing
- reflection at large obstacles
- scattering at small obstacles
- diffraction at edges

The major categories of fading are large scale fading and small scale fading.

The large scale fading is the loss that propagation models try to account for mostly dependant on the distance from the transmitter to the receiver also known as Large Scale Path Loss, Log-Normal Fading or Shadowing.

The small scale fading could be 20-30 dB over a fraction of a wavelength. It is caused by the superposition or cancellation of multipath propagation signals, the speed of the transmitter or receiver or the bandwidth of the transmitted signal. It is also known as Multipath.

1-2 Problems statements

Rapid changes in signal strength over a small distance or time interval. Also distance between transmitter and receiver cause reduce the received power.

1-3 Objectives

- Study fading effects.
- Investigate the parameters that affect the signal fading and the approaches to obtain accurate and optimum signal transmission.
- What are the multipath benefits.

1-4 Methodology

In the research the data and information about signal fading in mobile telecommunications taking the code division multiple access (CDMA) as a sample.

The research investigates the parameters that affect the signal fading and the approaches to obtain accurate and optimum signal transmission.

The multipath mechanism represented via simulation model by C++ program.

1-5 Research Outlines

Chapter 1: Introduction; this chapter is an introductory chapter, which also describes the aims of this project.

Chapter 2: Literature Review; this chapter gives a brief over view of the cellular network, Wireless Propagation Model and Evolution of Mobile Networks, also introduce CDMA.

Chapter 3: Case Study; Takes in-depth the Effects of Radio Frequency (RF) Propagation within the Work Place and IS95-A CDMA Modulation. Also fading solutions were discussed (diversity technology and power control).

Chapter 4: Simulation; The simulation using C++, the physical model and the program steps were discussed.

Chapter 5: Results and Discussion: this chapter discusses the results for the model that used in this project.

Chapter 6: Conclusion; Conclusion and summarizes the work in this research.

CHAPTER TWO

Cellular Network 2.1

A cellular network is a radio network made up of a number of radio cells (or just cells) each served by a fixed transmitter, known as a cell site or base station. These cells are used to cover different areas in order to provide radio coverage over a wider area than the area of one cell. Cellular networks are inherently asymmetric with a set of fixed main transceivers each serving a cell and a set of distributed (generally, but not always, mobile) transceivers which provide services to the network's users. Cellular networks offer a number of advantages over alternative solutions:

- increased capacity
- reduced power usage
- better coverage

A cellular network allows cellular subscribers to wander anywhere in the country and remain connected to the Public Switched Telephone Network (PSTN) via their mobile phones. A cellular network has a hierarchical structure and it is formed by connecting the major components mentioned below:

- Mobile phones - main piece of equipment as far as a subscriber is concerned

- Base Station(BS)
- Mobile Switching Centre(MSC)

2.1.1 Base Station(BS)

The base station serves a cell which could be a few kilometers in diameter as shown in figure 2.1 below.

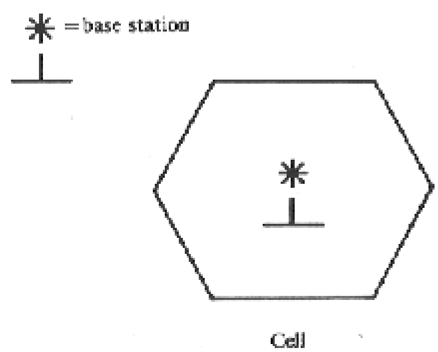


Figure 2.1; A base station area served.

The cells when grouped together form a cluster as shown in figure 2.2 below.

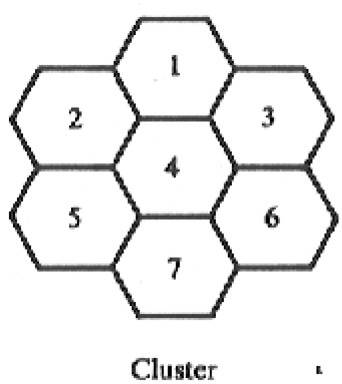


Figure 2.2; An example of a cluster.

All BSs within a cluster are connected to a Mobile Switching Centre (MSC) using land lines. Each MSC of a cluster is then connected to the MSC of other clusters and a PSTN main switching centre. This is shown in figure 2.3.

The MSC stores information about the subscribers located within the cluster and is responsible for directing calls to them.

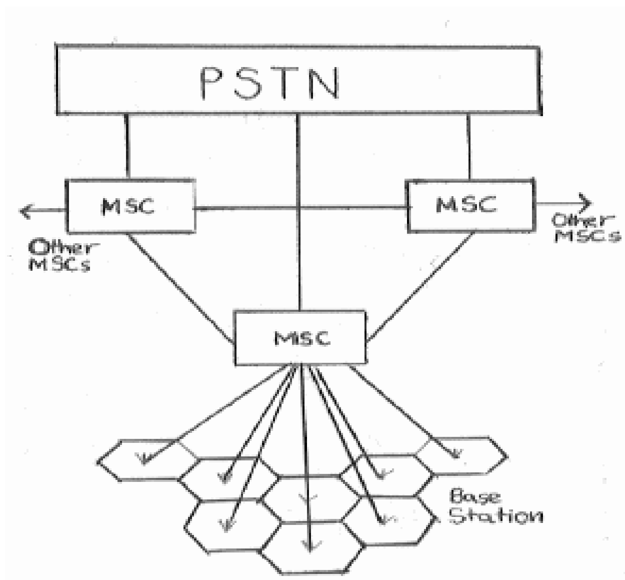


Figure 2.3; A sample of mobile network.

2.1.2 Cells and Clusters

The number of cells per cluster is restricted by the requirement that the clusters must fit together like jig-saw pieces. The possible cell clusters are the 4-,7-,12- and 21-cell clusters. Figure 2.4 below shows a 7-cell cluster which is commonly used.

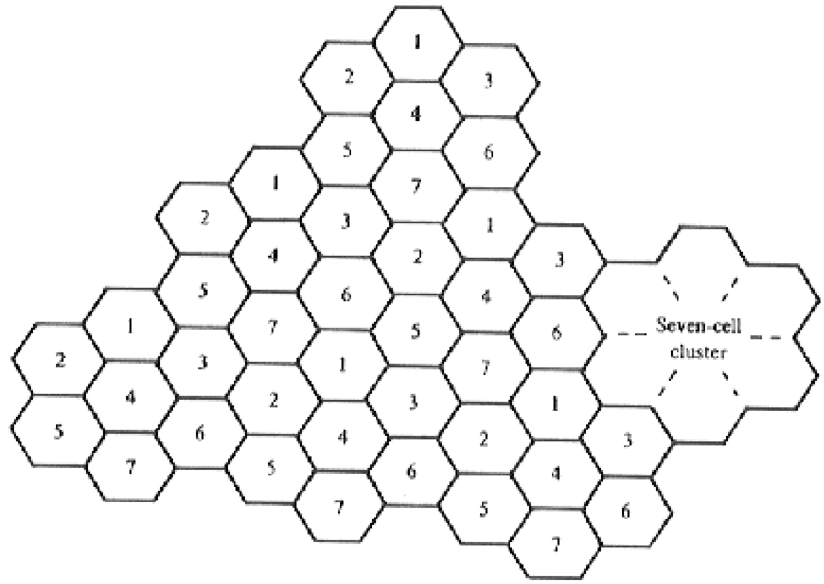


Figure 2.4: 7-cell cluster

Commonly in GSM the bandwidth made available for cellular networks ranges from 890 to 915MHz for base transmission and 935 to 960MHz for mobile transmission. All transmissions are made via channels. A channel consists of a pair of frequencies, one for each direction of transmission that is used for full-duplex operation. In the UK at 1992, the cellular networks had in total 1000 channels(300 allocated to Cellnet and another 300 allocated to Vodaphone, leaving 400 in reserve for pan-European system -GSM). This would suggest that fewer than 600 subscribers could access the system simultaneously when in fact the number of subscribers is in the range of millions. Research undertaken by Bell Labs has found a solution which involves re-using the same channel frequency in many different clusters. The cells in these different clusters using the same channel frequency must be separated far enough so that co-channel interference would not occur.

2.1.3 Cell : Shape and Size

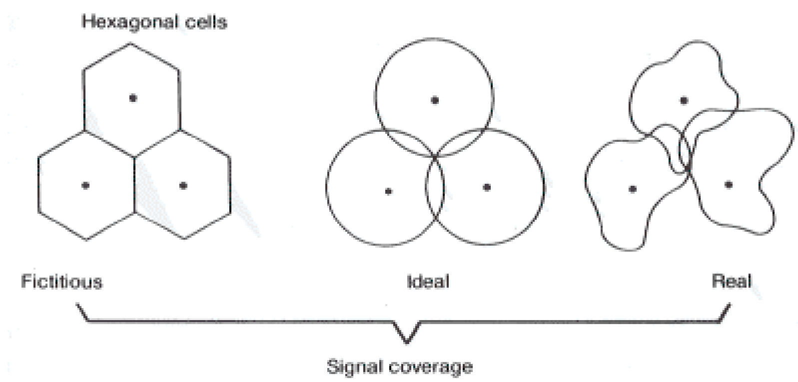


Figure 2.5; Cell shapes.

Hexagonal shaped cells shown in figure 2.5 are artificial and cannot be generated in the real world. However this shape is chosen to simplify planning and design of a cellular system as hexagons fit together without any overlap or gap in between them. Another advantage of using hexagons is that it approaches a circular shape which is the ideal power coverage area. The real cell shape is as shown above and its shape will keep changing due to prevailing conditions.

The size of the cell largely depends on the area in which the cell is located. Generally, rural areas have fewer subscribers compared to urban areas. So in an urban area more channels are needed to accommodate the larger number of subscribers. If each cell in a given rural and urban area had fixed number of channels, the cell size in the urban area would have to be smaller to allow more channels in the given area. Reducing the cell size would result in cells, using similar channel frequency, to be located closer to each other. Therefore reducing the size too much would cause an increase in co-channel interference.

Size of the cell can be varied by varying the power and sensitivity of the base station [1].

An alternative way to change the size of the cell is to split the cell. This involves reducing the radius of a cell by half and splitting an old cell into four small cells as shown in figure 2.6 below.

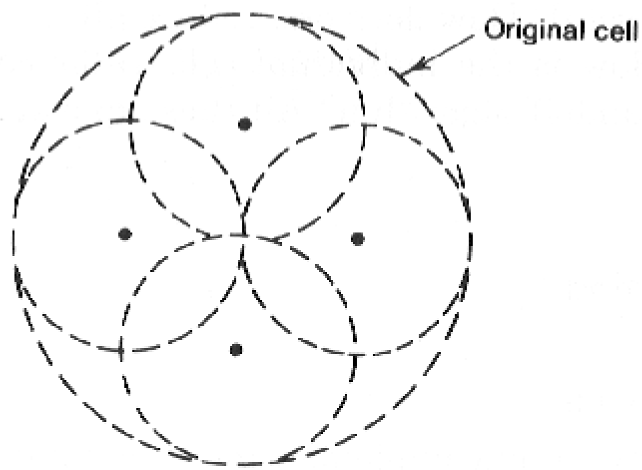


Figure 2.6:Cell splitting.

2.2 Wireless Propagation Model

Mechanisms of electromagnetic wave propagation are diverse, but in general the electromagnetic waves can be propagated via reflection, diffraction and scattering. The majority of cellular wireless systems operate in urban areas where there is no LOS path between the transmitter and the receiver and the high-rises cause strong diffraction loss. Besides, as there are multiple paths of propagation via different materials and the paths have varying lengths; electromagnetic waves propagated along such paths interact with each other and cause multi-path loss, and as the distance between the transmitter and the receiver increases, the electromagnetic intensity decreases.

Traditionally, research on the propagation model focuses on predicting the mean receiving field intensity within a given area and the fluctuation of the field intensity. The propagation model for predicting the mean field intensity and estimating the wireless coverage is called large-metric propagation model due to the fact that it deals with the intensity fluctuation over a long distance (of several hundred or several thousand meters) between the transmitter and the receiver (T-R). The propagation model for predicting the rapid fluctuation of the receiving field intensity over a short distance (of several wave lengths) or a short period of time (in seconds) is called the small-metric attenuation model.

When the mobile station moves within an extremely small area, it may cause rapid fluctuation in the instant receiving field intensity, which is called small-metric attenuation. The reason is that the phase changes in random, which in turn causes synthesization of received signals from different directions to fluctuate greatly. For the small-metric attenuation, the receiving field intensity may change in 3 or 4 levels (30dB or 40dB) if length of the mobile station movement equals the wave length. As the mobile station moves away from the transmitter and the local field intensity decreases, the mean receiving field intensity shall be predicted by applying the large-metric propagation model. Typically, the local field intensity is calculated with the mean value of signal measurements within 5λ- 40λ. For the cellular system with a frequency range between 1 GHz and 2 GHz, the measuring range shall be between 1m and 10m.

Error: Reference source not found shows the rapid small-metric attenuation and slow large-metric fluctuation of wireless communication system.

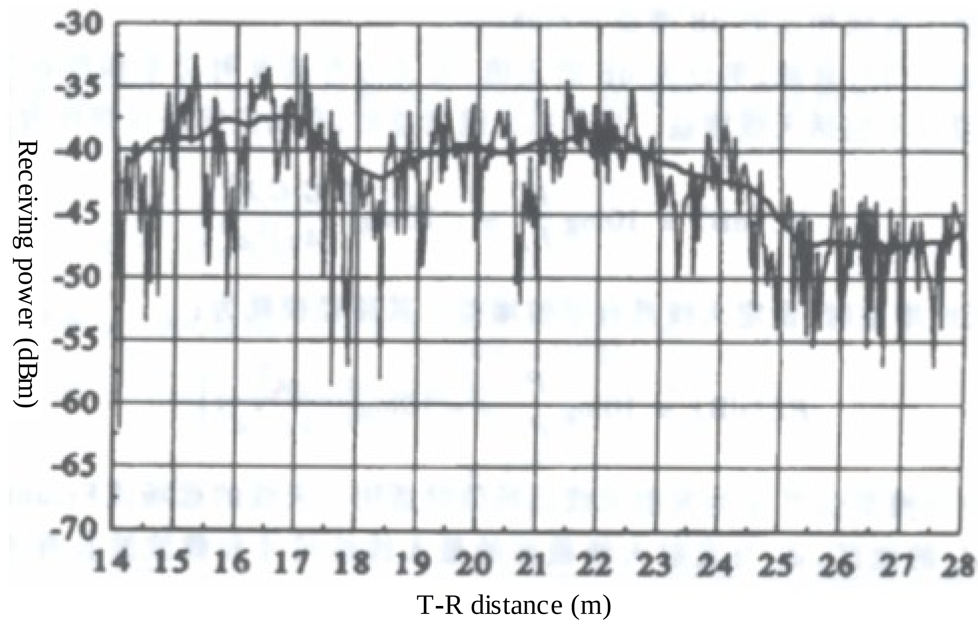


Fig. 2.7 Small-Metric Attenuation and Large-Metric Fluctuation

2.2.1 Free Space Propagation

The free space propagation model is used for predicting the receiving field intensity between the transmitter and the receiver where there are completely free LOS paths. Satellite communication and microwave wireless LOS link have typical free space propagation. Similar to the majority of large-metric radio wave propagation models, the free space propagation model predicts that attenuation of the receiving power is a function of the T-R distance (an idempotent function). The receiving power of the antenna in free space at a distance d from the transmitter is as shown by the Friis formula:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

(2.1)

Where P_t is the transmitting power; $P_r(d)$ is the receiving power, a function of the T-R distance; G_t is the gain of the transmitting antenna; G_r is the gain of the receiving antenna; d, in meters, is the T-R distance; L is the system loss factor which is independent of propagation; λ, in meters, is the wave length.

The antenna gain is subject to the effective section area of the antenna:

$$G = \frac{4\pi A_e}{\lambda^2}$$

(2.2)

The effective section area A_e is related to the physical dimensions of the antenna, while λ is related to the carrier:

$$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$$

(2.3)

Where f, in Hz, is the carrier frequency; ω_c, in rad/s, is the carrier; and c, in m/s, is the light speed. P_t and P_r shall have the same unit, and G_t and G_r are dimensionless values. Aggregate loss L ($L \geq 1$) is, typically, the total of transmitting line attenuation, filter loss and antenna loss. L = 1 indicates that the system hardware has no loss.

As revealed in Formula (2.1), the receiving power decreases with the square of the T-R distance. That is, the ratio of the attenuation of the receiving power to the T-R distance is 20dB/10 octave.

The ideal omni-antenna that has the same unit gain in all directions is usually used as the reference antenna of the wireless communication system. The effective omni-directional radiation power (EIRP) is defined as:

$$EIRP = P_t G_t$$

(2.4)

which is the maximum radiation power of the transmitter in the direction of maximum antenna gain as compared with the omni-antenna.

But in practice, the effective radiation power (ERP) usually replaces EIRP to indicate the maximum radiation power as against the half-wave bipolarized sub-antenna. As the bipolarized sub-antenna has 1.64 units of gain (which is 2.15dB higher the omni-antenna), ERP is 2.15dB lower than EIRP for the same transmission system. In effect, the antenna gain is in dBi (the gain in dB against the ideal zero-point omni-antenna) or in dBd (the gain in dB against the half-wave bipolarized sub-antenna).

The path loss, a positive value in dB indicating signal attenuation, is defined as the difference between the effective transmitting power and the receiving power, including or excluding the antenna gain. If the antenna gain is included, the free space path loss is:

$$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left[\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right]$$

(2.5)

If the antenna gain is excluded and it has the unit gain, hence the path loss:

$$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left[\frac{\lambda^2}{(4\pi)^2 d^2}\right]$$

(2.6)

Derived from equation (2.6):

$$\begin{aligned} PL(dB) &= 32.45dB + 20\log d_{km} + 20\log f_{MHz} \\ &= 36.58dB + 20\log d_{mi} + 20\log f_{MHz} \end{aligned}$$

(2.7)

The Friis free space propagation model applies if and only if d indicates the value of the far field of the transmitting antenna. The far field of the antenna is defined as the area beyond d_f, the far field distance that is related to the maximum linear dimensions of the transmitting antenna and the length of the carrier.

$$d_f = 2D^2/\lambda$$

(2.8)

Where D is the maximum physical dimension of the antenna. Also, for the far field, d_f shall meet the condition:

$$d_f >> D$$

(2.9)

and

$$d_f >> \lambda$$

(2.10)

Obviously, equation (2.1) does not allow d = 0. Therefore, the large-metric propagation model uses the near distance d_0 as the reference value of the receiving power. When $d > d_0$, the receiving power $P_r(d)$ is related to P_r at the distance d_0. $P_r(d_0)$ can be predicted from the equation (2.1) or derived from the mean measurement. The reference distance must be in the far field, i.e., $d_0 \geq d_f$, where d_0 is smaller than the actual distance applied in the mobile communication system. Hence, derived from equation (2.1) in the distance beyond d_0, the receiving power in the free space:

$$P_r(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^2 \qquad d \geq d_0 \geq d_f$$

(2.11)

In the wireless mobile system, it is common for P_r to have changes of several quantity levels within the typical coverage area of several square km. As the receiving level varies violently, it is usually represented in dBm or dBW. The equation (2.11) can have dBm or dBW as the unit, if both ends of the equation is multiplied by 10. For example, if P_r is in dBm, hence the receiving power:

$$P_r(d)dBm = 10\log\left[\frac{P_r(d_0)}{0.001W}\right] + 20\log\left(\frac{d_0}{d}\right) \qquad d \ge d_0 \ge d_f$$

(2.12)

Where $P_r(d_0)$ is in watts [5].

2.2.2Three Basic Propagation Mechanisms

In mobile communication, there are three basic mechanisms that affect propagation: reflection, diffraction and scattering. The receiving power (or its opposite: the path loss) is the most important parameter that the reflection, diffraction and scattering-based large-metric propagation model predicts. The three mechanisms also describe the small-metric attenuation and multi-path propagation.

When the electromagnetic wave encounters materials such as the earth surface, buildings, and building walls that have a much longer wave length, reflection occurs, as shown in Fig. 2.8.

When the wireless link between the transmitter and the receiver is blocked by sharp edges, diffraction occurs. The resulting secondary waves are diffracted in the space, even to the back of the barrier. Even if there exist no LOS path between the transmitter and the receiver, wave bending can also occur around the barrier. In the high frequency band, diffraction, just as reflection, is subject to the shape of the barrier as well as the incident wave amplitude at the diffraction point, its phase, and polarization, as shown in Fig. 2.9.

When the transmitting medium of the electromagnetic wave has materials smaller than the wave length and the quantity in the unit volume is prodigious, scattering occurs. The scattering wave is produced on the rugged surface, small materials and other things with irregular shapes. In the actual communication system, leaves, the street signs and light posts all cause scattering. Scattering is as shown in Fig. 2.9.

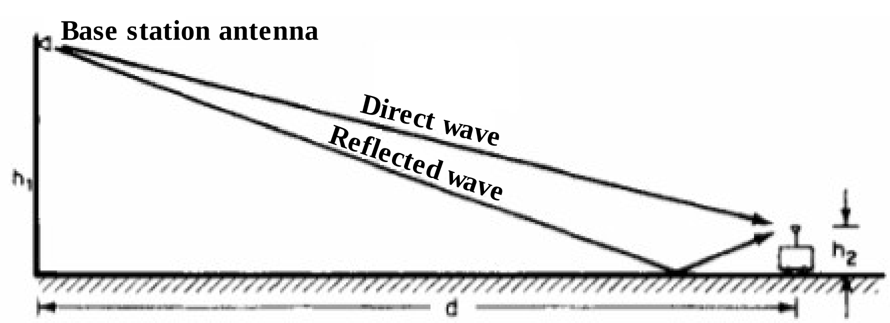


Fig. 2.8; Direct Wave and Wave Reflection

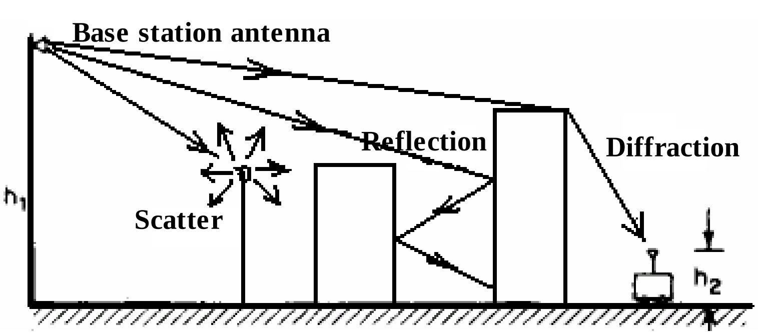


Fig. 2.9; Reflection, Diffraction and Scattering in Wave Propagation

As shown in Fig. 2.8 and Fig. 2.9, if the base station is installed high and it is an open area without blocking, signals received by the mobile station are mainly the superposition of direct waves and reflected waves; but in the urban area with densely planted high-rises and severe blocking, few direct waves can reach the mobile station, and in most cases, the signals received are the superposition of reflected waves, diffracted waves and scattered waves.

2.3 Evolution of Mobile Networks

Mobile wireless network is the very good example as a cellular network; the industry of it has started its technology creation, revolution and evolution since early 1970s. In the past few decades, mobile wireless technologies have experience 4 or 5 generations of technology revolution and evolution, namely from 0G to 4G. The cellular concept was introduced in the 1G technology which made the large scale mobile wireless communication possible. Digital communication has replaced the analogy technology in the 2G which significantly improved the wireless communication quality. Data communication, in addition to the voice communication, has been the main focus in the 3G technologies and a converged network for both voice and data communication is emerging.

There are many killer application opportunities for the 4G as well as technological challenges .The key technologies and protocols used in each generation of the mobile wireless communications in table 2.1 below.

Table 2.1 Mobile Network Evolution

Mobile Generat-ion	**Standard Systems & protocols**	**Description**

0G	PTT,MTS, IMTS:AMTS	0G refers to pre-cellular mobile telephony technology in 1970s. These mobile telephones were usually mounted in cars or trucks, though briefcase models were also made.
0.5G	PALM, ARP, HCMTS	0.5G is a group of technologies with improved feature than the basic 0G technologies.
1G	NMT,AMPS, TACS,JTAGS	1G (or 1-G) is the first-generation wireless telephone technology, cell phones. These are the analog cell phone standards that were introduced in the 1980s.all the first generation systems used Frequency Modulation (FM) for speech and Frequency Shift keying (FSK) for signaling, and the access technique used was Frequency Division Multiple Access (FDMA).
2G	GSM, IDEN, D-AMPS, CDMAOne PDC	2G (or 2-G) is the second-generation wireless telephone, which is based on digital technologies. 2G networks is basically for voice communications only, except SMS messaging is also available as a form of data transmission for some standards. Time Division Multiple Access (TDMA) is used as the access technique, except for IS-95, which is based on Code Division Multiple Access (CDMA).These systems provide Digital speech and short message services.
2.5G	GPRS, WIDEN	2.5G is a group of bridging technologies between 2G and 3G wireless communication. It is a digital communication allowing e-mail and simple Web browsing, in addition to voice.
2.75G	CDMA2000, EDGE	2.75G refer to the technologies which don't meet the 3G requirements but are marketed as if they do.
3G	WCDMA: UMTS: FOMA: CDMA2000 1xEV: TD-SCDMA:	3G stand for the third generation of wireless communication technologies, which support broadband voice, data and multi-media communications over wireless networks. It's employed via Universal Wireless Personal Communications (UWPC) systems, that implemented worldwide by the International Telecommunication Union (ITU) within the Framework of the Public Land Mobile Telecommunication Systems(FPLMTS)/International Mobile Telecommunication-2000(IMT-2000) activated in Europe, and supported by the Universal Mobile Telecommunications System (UMTS) program.
3.5G	HSDPA	The 3.5G generally refer to the technologies beyond the well defined 3G wireless/mobile technologies.
3.75G	HSUPA	The 3.75G refer to the technologies beyond the well defined 3G wireless/mobile technologies.
4G	LTE,UMB	4G is the name of technologies for high-speed mobile wireless communications designed for new data services and interactive TV through mobile network

2.4 Code Division Multiple Access (CDMA)

CDMA is the acronym for Code Division Multiple Access. All CDMA users use the same band, and the users and base stations are differentiated with encryption of various bit lengths, which provides enhanced privacy; meanwhile, as a result of all users using the same band, self-interference between users is produced, which increases as users multiply, and demodulation of the system is affected, which limits the reverse capacity of the system.

The original intention of CDMA technologies development was to protect communication from interference and interception by the enemy, and the CDMA technologies were first applied in military anti-interference communication. Due to some unsolved technological issues, CDMA technologies were not widely applied for commercial purposes until 1980s, when Qualcomm developed the soft switching, power control and other technologies. Since then, the CDMA technologies entered the civil market. In 1993, the CDMA technologies developed by Qualcomm were officially recognized as technical standard. Following this, the CDMA commercial system, based on IS95 and 1X, was widely used throughout the world and mainly in South Korea, Hong Kong, U.S.A, and Australia. Last year, EVDO of CDMA2000, which is one of the 3G technical standards, was put into large-scale commercial use in South Korea and also in Sudan.

CDMA technologies are different from FDMA (Frequency Division Multiple Access, as applied in GSM) and TDMA (Time Division Multiple Access, as applied in AMPS and TACS). FDMA technologies differentiate users by having them use different bands, whereas TDMA technologies differentiate users by having them use different time slots, as illustrated in figure 2.10:

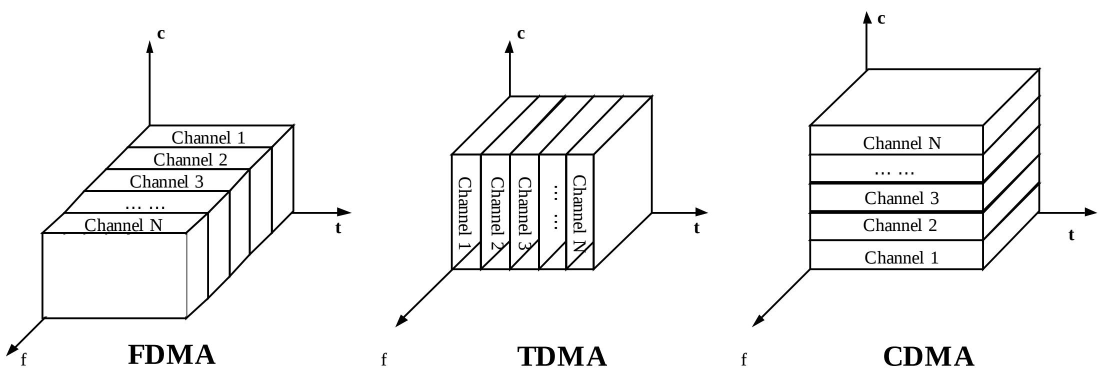


Fig. 2.10 Difference Among FDMA, TDMA and CDMA

One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. This allows several users to share a bandwidth of different frequencies. This concept is called multiplexing. CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel. By contrast, time division multiple access (TDMA) divides access by time, while frequency-division multiple access (FDMA) divides it by frequency. CDMA is a form of "spread-spectrum" signaling, since the modulated coded signal has a much higher data bandwidth than the data being communicated.

An analogy to the problem of multiple access is a room (channel) in which people wish to communicate with each other. To avoid confusion, people could take turns speaking (time division), speak at different pitches (frequency division), or speak in different languages (code division). CDMA is analogous to the last example where people speaking the same language can understand each other, but not other people. Similarly, in radio CDMA, each group of users is given a shared code. Many codes occupy the same channel, but only users associated with a particular code can understand each other.

2.4.1 Coding

CDMA uses unique spreading codes to spread the baseband data before transmission. The signal is transmitted in a channel, which is below noise level. The receiver then uses a correlator to despread the wanted signal, which is passed through a narrow bandpass filter. Unwanted signals will not be despread and will not pass through the filter. Codes take the form of a carefully designed one/zero sequence produced at a much higher rate than that of the baseband data. The rate of a spreading code is referred to as chip rate rather than bit rate. Figure 2.11 shows CDMA spreading.

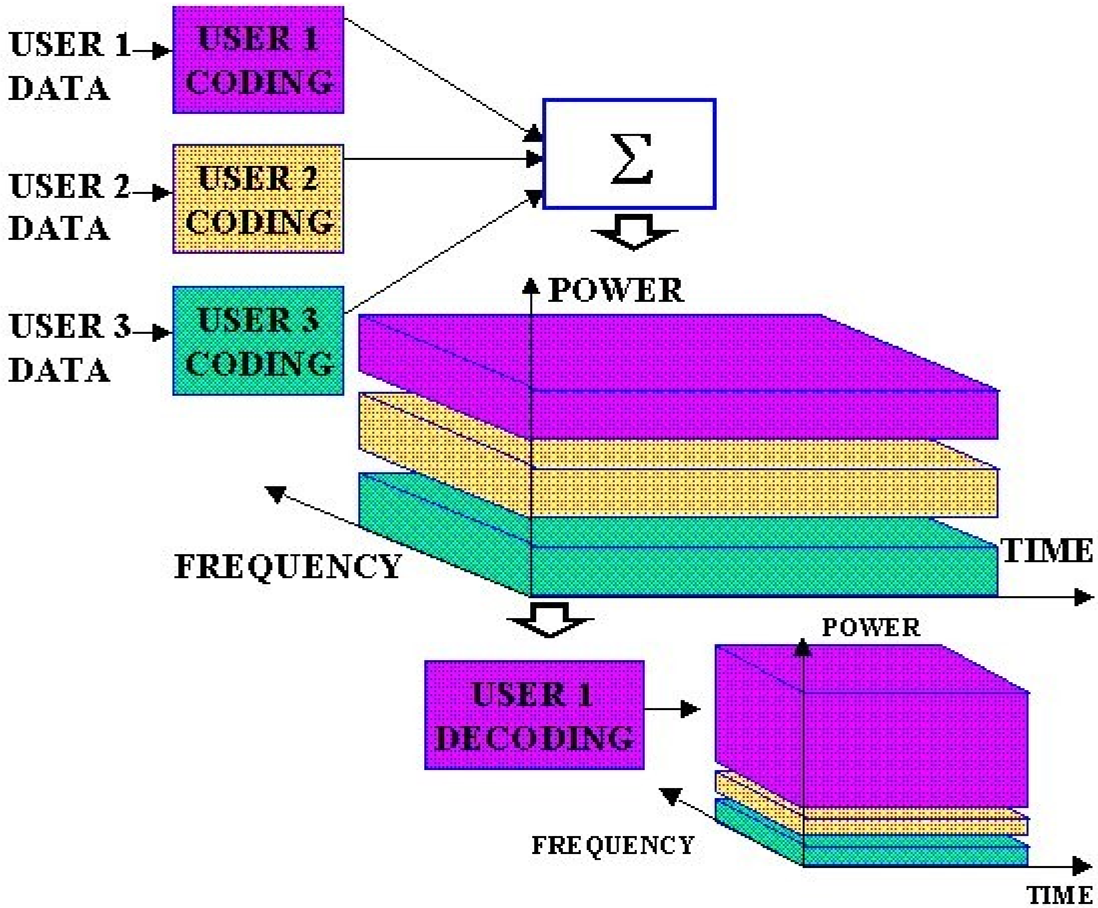


Figure 2.11; CDMA spreading

CDMA codes are not required to provide call security, but create a uniqueness to enable call identification. Codes should not correlate to other codes or time shifted version of itself. Spreading codes are noise like pseudo-random codes, channel codes are designed for maximum separation from each other and cell identification codes are balanced not to correlate to other codes of itself.

2.4.2 The Spreading Process

CDMA is a spread spectrum multiple access technique. A spread spectrum technique is one which spreads the bandwidth of the data uniformly for the same transmitted power. Figure 2.12 shows CDMA spreading signal.

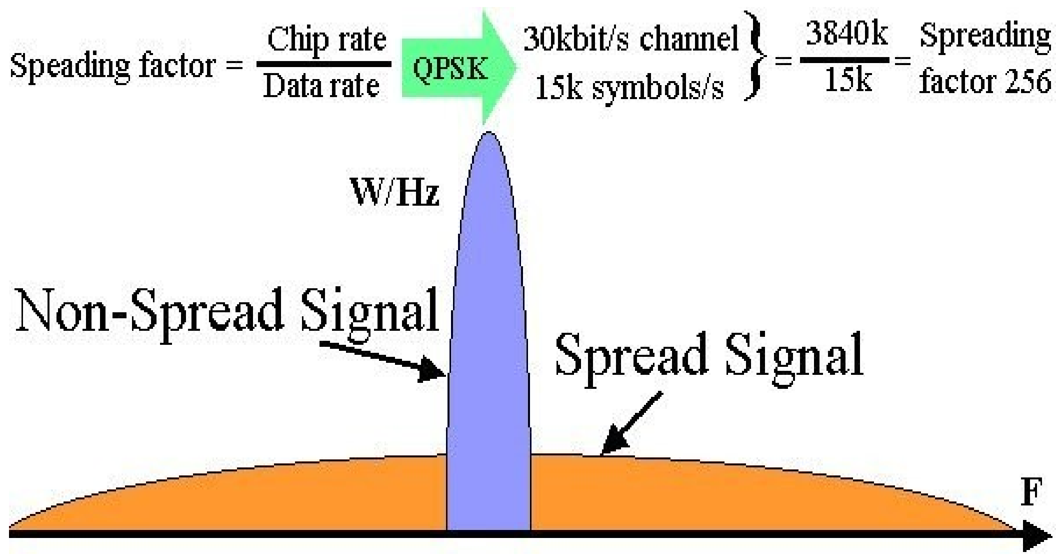


Figure 2.12; CDMA spreading signal

Spreading code is a pseudo-random code which has a narrow Ambiguity function unlike other narrow pulse codes. In CDMA a locally generated code runs at a much higher rate than the data to be transmitted. Data for transmission is simply logically XOR (exclusive OR) added with the faster code. Figure 2.13 shows how spread spectrum signal is generated. The data signal with pulse duration of T_b is XOR added with the code signal with pulse duration of T_c. (Note: bandwidth is proportional to 1 / T where T = bit time) Therefore, the bandwidth of the data signal is $1 / T_b$ and the bandwidth of the spread spectrum signal is $1 / T_c$. Since T_c is much smaller than T_b, the bandwidth of the spread spectrum signal is much larger than the bandwidth of the original signal. The ratio T_b / T_c is called spreading factor or processing gain and determines to certain extent the upper limit of total number of users supported simultaneously by a base station.

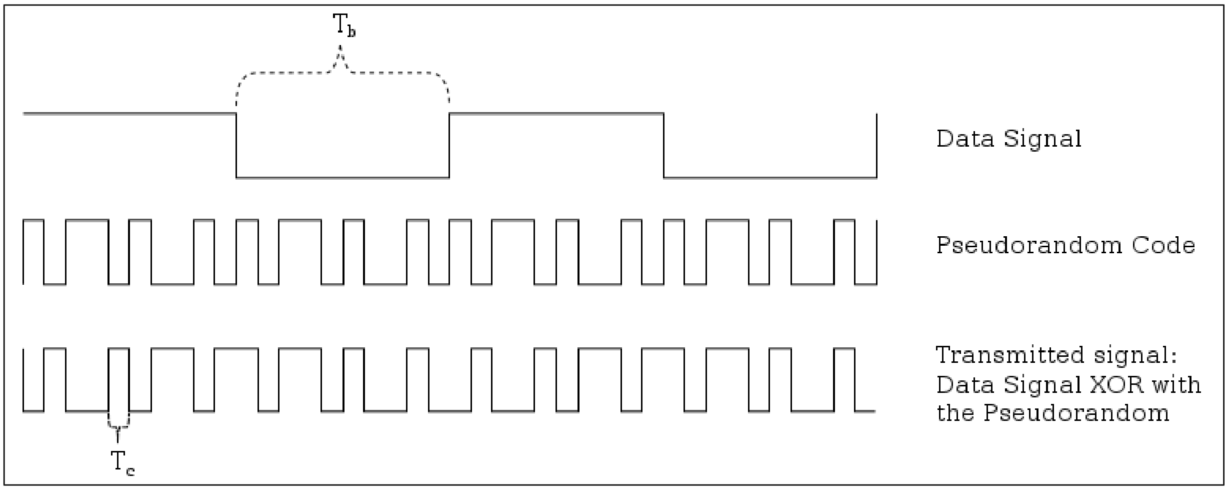


Figure 2.13; Spread spectrum signal generation.

Each user in a CDMA system uses a different code to modulate their signal. Choosing the codes used to modulate the signal is very important in the performance of CDMA systems. The best performance will occur when there is good separation between the signal of a desired user and the signals of other users.

The separation of the signals is made by correlating the received signal with the locally generated code of the desired user. If the signal matches the desired user's code then the correlation function will be high and the system can extract that signal. If the desired user's code has nothing in common with the signal the correlation should be as close to zero as possible (thus eliminating the signal); this is referred to as cross correlation. If the code is correlated with the signal at any time offset other than zero, the correlation should be as close to zero as possible. This is referred to as auto-correlation and is used to reject multi-path interference [8].

2.5 Spread Spectrum Characteristics of CDMA

Most modulation schemes try to minimize the bandwidth of this signal since bandwidth is a limited resource. However, spread spectrum techniques use a transmission bandwidth that is several orders of magnitude greater than the minimum required signal bandwidth. One of the initial reasons for doing this was military applications including guidance and communication systems. These systems were designed using spread spectrum because of its security and resistance to jamming. Asynchronous CDMA has some level of privacy built in because the signal is spread using a pseudorandom code; this code makes the spread spectrum signals appear random or have noise-like properties. A receiver cannot demodulate this transmission without knowledge of the pseudorandom sequence used to encode the data. CDMA is also resistant to jamming. A jamming signal only has a finite amount of power available to jam the signal. The jammer can either spread its energy over the entire bandwidth of the signal or jam only part of the entire signal.

CDMA can also effectively reject narrowband interference. Since narrowband interference affects only a small portion of the spread spectrum signal, it can easily be removed through notch filtering without much loss of information. Convolution encoding and interleaving can be used to assist in recovering this lost data. CDMA signals are also resistant to multipath fading. Since the spread spectrum signal occupies a large bandwidth only a small portion of this will undergo fading due to multipath at any given time. Like the narrowband interference this will result in only a small loss of data and can be overcome.

Frequency reuse is the ability to reuse the same radio channel frequency at other cell sites within a cellular system. In the FDMA and TDMA systems frequency planning is an important consideration. The frequencies used in different cells need to be planned carefully in order to ensure that the signals from different cells do not interfere with each other. In a CDMA system the same frequency can be used in every cell because channelization is done using the pseudorandom codes. Reusing the same frequency in every cell eliminates the need for frequency planning in a CDMA system; however, planning of the different pseudorandom sequences must be done to ensure that the received signal from one cell does not correlate with the signal from a nearby cell.

Since adjacent cells use the same frequencies, CDMA systems have the ability to perform soft handoffs. Soft handoffs allow the mobile telephone to communicate simultaneously with two or more cells. The best signal quality is selected until the handoff is complete. This is different from hard handoffs utilized in other cellular systems. In a hard handoff situation, as the mobile telephone approaches a handoff, signal strength may vary abruptly. In contrast, CDMA systems use the soft handoff, which is undetectable and provides a more reliable and higher quality signal.

CHAPTER THREE

3.1 The Effects of (RF) Propagation

Receiving a strong uninterrupted cellular signal is very hard to achieve, due to various multipath signal distortions. Indoors is where there is a large amount of interruptions which are caused by different multipath signals and free space loss (FSL). Within Multipath signals there are four physical modes: attenuation, reflections, diffractions, and scattering. These modes all achieve the same thing, meaning interrupting the path of a signal; but work in different ways.

3.1.1 Radio Propagation

RF propagation is a term used to explain how radio waves behave when they are transmitted, or are propagated from one point on the earth to another .Radio propagation is measured in decibels (dB) high, which is the standard. A decibel is a logarithmic measurement that reflects the tremendous range of sound intensity our ears can perceive of loudness [1].

RF propagation would ideally operate in a so-called "free space." Meaning every signal would leave a transmitter, and spread in all directions and successfully arrive without interruption to its intended target. In real world terms this "free space" theory is nearly impossible. What regularly occurs is free-space path loss (FSPL). This involves the strength loss of a signal or wave through a direct path. On a direct path realistically, a signal can be disrupted by objects and obstacles.

The ionosphere has a great impact on how radio signals propagate all over the earth; it is located in the top part of the atmosphere; and is ionized by solar radiation. Radio signals use the ionosphere to reflect transmitted signals back down to earth to arrive at its intended receiver. This signal can also be reflected back to the ionosphere in the same pattern. This allows radio communication to distances of many thousands of kilometers. The ionosphere plays a major role in radio propagation. Sometimes the ionosphere can be disturbed as it reacts to certain types of solar activity, particularly solar flares. "A solar flare is a sudden energy release in the solar atmosphere from which electromagnetic radiation and, sometimes, energetic particles and bulk plasma are emitted (Britannica.com)." This can interrupt the signal that is being reflected back down to earth to the receiver. Geomagnetic storms can also cause fading in the signal and cause scatter. A geomagnetic storm is a temporary disturbance of the earth's magnetosphere (a region that surrounds the earth) caused by a disturbance in space weather [8].

A geomagnetic Storm can last several days and the effects from the storm can linger in the ionosphere for one to two days. Figure 3.1 below shows a picture of a geomagnetic storm, this picture was taken at night.

Figure 3.1; Example of Geomagnetic Storm

Outdoors there are high amounts of multipath signals, due to more than one signal being transmitted. Indoors is where the amount of multipath signals is less predictable. Building structures are the main issue. It's nearly impossible to create an RF friendly building. For example even if a structure is built out of all wood still hard floors would be needed to support each floor with in the structure. Also location would be a huge factor; example most likely there is not a heavily wooded area anywhere. Not only would all the foliage be a problem but also the design of the building would be carefully considered. Buildings that may have areas that are underground or have walls made of metal can really harm the RF signal, causing a dead spot. A Dead spot is an area within a structure "for example" an office building. Where destructive waves interfere to such an extent that little to no radio signals can be received in the specific place. Dead spots are present in three dimensional spaces within a building and motions within only a few inches can move from no signal to full signal. This makes receiving or gaining reception on the cell phone difficult.

3.1.2 Free space propagation

In free space, all electromagnetic waves (radio, light, X-rays, etc) obey the inverse-square law which states that the power density of an electromagnetic wave is proportional to the inverse of the square of the distance from the source or:

$$\rho_P \propto \frac{1}{r^2}.$$

(3.1)

Where ρ_P the power density and r is is the distance.

Doubling the distance from a transmitter means that the power density of the radiated wave at that new location is reduced to one-quarter of its previous value.

The power density per surface unit is proportional to the product of the electric and magnetic field strengths. Thus, doubling the propagation path distance from the transmitter reduces each of their received field strengths over a free-space path by one-half. Table 3.1 below shows the radio frequencies and their primary mode of propagation [1].

Table 3.1; Radio frequencies and their primary mode of propagation

Band	Frequency Range	Wavelength Range	Propagation Media
Very Low Frequency	3–30 kHz	100–10 km	Guided between the earth and the ionosphere.
Low Frequency	30–300 kHz	10–1 km	Guided between the earth and the D layer of the ionosphere. Surface waves.
Medium Frequency	300–3000 kHz	1000–100 m	Surface waves. E, F layer ionospheric refraction at night, when D layer absorption

			weakens.
High Frequency (Short Wave)	3–30 MHz	100–10 m	E layer ionospheric refraction. F1, F2 layer ionospheric refraction.
Very High Frequency	30–300 MHz	10–1 m	Infrequent E ionospheric refraction. Extremely rare F1,F2 layer ionospheric refraction during high sunspot activity up to 80 MHz. Generally direct wave. Sometimes tropospheric ducting.
Ultra High Frequency	300–3000 MHz	100–10 cm	Direct wave. Sometimes tropospheric ducting.
Super High Frequency	3–30 GHz	10–1 cm	Direct wave.
Extremely High Frequency	30–300 GHz	10–1 mm	Direct wave limited by absorption.

Lower frequencies (between 30 and 3,000 kHz) have the property of following the curvature of the earth via ground wave propagation in the majority of occurrences.

In this mode the radio wave propagates by interacting with the semi-conductive surface of the earth. The wave clings to the surface and thus follows the curvature of the earth. Vertical polarization is used to alleviate short circuiting the electric field through the conductivity of the ground. Since the ground is not a perfect electrical conductor, ground waves are attenuated rapidly as they follow the earth's surface. Attenuation is proportional to the frequency making this mode mainly useful for LF and VLF frequencies.

Today LF and VLF are mostly used for time signals, and for military communications, especially with ships and submarines. Early commercial and professional radio services relied exclusively on long wave, low frequencies and ground-wave propagation. To prevent interference with these services, amateur and experimental transmitters were restricted to the higher (HF) frequencies, felt to be useless since their ground-wave range was limited. Upon discovery of the other propagation modes possible at medium wave and short wave frequencies, the advantages of HF for commercial and military purposes became apparent. Amateur experimentation was then confined only to authorized frequency segments in the range.

Line-of-sight is the direct propagation of radio waves between antennas that are visible to each other. This is probably the most common of the radio propagation modes at VHF and higher frequencies. Because radio signals can travel through many non-metallic objects, radio can be picked up through walls. This is still line-of-sight propagation. Examples would include propagation between a satellite and a ground antenna or reception of television signals from a local TV transmitter.

3.1.3 Multipath Signals

3.1.3a Attenuation

Attenuation absorbs radio waves and decreases signal strength. The amount of absorption in attenuation will depend on the size of an object. Thickness in an object can also aid in the loss of a signal. The amount of absorption will depend on the structure of the object; metal for this very reason is a great absorber of signals and waves. Attenuation is also measured in dB high. Figure 3.2 below shows an example of attenuation. Two signals are transmitted. They both go straight to the ionosphere, to then be reflected back down to earth. As you can see the signal on top reached the transmitter, but the one on the bottom did not. This happened because so much frequency was absorbed in the ionosphere for the bottom signal that it became usable [2].

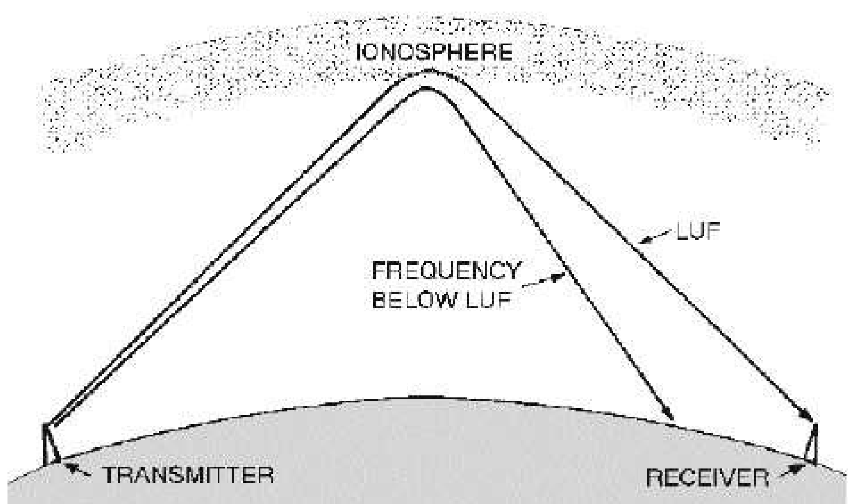


Figure 3.2; Example of Attenuation

3.1.3b Scattering

Scatter is another mode in multipath distortion. This occurs when there is more than one object in a single pathway. The objects are smaller in size when compared to the signal wavelength. Then the propagated wave front will break apart into many directions, creating scatter. “For example” Foliage—trees and leaves—which can absorb parts of a signal. Fading and the combining of signals can create distortion. Distortion degrades the ability of the receiver to recover the signal in a manner much like signal loss. The Example in figure 3.3 below shows you the different types of scattering. The rate of incident and the texture of the plane will determine the amount of scatter that is reflected off each plane.

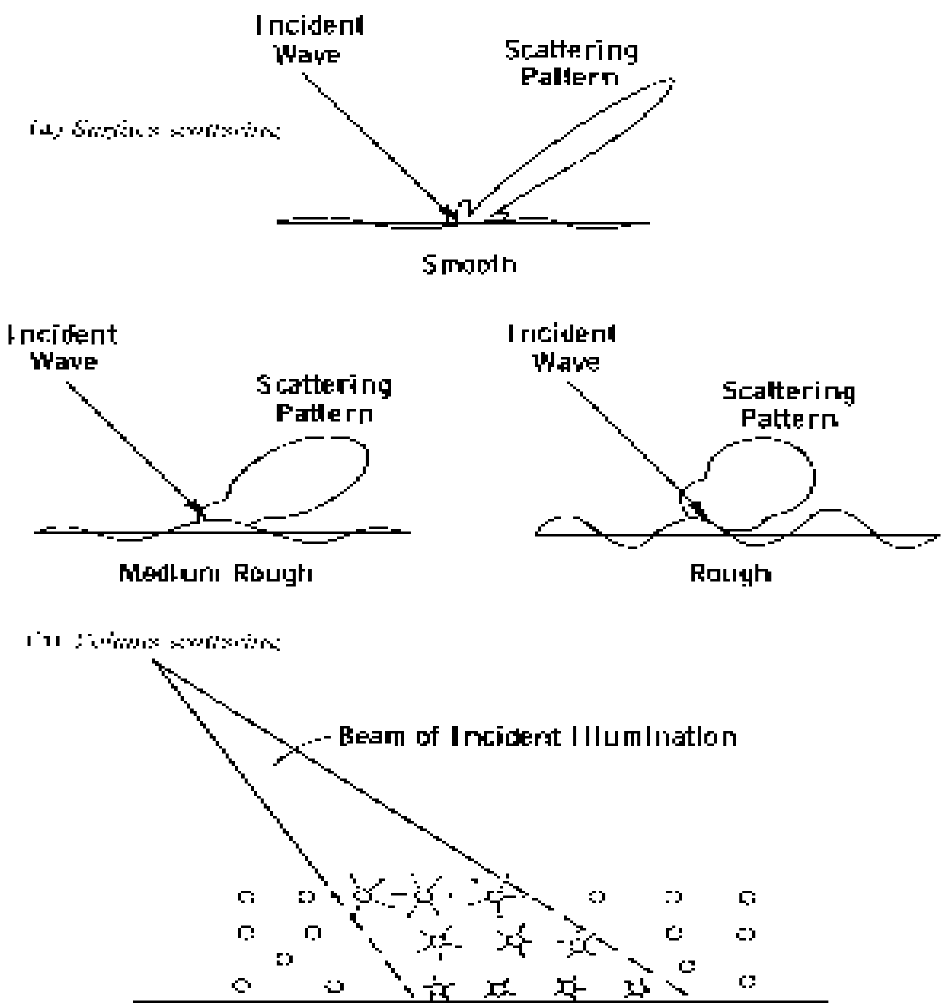


Figure 3.3; Examples of Scattering

3.1.3c Diffraction

Diffraction can occur when a signal is hindered by the sharp edges of an object in a direct pathway. The second wave that comes off of that sharp edge is able to bend behind, above, and below an object. Diffraction can occur even if a signal never had an intended direct path to a receiver. At high frequencies, diffraction depends on the geometry of the object, as well as the amplitude, phase, and polarization of the incident wave at the point of diffraction. Figure 3.4 below is an example of diffraction. The longest pole is the transmitter. The shortest pole represents the edge of a building, and the line represents a signal or wave being transmitted. The arrow is the receiver that the signal is being transmitted to. The arrow is the second diffracted wave that was reflected off the receiver.

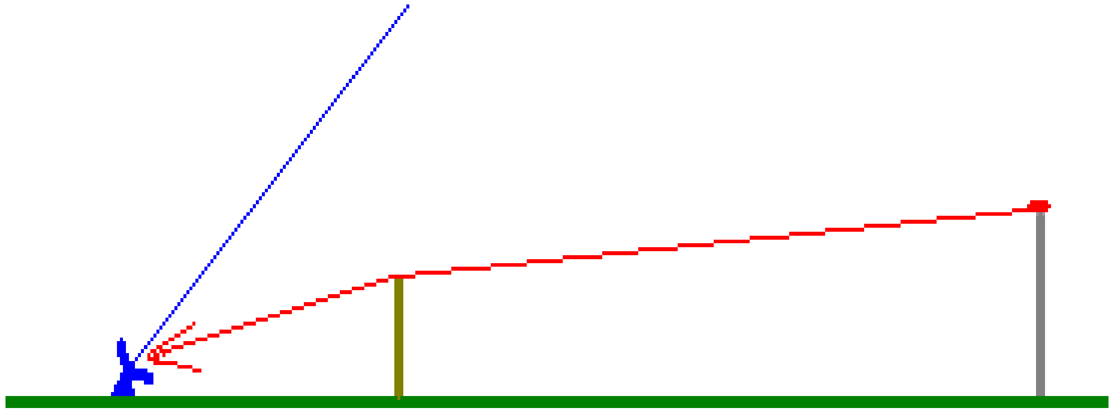


Figure 3.4; Example of Diffraction

3.1.3d Reflection

A reflection occurs when a signal or wave is propagated and strikes an obstacle. Reflections mostly occur from the surface of the earth and sides of buildings and walls. A transmitted signal can be reflected back to the transmitter rather than continuing to its receiver, this can cause an echo. Also a returning reflection that strikes another object or obstacle can send the signal back in its intended direction toward the receiver. This will create multiple echo effects. Echo effects within a signal from extended reflection can cause jitter. **Jitter is** an unwanted variation of one or more characteristics of a periodic signal. Figure 3.5 below is an example of a transmitted signal being reflected from some reflectors to the receiver.

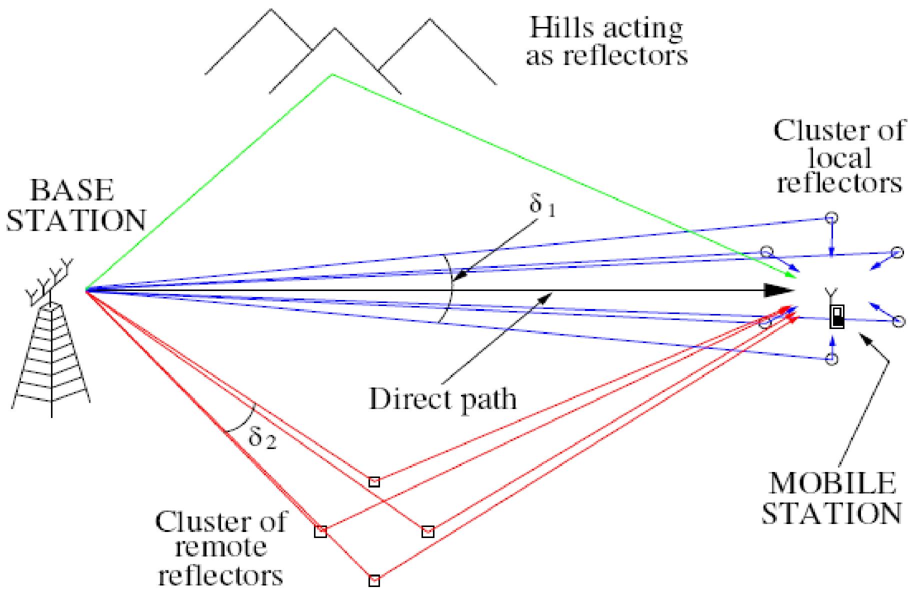


Figure 3.5; Example of Reflection

3.2 IS95-A CDMA Modulation

In the CDMA Digital Cellular Mobile Telecommunications System, mobile stations communicate with the base station in the way of Code Division Multiple Access (CDMA). Different from the Time Division Multiple Access (TDMA) and the Frequency Division Multiple Access (FDMA), the CDMA signals overlap with each other in frequency, time, and space. According to the communication directions, the CDMA channels are classified into forward channels (from the base station to the mobile station) and reverse channels (from the mobile station to the base station). Taking IS-95 system as an example, the forward channels include Pilot Channel (PICH), Synchronization Channel (SCH), Paging Channel (PCH), and Traffic Channel (TCH); the reverse channels include Access Channel (ACH) and Traffic Channel (TCH). In CDMA2000, more types of channels are provided. Figure 3.6 below shows the architecture of these channels [4].

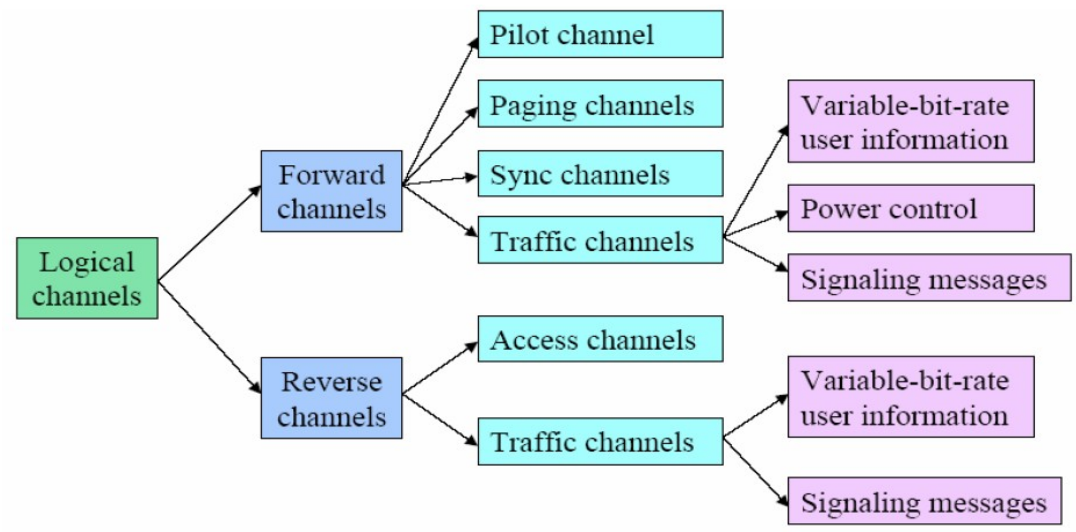


Fig. 3.6; Architecture of Physical Channels in IS95-A

3.2.1 Modulation of Forward Physical Channel in IS95-A

Each Forward CDMA Channel is orthogonally modulated through a Walsh function (Appendix A) and then uses a 1.2288 Mchip/s PN sequence for spreading spectrum. Because the Forward CDMA Channel uses a 64-ary . Walsh function for orthogonally spreading spectrum and each channel uses a unique Walsh function; each cell can use 64 code channels. Usually one pilot channel, one synchronization channel, seven (the maximum number allowed) paging channels, and fifty-five traffic channels are available for one CDMA cell. The allocation of the forward channels is not fixed. However the pilot channel must be provided and others can be configured according to the actual situations.

The forward channel (from base station to mobile) is made up of the following channels:

Pilot channel (always uses Walsh code W0) (Beacon Signals)

Paging channel(s) (use Walsh codes W1-W7)

Sync channel (always uses Walsh code W32)

Traffic channels (use Walsh codes W8-W31 and W33-W63) [4].

Figure 3.7 shows the forward channel.

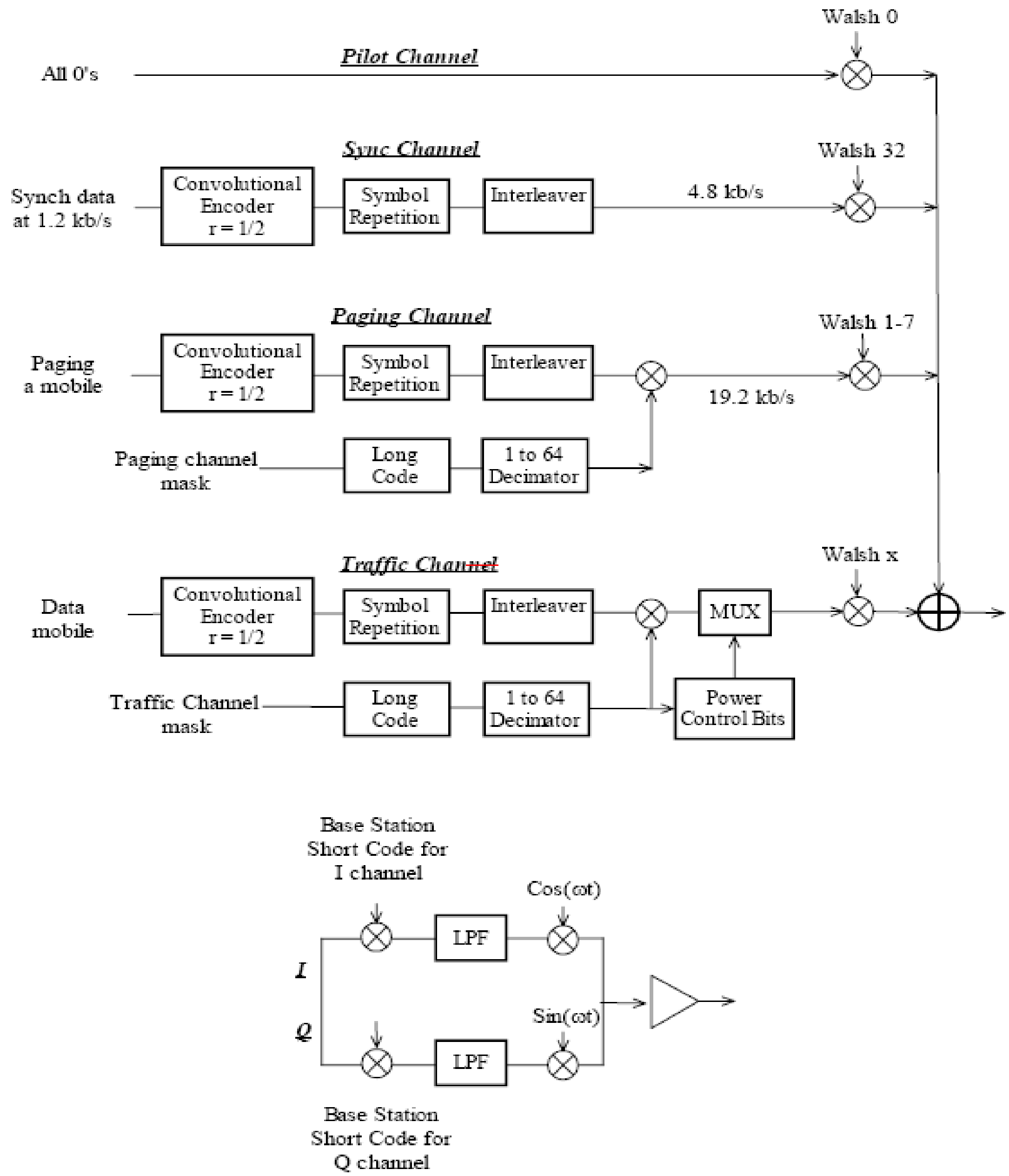


Fig. 3.7 Forward CDMA Channel

3.2.2 Modulation of Reverse Physical Channel in IS95-A

Reverse CDMA Channel includes access channels and reverse traffic channels. These channels adopt the direct sequence CDMA technology to share the same CDMA frequency. In IS-95, there are just two channels on which the mobile transmits, and even that never simultaneously. It is either on the access channel or it is transmitting traffic. The channel structure is similar but simpler to the forward channel, with the addition of 64-ary modulation figure 3.8 below shows the reverse channel.

One paging channel can correspond to a maximum of 32 reverse access channels numbered from 0 to 31. For each paging channel, at least one reverse access channel corresponds to it. Each access channel should be associated with one paging channel [4].

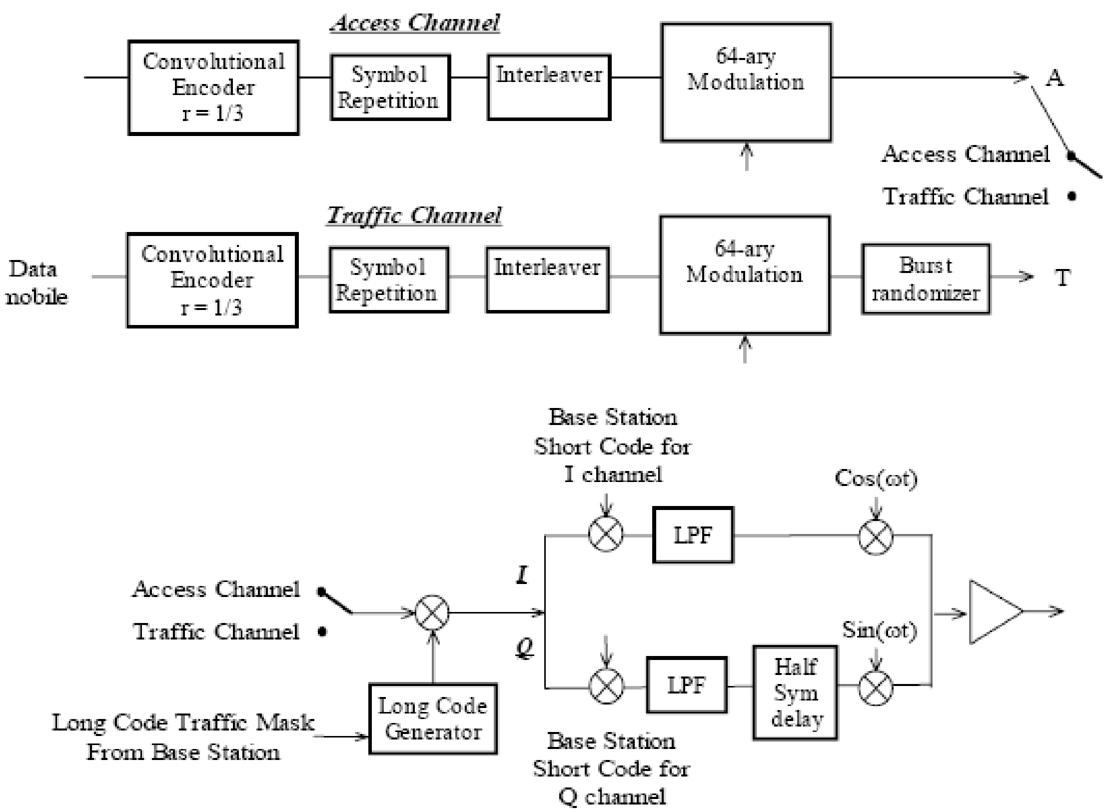


Fig.3.8 Reverse CDMA Channel

3.2.3 Convolutional coding

Before the transmission, convolutional coding is performed on the synchronization, paging, and forward traffic channels. The convolutional codes are used to correct random errors, burst errors, or both. The convolutional encoder is illustrated below.

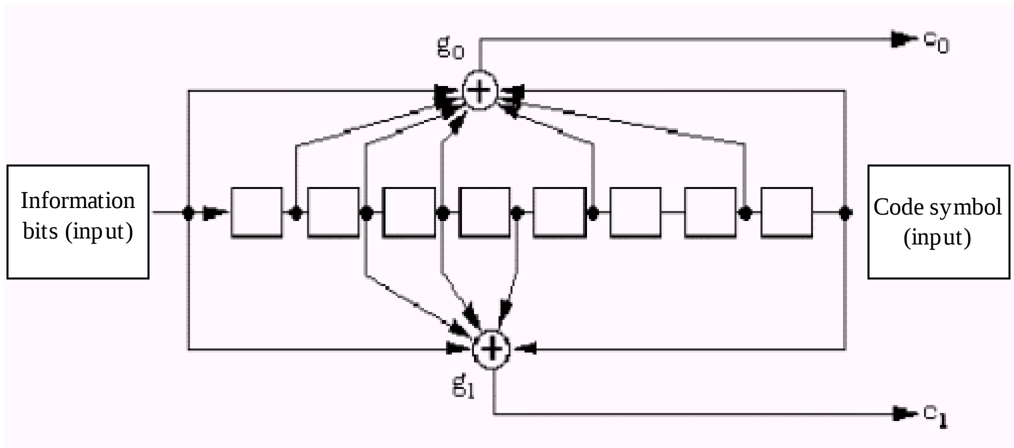


Fig. 3.9; Convolutional Encoder

The encoder ratio is 1/2. The constraint length is 9. The code generator functions are g0 = 753 (octal) and g1 = 561 (octal). The state of the convolutional encoder during the initialization is all zeros. That is, one data bit is input and two code symbols are output. In addition, the nine consecutive bits in the input data bit stream is relative [5].

3.2.4 Code symbol repetition

For the synchronization channel, each symbol after convolutional coding should be repeated before block interleaving, that is, each symbol is consecutively transmitted twice.

For the paging and traffic channels, code symbol is not repeated when the rate is 9600 bit/s, each is repeated once when the rate is 4800 bit/s, repeated three times when the rate is 2400 bit/s (each symbol appears four times consecutively). Each code symbol is repeated seven times when the rate is

1200 bit/s, that is, each symbol appears eight times consecutively. In this way, a fixed rate of 19200 modulation symbols per second is generated for all the data rates.

3.2.5 Block interleaving

On the synchronization, paging, and forward traffic channels, block interleaving is performed after the repetition to disorder the sequence of the transmitted symbols. When an error occurs to a particular length of consecutive bits during the transmission of the signals, the receiver deinterleaves them in the demodulation process so that the consecutive error bits are no longer consecutive. Furthermore, the error bits are corrected through a error-correcting mechanism and thus they can be demodulated correctly. The block interleaving is performed like this: the modulation symbols are padded into a matrix block and then read out in the changed sequence.

On the synchronization channel, the length of an interleaved frame is 26.66 ms. The paging channel and the forward traffic channel use the same block interleaver, and the frame length is 20 ms [5].

3.3 Diversity Technology

Mobile communication channel is a type of multipath fading channel. Transmitted signals pass multiple transmission paths, such as mirrored, reflected, and scattered, before arriving at the receiver. With the movement of the mobile station, the amplitude, the delay, and the phase of the signals on the various transmission paths always change. Accordingly the level of the received signals is neither flat nor stable. These multipaths are superimposed and fading appears.

The diversity technology is a good solution to overcome the fading influence. On several tributaries, signals carrying the same message but with little relativity are received, and then through the combination technology the tributary signals are combined and output, thus greatly reducing the probability of deep fading at the receiver. This is the diversity technology.

To obtain at the receiver different multipaths that are nearly independent of each other, a variety of methods can be used in terms of space, time, and frequency. The most basic types of diversity reception include time diversity, frequency diversity, and space diversity.

3.3.1 Time Diversity

Due to the movement of the mobile station, doppler frequency shift occurs to received signals. In the multipath environments, the frequency shift results in doppler spread. The reciprocal definition of doppler spread is coherent time which represents the fading meter of the time vary channel on the signals. This type of fading occurs at a particular time point of the transmission wave, which is called time-selective fading. It has an outstanding effect on bit errors of digital signals.

If sequential sampling is adopted on the amplitude, two sample points with enough large time interval (greater than the coherent time) are not associated. Therefore, time diversity can be used to reduce the influence. For example, a given signal is repeatedly transmitted for N times every time after a particular time interval. As long as the time interval is greater than the coherent time, independent N diversity tributaries can be obtained.

The convolutional coding, interleaving, and error correction coding technologies in the CDMA can be used to achieve time diversity.

1. The convolutional coding technology can effectively eliminate random individual data errors. Convolutional code was put forward by Elias in 1955. It was named for its coding method can be expressed in the form of convolution operation. Convolutional code has a memory. For any given time segment, the n coded outputs are not only associated with k inputs during this time segment but also associated with the m inputs saved in the encoder. Convolutional code needs to select encoding constraint length and code rate. The constraint length should be set as large as possible to obtain good performance. However with the increasing of the encoding constraint length, decoding complexity is increased.

2. The purpose of the block interleaving technology is to avoid continuous burst data errors as much as possible so that the number of the errors in each receive field after deinterleaving at the receiver is not greater than the number of the correctable error correcting codes. In land mobile communications, bit errors continuously appear on this type of parameter vary channel because a continuously lasting deep fading vale point affects a string of bits. However, channel code is valid only when detecting and correcting a limited number of errors and a string of errors which is not very long. To solve that problem, an approach is expected to separate consecutive bits in a message, that is, to transmit the consecutive bits in the message in a non-consecutive (distributed) way. In this way, even though a string of errors appear in the transmission, only a single error or several

errors can be encountered when the message with a string of consecutive bits is regenerated after deinterleaving. This method is called the interleaving technology. After deinterleaving, the receive field containing random errors is corrected through error-correcting code and the original message is recovered. Performance improvement brought by interleaving depends on the diversity level and the average fading interval of the channel. The interleaving length is subject to service delay requirements. The delay for voice service is shorter than that for data service. Therefore, it is required to match interleaving depth with different services.

3.2.2 Frequency Diversity

The frequency diversity technology refers to modulating information to be transmitted on different carriers before being transmitted to the channel. Because fading has frequency selection ability, two frequencies with an separation larger than the correlated bandwidth receive different fading effects. In other words, carrier separation *Δf* should be large enough and is larger than the correlated bandwidth, that is,

$$\Delta f \geq \Delta F = 1/L$$

in which, *L* is the bandwidth of receive signal delay power spectrum.

For example, in the 800 ~ 900 MHz frequency band transmission environments, a typical delay diffusion value is 5 *μs*. In this case,

$$\Delta f \geq \Delta F = 1/L = 1/5\mu s = 200kHz$$

That is, the carrier separation in frequency diversity should be larger than 200 kHz.

The correlated bandwidth is about 50 kHz in urban area and about 250 kHz in rural area. For broad frequency signal, fading is like a trap filter. Trap is only a part of broad frequency signal on the spectrum. The signal bandwidth in the CDMA is 1.23 MHz. It far satisfies the requirement for the correlated bandwidth no matter whether it is in urban area or rural area. Therefore, being a broadband system, the CDMA can achieve frequency diversity by itself.

3.2.3 Space Diversity

More than one horizontally or vertically spacing antenna are built at the receiver to reduce fading influence by making use of incomplete coherence of signals when electromagnetic waves arrive at respective receive antennas. This is space diversity. In the case of multipath fading, deep fading occurs to signals of one receive antenna but the signals received at the other antenna can retain the same.

There are two types of space diversity: horizontal space diversity and vertical space diversity. If the spacing distance between vertical space diversity antennas is too great, the difference between diversity antenna coverage areas is great; if the spacing distance is too small, the effect of diversity gain is small. Therefore, vertical diversity is not practical in actual applications. Typically, horizontal space diversity is employed.

Antenna horizontal space diversity gain is affected by a number of factors including:

1. Antenna height (h);

2. Distance between antennas (d);

3. Inclination between the mobile station and the perpendicular bisector of the connection line of the two antennas (α);

4. Number of used antennas (synthesis gain);

5. Gain difference between antennas (caused by the movement of the mobile station around the base station).

Diversity gain and antenna height are associated with distance between antennas, which can be used to define a parameter η as in:

$$\eta = \frac{h}{d}$$

According to the analysis of horizontal space diversity gain, we believe the following points:

1. A number of factors affect horizontal space diversity gain. The synthesis gain of diversity antennas has the greatest effect on diversity gain of the system. The greater the number of diversity antennas (N), the better the diversity effect. However non-diversity difference and diversity difference are great, which is a qualitative change. Diversity gain is in direct proportion to the number of diversities (N). Only limited improvement can be achieved, which is a quantitative change. In addition, the improvement reduces when the number of diversities (N) increases. Typically N is specified to be 2 ~ 4, which takes both performance and complexity into account.

2. In a 400 MHz system, when η is greater than 10, 4 dB gain is achieved by using the horizontal space diversity technology. In an 800 MHz system, when η is greater than 20, 4 dB gain is achieved by using the horizontal space diversity technology.

3. According to analysis, it is recommended to specify η to be 5.5 in a 400 MHz system and 11 in an 800 MHz system. In this case, diversity gain is about 4.7 dB. When designing the horizontal diversity distance for a station, select a suitable value for η according to the actual engineering

conditions so that the effect of diversity gain can be achieved and the actual engineering conditions can be satisfied.

Space diversity has two variants as follows:

1. Polarization diversity: Signals transmitted from two antennas with mutually orthogonal polarization directions at the same site can show irrelative fading features for diversity reception. That is, orthogonal polarized antennas are built on transmit and receive antenna, and thus polarization diversity can be performed on the two channels of signals received with irrelative fading features. Polarization diversity has some advantages (compact structure and saved space) and some disadvantages (3 dB loss due to distribution of transmit power onto two antennas).

2. Angle diversity: In different receive environments such as topography, physiognomy, and buildings, different path signals received at the receiver might be from different directions. In this case, directional antennas can be used at the receiver, respectively pointing to different directions. Multipath signals received at each directional antenna are irrelative.

3.2.4 Rake Receiver

Spread spectrum signals from a transmitter are reflected and refracted by various obstacles such as buildings and hills during the transmission. Each wave packet arriving at the receiver has a different delay and generates a multipath signal. If the delay of different path signals exceeds the chip delay of a pseudo code, different wave packets can be distinguished at the receiver. The different wave packets are guided along different delay lines, aligned, and then combined. In this way, the originally interfering signals are processed to be useful signals and combined. This is the basic principle of a rake receiver. In other words, the space diversity technology is employed in a rake receiver.

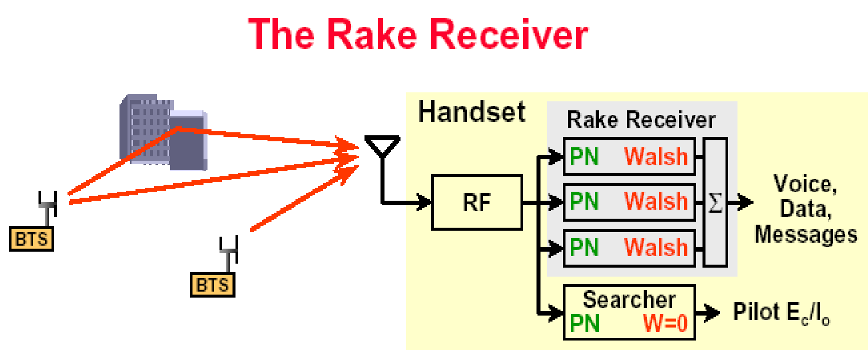


Fig. 3.10 Principle of Rake Receiver

A rake receiver is typically composed of three modules: searcher, finger, and combiner. A searcher searches paths under the key principle of self-correlated and cross-correlated features of codes. A finger dispreads and demodulates signals. The number of fingers determines the number of demodulation paths. Usually one rake receiver in a CDMA base station system has four fingers and one mobile station has three fingers. A combiner combines outputs from multiple fingers. Universal combination algorithms include selective addition combination, equal gain combination, and maximum ratio combination. Combined signals are output to a decoder element for channel decoding processing.

Specifically, each tributary of a rake receiver uses a correlator to dispread the received signals. For coherent demodulation, dispread signals are multiplied by a complex amplitude to correct phase errors and each tributary is weighted according to a selected combination policy (maximum ratio combination or equal gain combination). The pulse response measurement module continuously measures multipath profile. When the pulse response delay changes, the measurement module allocates a new code phase to the code trace module to trace minute changes. Signals of different rake tributaries are combined before interleaving and translation of channel codes. In addition, a searcher continuously scans pilot signals of adjacent cells to provide measurement of pilot signals for handoff. The number of rake tributaries depends on channel profile and chip rate. If the chip rate is high, relatively many paths can be separated. However, when there are a number of rake tributaries, a great deal of energy has to be obtained from the channel to maintain good performance. When there are a large number of rake tributaries, combination loss occurs.

Let's further describe pulse response measurement, code search and capture, code trace, complex amplitude estimation, and searcher. Pulse response measurement refers to correlating pilot codes of different phases with received signals to find multipath components. Measurement speed required in pulse response measurement depends on the speed of the mobile station and the radio environments. The higher the speed of the mobile station is, the quicker the measurement is required to complete, so that the rake tributary can obtain the best multipath component. However a wide scan widow is required in long delay extension environments. Besides the measurement function, the module is responsible for allocation of rake tributaries, that is, allocating multipath components to rake tributaries. Different policies can be applied to the allocation of codes. The allocation is implemented after the whole pulse response measurement is completed or an enough strong multipath component is found. Code search and capture is implemented before synchronization search and capture of the system.

The mobile station scans pilot signals. The sequence of pilot signal priorities can be determined based on the nearest or adjacent pilot signal. If a link is lost for some reason, the scan starts from the pilot signal with the highest priority. In strong interference situations, code search and capture might be a bottleneck. A match filter can be used for quick code search and capture. A typical code trace loop is to pilot the early, delay the later, and lock the loop. It involves two correlators (one for piloting the early and the other for delaying the later). A chip allocated by them is different from the standard aligned chip by half a chip. According to the related results, the code phase is adjusted. The performance of the trace loop depends on the bandwidth of the loop. If update is quicker than the movement of multipath component delay, synchronization error can be ignored. Otherwise, loop noise will be increased. This requirement also depends on the policy for detection, that is, applying routine or multi-user detection.

Complex amplitude estimation includes amplitude estimation and phase estimation. In the maximum ratio combination, signal weight is the complex conjugate of complex amplitude. In the case of equal gain combination, only phase errors are corrected. For each rake tributary, it can be considered to be equally weighted. Complex amplitude estimation should be averaged in a reasonable period length. In this case, the coherent time is set to be the upper limit of the average time. A searcher scans pilot signals of other cells. During call conversation, the mobile station scans pilot signals, measures downlink interference, and possibly receive uplink interference results. Because the number of pilot signals is very large, long time might be required to notice a pilot signal in the neighbor set.

Therefore, search time might limit the performance of the system especially in microcell environments where a new base station will quickly become active due to corner effect. An approach to reduce required hardware components is to flexibly allocate rake and searcher tributaries.

The number of tributaries required for scan depends on the expected speed of scanning pilot signals.

3.4 Power Control

CDMA power control includes forward power control and reverse power control. If all users in a cell use the same power for transmission, the signals from the mobile stations closer to the base station are very strong when arriving at the base station and the signals from the mobile stations far away from the base station are very weak when arriving at the base station. This causes a consequence: strong signals conceal weak signals. This is the well-known “far-close effect” in the mobile communications system.

The CDMA is a self-interference system. All users share the same frequency. Certainly the “far-close effect” is very prominent. If a user, in the CDMA system, has signals with strong power (including forward power and reverse power), it is helpful for that user to be received correctly, but it enhances the interference on other users in the shared frequency band and even inundates the signals of other users. Consequently, the communication quality enjoyed by other users becomes poor and the capacity of the system is reduced. To eliminate the far-close effect, the power necessary for the transmitter must be adjusted in real time depending on the communication distance, which is “power control”.

3.4.1 Forward Power Control

For a forward link, when the mobile station moves towards the base station, the interference of intra-cell multipath on the mobile station becomes stronger. This type of interference affects the reception of signals and degrades the quality of communication. Furthermore, the link cannot be set up. Therefore, power control is introduced into the forward link in the CDMA system, to possibly minimize the transmit power of the forward traffic channel on the premise of satisfying the minimum signal noise ratio necessary for the mobile station for demodulation. Through appropriate adjustment, the communications between the base station and the mobile stations at the edge of the cell can be maintained, and meanwhile, the forward transmit power can be minimized on the premise of good communication transmission features to reduce the interference on the adjacent cells and add the capacity of the forward link.

3.4.2 Reverse Power Control

The capacity of the CDMA system is mainly limited by the mutual interference between mobile stations in the system. That is, if the signals of each mobile station reach the minimum required signal noise ratio when arriving at the base station, the system reaches the maximum capacity. The purpose of CDMA power control is to not only maintain high-quality communications but also minimize the interference on other users. Therefore, power control is introduced to the reverse link of the CDMA system: by adjusting the power of the user's transmitter, it can be guaranteed that user signals arrive, with the same power, at the base station's receiver regardless of the location of the users in the base station's coverage area as well as the transmission environments. In the actual system, the transmission environments of user signals are not stable due to users' mobility. Consequently, the transmission path, the strength, the delay, and the phase of the signals change at any time and the receive signal power fluctuates along an expected value.

Reverse power control includes open loop power control, close loop power control, and outer loop power control.

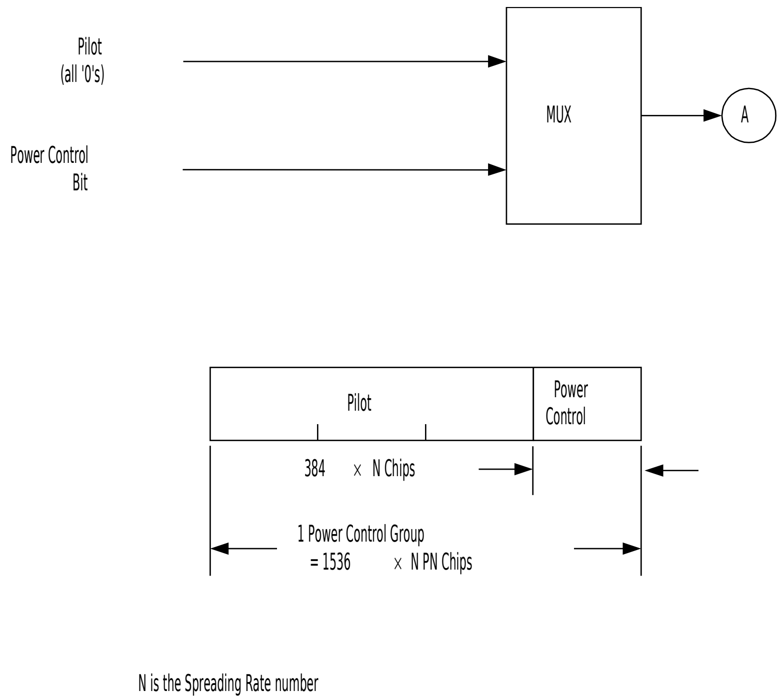


Fig. 3.11; Structure of Reverse Power Control Subchannel

In the actual system, the three types of power control cooperate together to implement the reverse power control. That is, an open loop estimation is made on the transmit power of the mobile station, and then close loop power control and outer loop power control take effect to more precisely correct the open loop estimation.

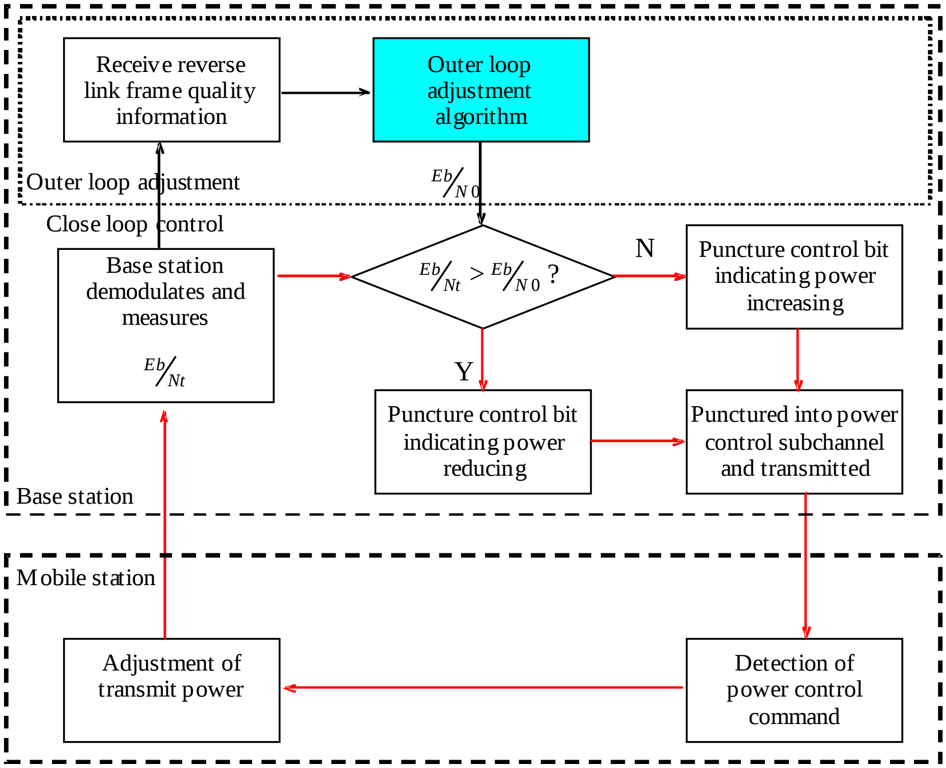


Fig. 3.12 Reverse Close Loop Power Control

a) Reverse Open Loop Power Control

Each mobile station in the CDMA system keeps calculating the path loss from the base station to the mobile station. If the mobile station receives strong signals from the base station, the mobile station might be close to the base station or there might be a good transmission path between them. In this case, the mobile station can reduce its transmit power and the base station can still receive signals normally. Contrarily, if the mobile station receives weak signals from the base station, it increases the transmit power to counteract fading and loss. This is open loop power control. Open loop power control is simple and has a direct effect. It is unnecessary to exchange control information between the mobile station and the base station. In addition, the control speed is very quick and little overhead is used. However in the CDMA system, different frequencies are used in forward transmission and reverse transmission. (The frequency difference is 45 MHz as specified in the IS-95) The frequency difference is far beyond the coherent bandwidth of the channel. Therefore, the fading feature on the forward channel is not equal to the fading feature on the reverse channel, which is a limit of open loop power control.

b) Reverse Close Loop Power Control

To eliminate the irrelative fading on forward link and reverse link, the base station can detect the signal noise ratio of the signals from the mobile station and compares it with a threshold value. According to the comparison result, the base station sends an instruction through the forward channel to the mobile station to indicate it to increase or reduce the power. The mobile station receives the instruction and accordingly adjusts its transmit power. This is close loop power control. The key to achieve close loop power control is the quick generation, transmission, processing, and execution of the power control instruction to track the uplink fading.

In the close loop power control, the threshold value of the signal noise ratio is not fixed, but dynamically changed under the outer loop power control.

When IS-95 has a open-loop and a closed loop power management system. The open loop is a quicker way to manage power levels. The forward and reverse links are at different frequencies so they fade differently and open loop power control allows the mobile to adjust its power without consulting with the base station. In closed loop power control the base station measures the power level of the access channel signal sent by the mobile and then commands with 1 in the synch channel if the power needs to be raised and with 0 if it is to be reduced by 1 dB at a time. The closed loop power control also uses an outer loop power control. This method measures the Frame Error Rate (FER) both by the mobile and the base station and then adjusts the power according to whether the FER is acceptable.

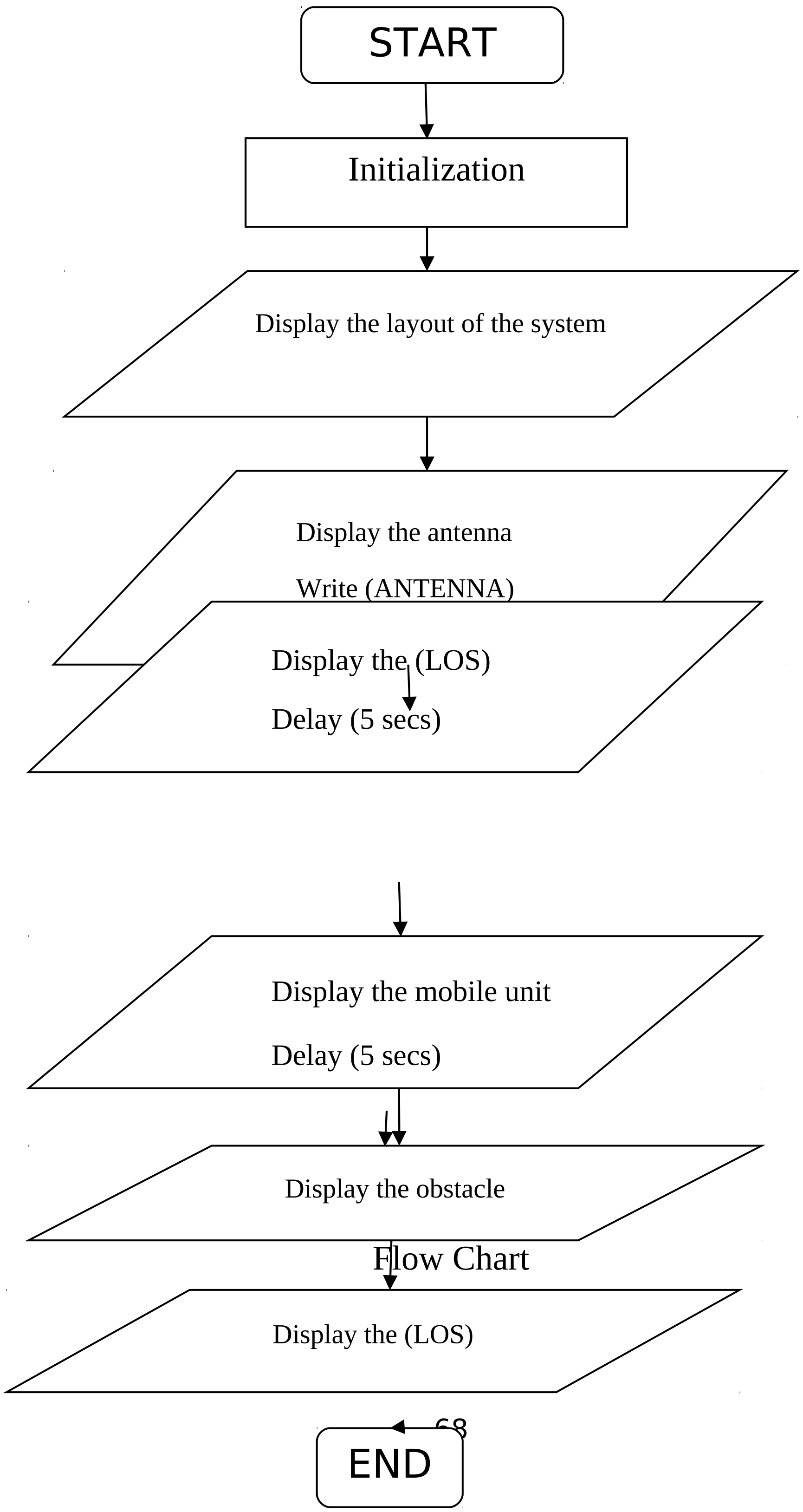
CHAPTER FOUR

Simulation

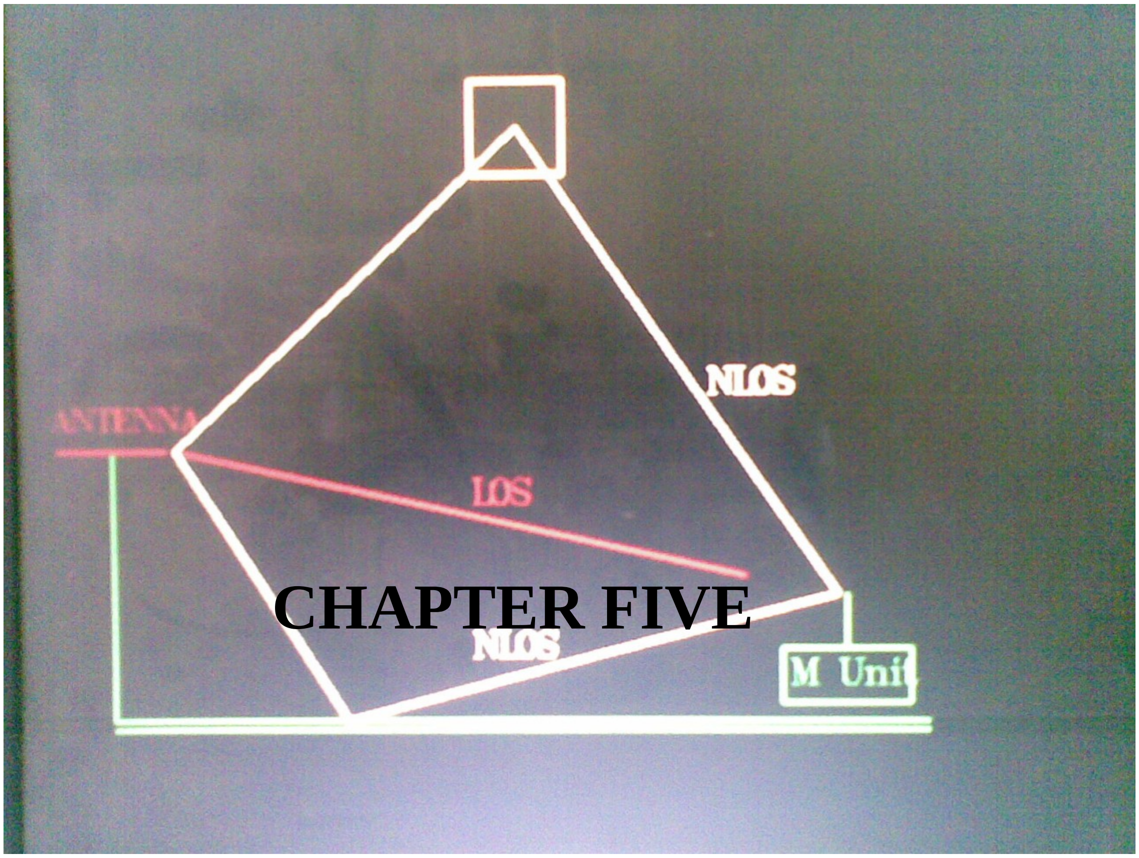
In mobile communication systems, the RF signal propagates from the transmitter to the receiver via multiple different paths due to the obstacles and reflectors existing in the wireless channel. These multipaths are caused by mechanisms of reflection, diffraction, and scattering from buildings, structures, and other obstacles existing in the propagation environment. Multipath propagation is usually described by line of sight (LOS) path and non line of sight (NLOS) paths.

When the mobile unit is considerably far from the base station, the LOS signal path does not exist and reception occurs mainly from the indirect signal paths. These multiple paths have different propagation lengths, and thus will cause amplitude and phase fluctuations and time delay in the received signal. Therefore, the main effect of multipath propagation can be described in terms of fading and delay spread. When the waves of multipath signals are out of phase, reduction of the signal strength at the receiver can occur. This causes significant fluctuations in the received signal amplitude with time leading to a phenomenon known as multipath fading or small scale fading, a representation of multipath fading.

Below the flow chart of the program code of C++ (Appendix B) which represents multipath fading. Simulation contain antenna of a base station and the mobile station representing the signal multipath (LOS and NLOS). NLOS reflected by earth and an obstacle. Finally the simulation result has been attached.



Flow Chart



CHAPTER FIVE

Results and Discussion

When measuring path loss, the different types of environments must be considered to know the optimum quality of service and therefore use the best model available. This is because the precision in the calculations differ from one model to another.

Small-scale fading is also called Rayleigh fading because if the multiple reflective paths are large in number and there is no line-of-sight signal component, the envelope of the received signal is statistically described by Rayleigh distribution. When there is a dominant nonfading signal component present, such as a line-of-sight propagation path, the small scale fading envelope is described by Rician distribution and, thus, is referred to as Rician fading.

Once the case of the building structure has been studied, a better idea on the best model to use can be acquired .When studying building path loss, simple or more complex models can be used. When using complex models, it is found that the path loss is less than when using a simple model, this could be considered as multipath benefits.

Because multiple reflections of the transmitted signal may arrive at the receiver at different times, this can result in inter-symbol interference (ISI) due to the crashing of bits into one another. This time dispersion of the channel is called multipath delay spread and is an important parameter to assess the performance capabilities of wireless communication systems.

CHAPTER SIX

Conclusion and Recommendation

From this study, it is established that all radio systems suffer from signal fading, which are influenced by either the distance between transmitter and receiver, motion, and/or by terrain effects. Also, it is obvious that fading has different impact on different frequency bands in different ways due to how the signal travels in each band (wavelengths).

The mobile radio channel places fundamental limitations on the performance of wireless communication system. The transmission path between the transmitter and the receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, mountains, and foliage. Unlike wired channels that are stationary and predictable, radio channels are extremely impacts how rapidly the signal level fades as a mobile terminal moves in space.

As a mobile move over very small distances, the instantaneous received signal strength may fluctuate rapidly giving rise to small-scale fading. The reason for this is that the received signal is a sum of much contribution coming from different direction.

As a mobile move away from the transmitter over much larger distances, the local average received signal will gradually decrease, and it is the local average signal level that is predicted by large-scale propagation models.

Fading effects in mobile reception are difficult to avoid since it occur as a result of the environment whereby the radio signal is being propagated. However, the work as shown that with application of diversity scheme, the effect of fading can be minimized. The negative effect of signal fading will be reduced if not completely eliminated. Also from the result of this study, it is obvious that the implementation of scheme in mobile communication system will indeed enhance information transfer on CDMA wireless communication systems.

On the demodulation side, the most notable item is the Rake receiver. Due to the presence of multipath, Rake receivers which allow maximal combining of delayed and attenuated signal, make the whole thing work within reasonable power requirements. Without Rake receivers, the cell phone would not be as small as it is.

The CDMA systems manage the power levels of all mobiles so that the power level of each mobile is below a certain required level and is about the same whether the mobile is very close to the base station or far at the edge of the cell. Multipath and fading also attenuate power levels so the system maintains a power control loop.

Multipath not always has negative impacts in wireless communication, because it is useful in mobile communication when mostly there is absence of LOS pass.

In CDMA network planning the nature of the area should be considered whether it is urban or rural area to implement optimal positions and number of base stations. Also propagation environment should be considered.

References

1. Theodore S. Rappaport, "*Wireless Communications*", Prentice-Hall PTR. 1996.
2. Marvin K. Simon & Mohamed-Slim Alouini, "*Digital Communication over Fading Channels*", John Wiley & Sons, Inc. 2000.
3. Jeffrey Wheat, Randy Hiser, Jackie Tucker, Alicia Neely & Andy McCullough, "*Designing a Wireless Network*", Syngress Publishing, Inc. 2001.
4. Krzysztof Wesolowski, "*Mobile Communication Systems*", John Wiley & Sons, Inc. 2002.
5. Samuel C. Yang, "*CDMA RF System Engineering*", Artech House, Inc. 2006.
6. http://www.eecs.wsu.edu/~hudson/Teaching/ee432/notes/fading.htm
7. http://www.ctr.columbia.edu/~campbell/e6950/summer97/lecture4_jon.htm
8. http://en.wikipedia.org/wiki/Code_division_multiple_access

Appendices

Appendix A:

Walsh codes

. Walsh codes do not have the properties of m-sequences regarding cross correlation.. IS-95 uses 64 Walsh codes and these allow the creation of 64 channels from the base station. In other words, a base station can talk to a maximum of 64 (this number is actually only 54 because some codes are used for pilot and synch channels) mobiles at the same time. CDMA 2000 used 256 of these codes.

Walsh codes are created out of Haddamard matrices and Transform. Haddamard is the matrix type from which Walsh created these codes. Walsh codes have just one outstanding quality. In a family of Walsh codes, all codes are orthogonal to each other and are used to create channelization within the 1.25 MHz band.

Below are first four Hadamard matrices. The code length is the size of the matrix. Each row is one Walsh code of size N. The first matrix gives us two codes; 00, 01. The second matrix gives: 0000, 0101, 0011, 0110 and so on. In the first matrix the code of user 1 is the first column, i.e., (0, 0), the code of user 2 is the second column, i.e., (0, 1)

$$H1 = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

$$H2 = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{pmatrix}$$

$$H3 = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \end{pmatrix}$$

Appendix B:

Program Code

```
#include <graphics.h>

#include <stdlib.h>

#include <stdio.h>

#include <conio.h>

#include <dos.h>

int main(void)

{

   /* request auto detection */

   int gdriver = DETECT, gmode, errorcode;
```

```
   /* initialize graphics and local variables */
   initgraph(&gdriver, &gmode, "");

   /* read result of initialization */
   errorcode = graphresult();
   if (errorcode != grOk)  /* an error occurred */
   {
      printf("Graphics error: %s\n", grapherrormsg(errorcode));
      printf("Press any key to halt:");
      getch();
      exit(1); /* terminate with an error code */
   }
/*    setcolor(getmaxcolor());    */
/* sketch the layout of the system */
  setcolor(GREEN);
  setlinestyle(0,1,3);
   line(50,400,500,400);
   line(50,405,500,405);
   line(50,400,50,250);

/* sketch the antenna */
   setcolor(RED);
   line(20,250,80,250);
```

```
/* write the   ANTENNA */
   moveto(18,220);
    settextstyle(1,0,1);
    outtext("ANTENNA");
    delay(5000);

/* sketch the LOS */
los:
   line(85,250,400,320);

/* write the   LOS */
   moveto(250,260);
    settextstyle(1,0,2);
    outtext("LOS");
    delay(5000);

/* Draw a car (rectangle)+perpendicular line */
    setcolor(BLUE);
   rectangle(420,360,490,390);
   line(455,360,455,330);

/* write the   Mobile Unit */
   moveto(425,360);
    settextstyle(1,0,2);
    outtext("M Unit");
```

```
    delay(5000);

/* sketch the  NLOS */
    setcolor(WHITE);
   line(85,250,180,400);
   line(180,400,450,330);

/* write the  NLOS */
   moveto(250,345);
    settextstyle(1,0,2);
    outtext("NLOS");
    delay(5000);



/* Draw a building  (rectangle)+NLOS */
    setcolor(YELLOW);

   rectangle(250,50,300,100);
    setcolor(WHITE);
   line(85,250,275,75);
   line(275,75,450,330);

/* write the  NLOS */
   moveto(380,200);
    settextstyle(1,0,2);
```

```
    outtext("NLOS");
    delay(5000);

   /* clean up */
finish:
   getch();
   closegraph();
   return 0;
}
```