Cellular and Mobile Communications

Course and Subject File

Contents:

GEETHANJALI COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF *Electronics and Communication Engineering*

(Name of the Subject) : CELLULAR AND MOBILE COMMUNICATIONS

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Approved by : (HOD) 1) Name : **2) Sign :** **3) Date :**	

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY
HYDERABAD

IV Year B.Tech. ECE - II Sem

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(58024) CELLULAR AND MOBILE COMMUNICATIONS (ELECTIVE-III)

Unit I : Introduction To Cellular Mobile Radio Systems:

Limitations of conventional mobile telephone systems. Basic Cellular Mobile System. First, second, third and fourth generation cellular wireless systems. Uniqueness of mobile radio environment-Long term fading. Factors influencing short term fading. Parameters of mobile multipath fading-Time dispersion parameters. Coherence bandwidth. Doppler spread and coherence time. Types of small scale fading.

Unit II : Fundamentals Of Cellular Radio System Design:

Concept of frequency reuse. Co-channel interference. Co-channel Interference reduction factor. Desired C/I from a normal case in a omni directional antenna system, system capacity. Trunking and grade of service. Improving coverage and capacity in cellular systems- Cell splitting. Sectoring. Microcell zone concept.

Unit III : Co-Channel Interference :

Measurement of real time Co-Channel interference. Design of antenna system. Antenna parameters and their effects. Diversity techniques-Space diversity. Polarization diversity. Frequency diversity. Time diversity.

Unit-IV : Non-Co-Channel Interference

Adjacent channel interference. Near end far end interference. Cross talk. Effects on coverage and interference by power decrease. Antenna height decrease. Effects of cell site components. UHF TV interference.

Unit V : Cell Coverage for Signal and Traffic

Signal reflections in flat and hilly terrain. Effect of human made structures. Phase difference between direct and reflected paths. Constant standard deviation. Straight line path loss slope. General formula for mobile propagation over water and flat open area. Near and long distance propagation. Path loss from a point to point prediction model in different conditions. merits of Lee model .

Unit VI : Cell Site and Mobile Antennas

Sum and difference patterns and their synthesis. Coverage-omni directional antennas. Interference reduction- directional antennas for interference reduction. Space diversity antennas. Umbrella pattern antennas. and Minimum separation of cell site antennas. mobile antennas.

Unit-VII : Frequency Management and Channel Assignment

Numbering and grouping. Setup access and Paging channels. Channel assignments to cell sites and mobile units. Channel sharing and Borrowing. Sectorization. Overlaid cells. Non fixed channel assignment.

Unit-VIII : Handoffs and Dropped Calls

Handoff initiation. Types of handoff. Delaying handoff. Advantages of handoff. Power difference handoff. Forced handoff. Mobile assisted and soft handoff. Intersystem handoff. Introduction to dropped call rates and their evaluation.

TEXT BOOKS:

1. Mobile Cellular Telecommunications – W.C.Y. Lee. Mc Graw Hill. 2nd Edn., 1989.
2. Wireless Communications - Theodore. S. Rapport. Pearson education. 2nd Edn., 2002.

REFERENCES

1. Principles of Mobile Communications – Gordon L. Stuber. Springer International. 2nd Edn., 2001.
2. Modern Wireless Communications-Simon Haykin. Michael Moher,Pearson Eduction. 2005.
3. Wireless communications theory and techniques. Asrar U. H .Sheikh. Springer. 2004.
4. Wireless Communications and Networking. Vijay Garg. Elsevier Publications. 2007.
5. Wireless Communications – Andrea Goldsmith. Cambridge University Press. 2005.

Vision of the department

To impart quality technical education in Electronics and Communication Engineering emphasizing analysis, design/synthesis and evaluation of hardware/embedded software using various Electronic Design Automation (EDA) tools with accent on creativity, innovation and research thereby producing competent engineers who can meet global challenges with societal commitment.

Mission of the Department

i.) To impart quality education in fundamentals of basic sciences, mathematics, electronics and communication engineering through innovative teaching-learning processes.

ii.) To facilitate Graduates define, design, and solve engineering problems in the field of Electronics and Communication Engineering using various Electronic Design Automation (EDA) tools.

iii.) To encourage research culture among faculty and students thereby facilitating them to be creative and innovative through constant interaction with R & D organizations and Industry.

iv.) To inculcate teamwork, imbibe leadership qualities, professional ethics and social responsibilities in students and faculty.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs):

The Educational Objectives of the Electronics and Communication Engineering Program at Geethanjali College of Engineering and Technology are as follows:

1. To prepare students with excellent comprehension of basic sciences, mathematics and engineering subjects facilitating them to gain employment or pursue postgraduate studies with an appreciation for lifelong learning.
2. To train students with problem solving capabilities such as analysis and design with adequate practical skills wherein they demonstrate creativity and innovation that would enable them to develop state of the art equipment and technologies of multidisciplinary nature for societal development.

3. To inculcate positive attitude, professional ethics, effective communication and interpersonal skills which would facilitate them to succeed in the chosen profession exhibiting creativity and innovation through research and development both as team member and as well as leader.

<u>Programme Outcomes of ECE Programme:</u>

1. An ability to apply knowledge of Mathematics, Science, and Engineering to solve complex engineering problems of Electronics and Communication Engineering systems.
2. An ability to model, simulate and design Electronics and Communication Engineering systems, conduct experiments, as well as analyze and interpret data and prepare a report with conclusions.
3. An ability to design an Electronics and Communication Engineering system, component, or process to meet desired needs within the realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
4. An ability to function on multidisciplinary teams involving interpersonal skills.
5. An ability to identify, formulate and solve engineering problems of multidisciplinary nature.
6. An understanding of professional and ethical responsibilities involved in the practice of Electronics and Communication Engineering profession.
7. An ability to communicate effectively with a range of audience on complex engineering problems of multidisciplinary nature both in oral and written form.
8. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.
9. A recognition of the need for, and an ability to engage in life-long learning and acquire the capability for the same.
10. A knowledge of contemporary issues involved in the practice of Electronics and Communication Engineering profession
11. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

12. An ability to use modern Electronic Design Automation (EDA) tools, software and electronic equipment to analyze, synthesize and evaluate Electronics and Communication Engineering systems for multidisciplinary tasks.
13. Apply engineering and project management principles to one's own work and also to manage projects of multidisciplinary nature.

Course objectives:

1. To have an overview of wireless and mobile communications in different generations.
2. To study the operation of basic cellular system and performance criterion, handoff mechanism.
3. To study the design of cellular mobile system.
4. To develop the ability to search, select, organize and present information on new technologies in mobile and cellular communications.

Course Outcomes:

1. Students are capable to analyze and solve problems in the field of telecommunications.
2. Students will have the understanding of different generations, operations and design of wireless and mobile communications.

Brief notes on the importance of the course and how it fits into the curriculum

Wireless communications has become essential part in our day to day life. During recent years there has been significant improvement in the field of wireless communication technology and has rapidly evolved from first generation (1G) to fourth generation (4G). The rapid growth of cellular phones, which principle carry voice are now being widely used for communicating data and images. The communication aspects of this subject depends on the fundamentals of communication engineering. To understand this technology, it is important to know in detail, a number of concepts associated with cellular mobile communication. This course is mainly aimed toward senior year students of the ECE discipline, and in particular, for the final year BTech, and first year M.Tech. However, this does not necessarily imply that any other discipline students can not study this course. Rather, they also should delve deeper into this course since mobile communication is a familiar term to everyone nowadays.

Prerequisites: Modulation techniques, Multiple accessing techniques, and Probability.

Instructional Learning Outcomes

Unit Wise Learning Outcomes:

UNIT I

CELLULAR MOBILE RADIO SYSTEMS :

Students can be able to:

- **Identify the difference between Mobile and Cellular communication.**
- **Measure the performance of a cellular system.**
- **Understand, why to use Hexagonal shaped cells.**
- **Differentiate between Analog and Digital Cellular systems.**

UNIT II

FUNDAMENTALS OF CELLULAR RADIO SYSTEM DESIGN:

Students can be able to:

- **Understand the concept of frequency channels.**
- **Estimate the Co-Channel Interference Reduction Factor and C/I.**
- **Understand the concept of omni directional Antenna system.**
- **Understand the concept of Cell splitting.**

UNIT III

CO-CHANNEL INTERFERENCE :

Students can be able to:

- **Understand the concept of Co-Channel Interference.**
- **Understand the concept of real time Co-Channel interference.**
- **Understand the concept of Co-Channel measurement.**
- **Can design an Antenna system.**
- **Understand the concept of Antenna parameters and their effects.**

- **Understand the concept of Diversity receiver, non-co-channel interference- different types**.

UNIT IV

NON CO- CHANNEL INERFERENCE :

Students can be able to:

- **Study about adjacent channel interference, near and far end interference .**
- **Understand the effects of cell site components.**
- **Understand the concept of UHF interference.**

UNIT V

CELL COVERAGE FOR SIGNAL AND TRAFFIC :

Students can be able to:

- **Know the concept of signal reflects in flat and hilly terrain.**
- **Understand the concept of phase difference between direct and reflected paths.**
- **Understand the concept of general formula for mobile propagation over water and flat open area.**

UNIT VI

CELL SITE AND MOBILE ANTENNAS:

Students can be able to:

- **Understand the concept of sum and difference patterns and their synthesis.**
- **Understand the concept of interference reduction.**

UNIT VII

FREQUENCY MANAGEMENT AND CHANNEL ASSIGNMENT:

Students can be able to:

- **Understand the concept of numbering and grouping, setup access and paging channels.**
- **Understand the concepts of channel assignments to cell sites and mobile units.**
- **Understand the concepts of channel sharing and borrowing , sectorization**

UNIT VIII

HANDOFFS AND DROPPED CALLS:

Students can be able to:

- **Understand what is Handoff.**
- **Understand the concepts of dropped calls and cell splitting, types of handoff.**
- **Understand the concepts of handoff invitation, delaying handoff, forced handoff, mobile assigned handoff.**
- **Understand the concepts of Intersystem handoff, cell splitting, micro cells, vehicle locating methods, dropped call rates and their evaluation.**

Course mapping with PEOs and Pos

PROGRAMME OUTCOMES:

1. An ability to apply knowledge of Mathematics, Science, and Engineering to solve complex engineering problems of Electronics and Communication Engineering systems.
2. An ability to model, simulate and design Electronics and Communication Engineering systems, conduct experiments, as well as analyze and interpret data and prepare a report with conclusions.
3. An ability to design an Electronics and Communication Engineering system, component, or process to meet desired needs within the realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
4. An ability to function on multidisciplinary teams involving interpersonal skills.
5. An ability to identify, formulate and solve engineering problems of multidisciplinary nature.
6. An understanding of professional and ethical responsibilities involved in the practice of Electronics and Communication Engineering profession.
7. An ability to communicate effectively with a range of audience on complex engineering problems of multidisciplinary nature both in oral and written form.
8. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.
9. A recognition of the need for, and an ability to engage in life-long learning and acquire the capability for the same.
10. A knowledge of contemporary issues involved in the practice of Electronics and Communication Engineering profession

11. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.
12. An ability to use modern Electronic Design Automation (EDA) tools, software and electronic equipment to analyze, synthesize and evaluate Electronics and Communication Engineering systems for multidisciplinary tasks.
13. Apply engineering and project management principles to one's own work and also to manage projects of multidisciplinary nature.

Mapping of Course with Programme Educational Objectives: (Sample)

S.No	**Course component**	**code**	**course**	**Semester**	**PEO 1**	**PEO 2**	**PEO 3**
1	CMC		CMC	1	√	√	

Mapping of Course outcomes with Programme outcomes:

*When the course outcome weightage is < 40%, it will be given as moderately correlated (1).
*When the course outcome weightage is >40%, it will be given as strongly correlated (2).

POs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
CMC	**1**	**2**	**2**	**2**	**2**	**2**		**2**	**2**		**2**		
CMC1. Understand Mobile and Cellular Communication.	**1**	**2**		**2**									
CMC2. Understand Cellular Dialing.	**1**	**2**	**2**	**2**		**2**			**2**				**CMC**
CMC3.Understand Different Communication networks.	**1**	**2**	**2**	**2**	**2**	**2**		**2**	**2**		**2**		

I/C

Dr. V. Satya Srinivas

Class Time Table

Individual Time Table

Micro Plan with dates and closure report:

Sl. No.	Unit No.	Total no. of Periods	Date	Topic to be covered	Reg/ Additional Topics	Teaching aids used LCD/OHP /BB	Remarks
1.	UNIT I	7		**CELLULAR MOBILE RADIO SYSTEMS:**			
2				Introduction to Cellular Mobile system,	Regular	PPT/BB	
3				Performance criteria,	Regular	PPT/BB	
4				uniqueness of mobile radio Environment,	Regular	PPT/BB	
5				operation of cellular systems, Hexagonal Shaped cells,	Regular	PPT/BB	
6				Analog and Digital cellular systems.	Regular	PPT/BB	
7				**Tutorial class**		BB	
8				Trend of mobile Wireless	**Additional**	PPT/BB	
9.	UNIT II	9		**ELEMENTS OF CELLULAR RADIO SYSTEM DESIGN:**			
10				General description of the problem ,	Regular	PPT/BB	
11				Frequency channels, Co-channel interference reduction Factor,	Regular	PPT/BB	
12				Desired C/I in a Omni directional Antenna Systems,	Regular	PPT/BB	
13				Cell splitting,	Regular	PPT/BB	
14				Consideration of the Components Of Cellular systems.	Regular	PPT/BB	
15				Standard bodies Spectrum for 3G	**Additional**	PPT/BB	
16				**Tutorial class**		BB	
17				**Solving university Papers**		BB	
18				**Assignment**			
19	UNIT III	5		**CO-CHANNEL INTERFERENCE:**			
20				Introduction to Co-Channel Interference,	Regular	PPT/BB	
21				Real time Co-Channel Interference, Co Channel measurement,	Regular	PPT/BB	
22				design of Antenna systems,	Regular	PPT/BB	
23				Antenna Parameters and their effects, diversity receiver	Regular	PPT/BB	
26				**Tutorial class**		BB	
27	UNIT IV	5		**NON CO-CHANNEL INTERFERENCE:**			
28				Adjacent channel interference, near end far end interference	Regular	PPT/BB	
29				Cross talk, effects on coverage and interference by power decrease	Regular	PPT/BB	
30				Antenna height decrease	Regular	PPT/BB	
31				Effects of cell site components	Regular	PPT/BB	
32				UHF TV interference	Regular	PPT/BB	
				Tutorial class	Regular	BB	

				Mid Test I			
33	**UNIT V**			**CELL COVERAGE FOR SIGNAL AND TRAFFIC:**			
34				Signal reflections in flat and hilly terrain effect of human made Structures,	Regular	PPT/BB	
35				phase difference b/w direct & reflected paths,	Regular	LCD /BB	
36				Constant standard deviation, straight line path loss slope,	Regular	PPT/BB	
37		**9**		General formula for propagation over water & Flat open area, near and long distance	Regular	PPT/BB	
38				Antenna height gain, form of a Point to point model.	Regular	PPT/BB	
39				Special features of Handling Traffic	**Additional**	PPT/BB	
40				**Solving university Papers**		BB	
41				**Tutorial class**		BB	
42				**Assignment**			
43				**Mid test I**			
44	**UNIT VI**			**CELL SITE AND MOBILE ANTENNAS:**			
45				Sum & difference Patterns & their synthesis, omni directional antennas	Regular	PPT/BB	
46				Directional antennas for interference reduction	Regular	PPT/BB	
47		**6**		space Diversity antennas, umbrella pattern antennas,	Regular	PPT/BB	
48				minimum Separation of cell site antennas,	Regular	PPT/BB	
49				High gain antennas	Regular	PPT/BB	
50				**Tutorial class.**		BB	
51	**UNIT VII**			**FREQUENCY MANAGEMENT AND CHANNEL ASSIGNMENT**		PPT/BB	
52				Numbering and grouping, setup access & Paging channels,	Regular	PPT/BB	
53				channel assignments to cells sites and Mobile units,	Regular	PPT/BB	
54		**8**		channel sharing & borrowing,	Regular	PPT/BB	
55				sectorization,	Regular	PPT/BB	
56				Overlaid cells on fixed Channels assignment.	Regular	PPT/BB	
57				**Solving university Papers**		BB	
58				**Tutorial class**		BB	
59				**Assignment**			
60	**UNIT VII**			**HAND OFF AND TRAFFIC**:			
61				types of Handoff, dropped calls & cell splitting,	Regular	PPT/BB	
62				handoff, handoff invitation, delaying handoff, forced handoff,	Regular	PPT/BB	
63				Mobile assigned handoff, intersystem handoff,	Regular	PPT/BB	
64		**7**		cell splitting, micro cells, vehicle locating methods,	Regular	PPT/BB	
65				dropped call rates and their Evaluation,	Regular	PPT/BB	
66				Power Difference Handoff	**Additional**	PPT/BB	
67				**Tutorial class.**		BB	
				Mid test II			

Course Review (By the concerned Faculty):

(I)Aims

(II) Sample check

(III) End of the course report by the concerned faculty

GUIDELINES:

Distribution of periods:

No. of classes required to cover JNTU syllabus	**:**	**51**
No. of classes required to cover Additional topics	**:**	**05**
No. of classes required to cover Assignment tests (for every 2 units 1 test)		
No. of classes required to cover tutorials	**:**	**06**
No. of classes required to cover Mid tests	**:**	**3**
No of classes required to solve University	**:**	**2**
Total	**:**	**67**

Detailed Lecture notes

Unit I

Cellular Mobile Radio Systems

1. Introduction

A wireless mobile communication network enables users equipped with mobile terminals to initiate and receive phone calls. This capability is referred to as cellular telephony. In the following we describe mobile networks and the mobile terminals used by mobile subscribers to carry out cellular calls. We proceed with an account of the history of cellular telephony and elaborate on the evolution of networks and subscriber services, including the convergence of data networks towards the wired Internet standards.

Cellular telephony has evolved to include many services that are based on the transmission of data and multimedia, not just voice. Mobile subscriber services offered by cellular operators are described next. The underlying technologies of some services are detailed as well. Finally, we end with a description of cellular telephony quality-of-service and explain how cellular operators bill for user services.

2. Mobile networks

Cellular telephony derives its name from the partition of a geographic area into small "cells". Each cell is covered by a local radio transmitter and receiver just powerful enough to enable connectivity with cellular phones, referred to also as mobile terminals, within its area (Figure 1). The set of cells forms the radio access network, and the radio frequencies used for the transmission of calls and data can be reused between cells. A different type of reuse, digital code reuse, is used in CDMA-based networks described later on. Voice and data exchanged between a mobile terminal and regular phone networks, or the Internet, are transmitted via the mobile network which consists of the cellular operator's radio access network and core network.

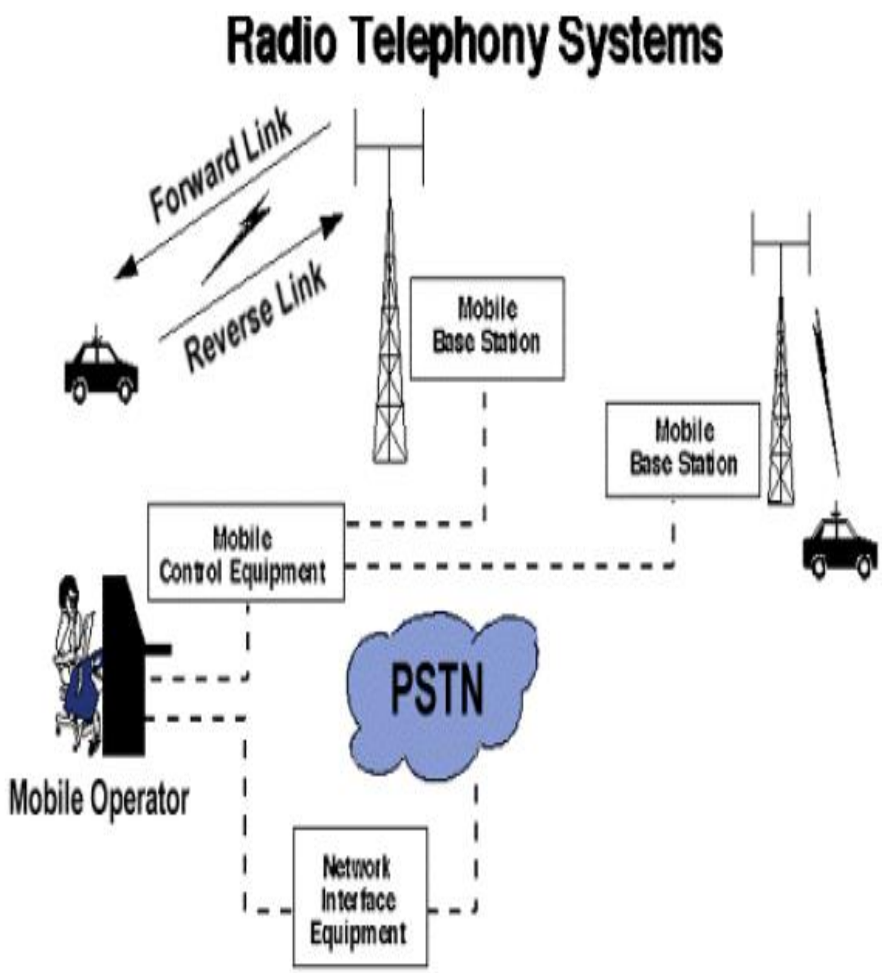


Fig 1: Basic Mobile Telephone service Network

Mobile Telephone using Cellular Concepts:

Interference problems caused by mobile units using the same channel in adjacent areas proved that all channels could not be reused in every cell. Areas had to be skipped before the same channel could be reused. Even though this affected the efficiency of the original concept, frequency reuse was still a viable solution to the problems of mobile telephony systems.

Engineers discovered that the interference effects were not due to the distance between areas, but to the ratio of the distance between areas to the transmitter power (radius) of the areas. By reducing the radius of an area by fifty percent, service providers could increase the number of potential customers in an area fourfold. Systems based on areas with a one-kilometer radius would have one hundred times more channels than systems with areas ten kilometers in radius. Speculation led to the conclusion that by reducing the radius of areas to a few hundred meters, millions of calls could be served.

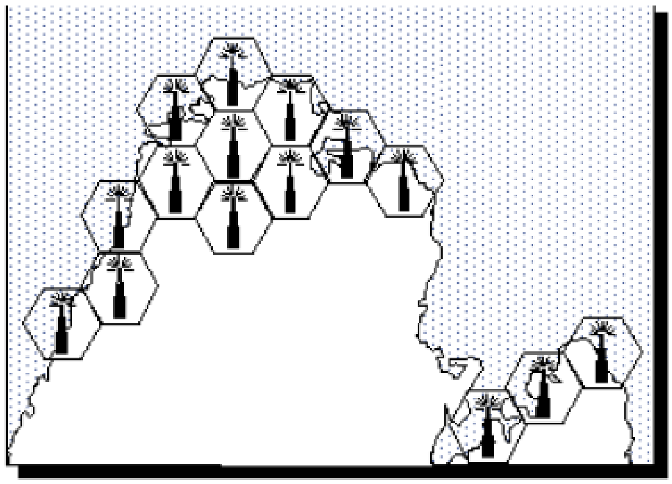


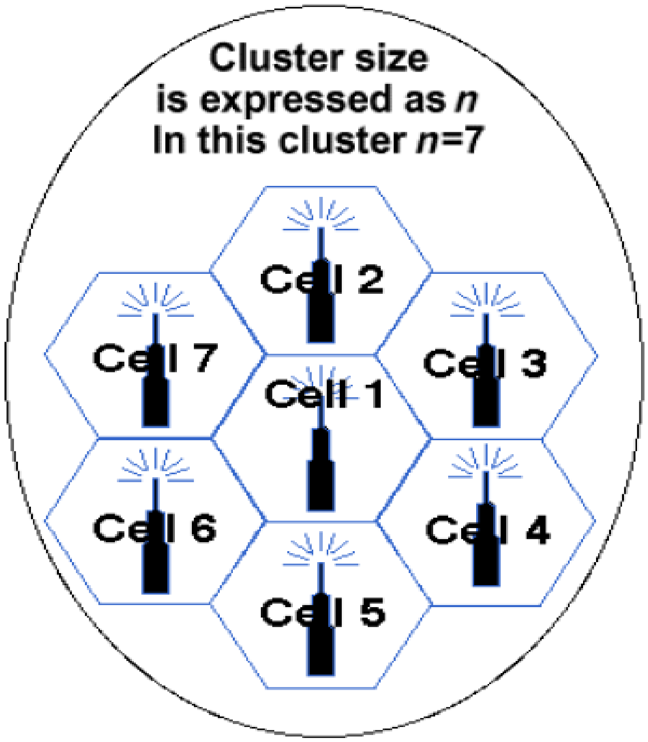
Fig 2 :Mobile Telephone System using Cellular Architecture

The term *cellular* comes from the honeycomb shape of the areas into which a coverage region is divided. Cells are base stations transmitting over small geographic areas that are represented as hexagons. Each cell size varies depending on the landscape. Because of constraints imposed by natural terrain and man-made structures, the true shape of cells is not a perfect hexagon.

Clusters

A cluster is a group of cells. No channels are reused within a cluster. Figure 4 illustrates a seven-cell cluster.

Figure 4: A Seven-Cell Cluster

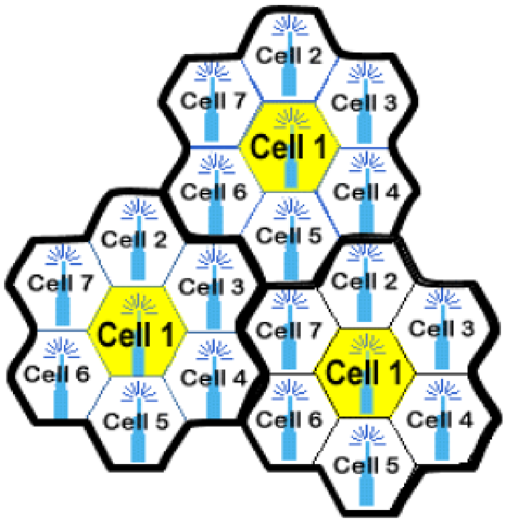


Frequency Reuse

Because only a small number of radio channel frequencies were available for mobile systems, engineers had to find a way to reuse radio channels in order to carry more than one conversation at a time. The solution the industry adopted was called frequency planning or frequency reuse. Frequency reuse was implemented by restructuring the mobile telephone system architecture into the cellular concept.

The concept of frequency reuse is based on assigning to each cell a group of radio channels used within a small geographic area. Cells are assigned a group of channels that is completely different from neighboring cells. The coverage area of cells are called the footprint. This footprint is limited by a boundary so that the same group of channels can be used in different cells that are far enough away from each other so that their frequencies do not interfere (see Figure 5).

Figure 5: Frequency Reuse



Cells with the same number have the same set of frequencies. Here, because the number of available frequencies is 7, the frequency reuse factor is 1/7. That is, each cell is using 1/7 of available cellular channels.

Cell Splitting

Unfortunately, economic considerations made the concept of creating full systems with many small areas impractical. To overcome this difficulty, system operators developed the idea of cell splitting. As a service area becomes full of users, this approach is used to split a single area into smaller ones. In this way, urban centers can be split into as many areas as necessary in order to provide acceptable service levels in heavy-traffic regions, while larger, less expensive cells can be used to cover remote rural regions (see Figure 6).

Figure 6: Cell Splitting

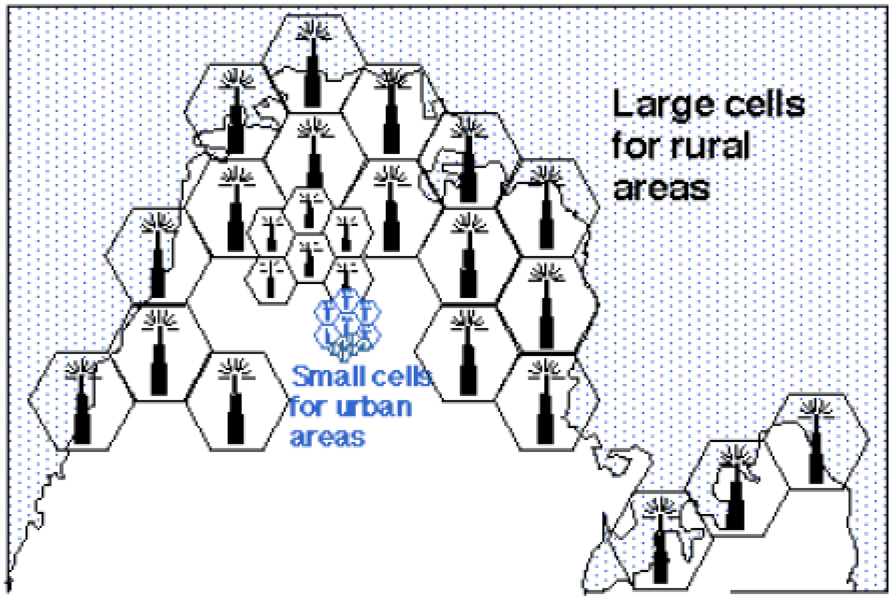
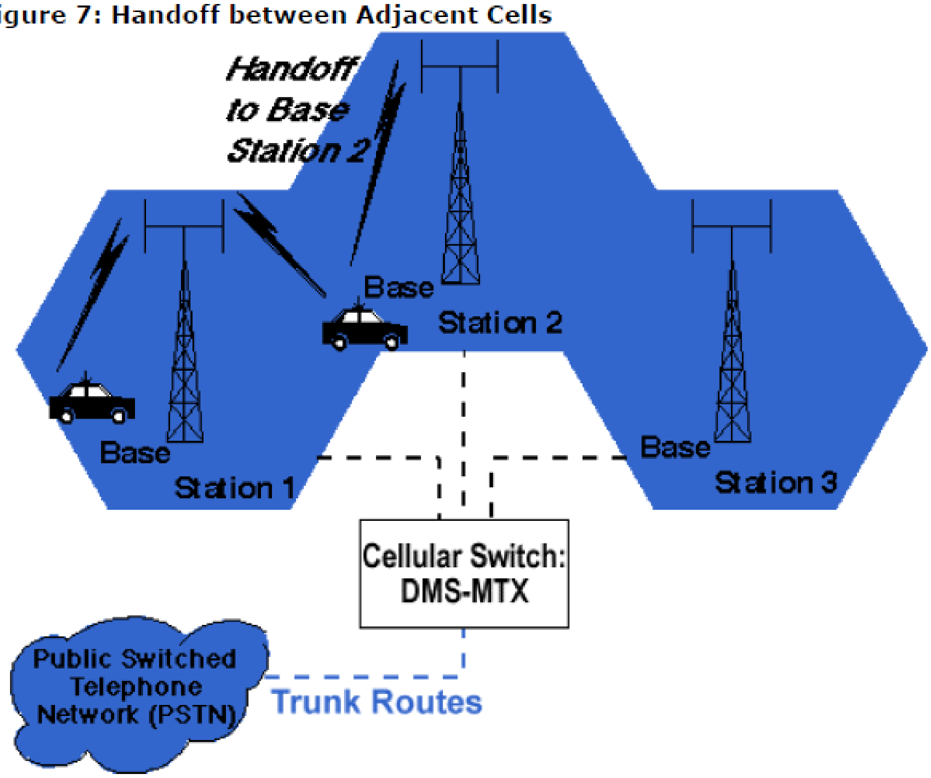


Figure 7: Handoff between Adjacent Cells



4. North American Analog Cellular Systems

Originally devised in the late 1970s to early 1980s, analog systems have been revised somewhat since that time and operate in the 800-MHz range. A group of government, telco, and equipment manufacturers worked together as a committee to develop a set of rules (protocols) that govern how cellular subscriber units (mobiles) communicate with the "cellular system." System development takes into consideration many different, and often opposing, requirements for the system, and often a compromise between conflicting requirements results. Cellular development involves some basic topics:

1. frequency and channel assignments
2. type of radio modulation
3. maximum power levels
4. modulation parameters
5. messaging protocols
6. call-processing sequences

The Advanced Mobile Phone Service (AMPS)

AMPS was released in 1983 using the 800-MHz to 900-MHz frequency band and the 30 kHz bandwidth for each channel as a fully automated mobile telephone service. It was the first standardized cellular service in the world and is currently the most widely used standard for cellular communications. Designed for use in cities, AMPS later expanded to rural areas. It maximized the cellular concept of frequency reuse by reducing radio power output. The AMPS telephones (or handsets) have the familiar telephone-style user interface and are compatible with any AMPS base station. This makes mobility between service providers (roaming) simpler for subscribers. Limitations associated with AMPS include:

1. low calling capacity
2. limited spectrum
3. no room for spectrum growth
4. poor data communications
5. minimal privacy
6. inadequate fraud protection

AMPS is used throughout the world and is particularly popular in the United States, South America, China, and Australia. AMPS uses frequency modulation (FM) for radio transmission. In the United States, transmissions from mobile to cell site use separate frequencies from the base station to the mobile subscriber.

BASIC CELLULAR SYSTEMS

There are two basic cellular systems; one is the circuit-switched system and the other is the packet-switched system.

Circuit-Switched Systems

In a circuit-switched system, each traffic channel is dedicated to a user until its cell is terminated. We can further distinguish two circuit-switched systems: one for an analog system and one for a digital system.

A. Analog System

A basic analog cellular system[1-3] consists of three subsystems: a mobile unit, a cell site,
and a mobile telephone switching office (MTSO), as Fig. 2.1 shows, with connections
to link the three subsystems.

1. **Mobile units.** A mobile telephone unit contains a control unit, a transceiver, and an antenna system.
2. **Cell site.** The cell site provides interface between the MTSO and the mobile units. It has a control unit, radio cabinets, antennas, a power plant, and data terminals.
3. **MTSO.** The switching office, the central coordinating element for all cell sites, contains the cellular processor and cellular switch. It interfaces with telephone company zone offices, controls call processing, provides operation and maintenance, and handles billing activities.
4. **Connections.** The radio and high-speed data links connect the three subsystems. Each mobile unit can only use one channel at a time for its communication link. But the channel is not fixed; it can be any one in the

entire band assigned by the serving area, with each site having multichannel capabilities that can connect simultaneously to many mobile units.

B. Digital Systems

A basic digital system consists of four elements: mobile station, base transceiver station (BTS), base station controller (BSC), and switching subsystems, as shown in Fig. 2.2.

- **MS:** It consists of two parts, mobile equipment (ME) and subscriber identify module (SIM). SIM contains all subscriber-specific data stored on the MS side.
- **BTS:** Besides having the same function as the analog BTS, it has the Transcoder/Rate Adapter Unit (TRAU), which carries out coding and decoding as well as rate adaptation in case data rate varies.
- **BSC:** A new element in digital systems that performs the Radio Resource (RR) management for the cells under its control. BSC also handles handovers, power management time and frequency synchronization, and frequency reallocation among BTSs.
- Switching subsystems:

MSC: The main function of MSC is to coordinate the setup of calls between MS and PSTN users.

a. VLR (Visitor Location Register): A database of all mobiles roaming in the MSC's area of control.
b. HLR (Home Location Register): A centralized database of all subscribers registered in a Public Land Mobile Network (PLMN).
c. AUC (Authentication Center): Provides HLR with authentication parameters and ciphering keys that are used for security purposes.
d. EIR (Equipment Identity Register): A database for storing all registered mobile equipment numbers.
e. IWF: Provides the subscriber with data services that can acessdatarate and protocol conversion facilities and interfaces with public and private data networks.
f. EC (Echo Canceller): Used on the PSTN side of the MSC for all voice circuits.
g. XC (Transcoder): Usually installs in each BTS. But for the cost reason, it can be installed in BSC or MSC.
h. OMC (Operational and Maintenance Center): This function resided in analog MSC but became a separated entity in digital systems.

Packet-Switched System

A cellular packet-switched system is shown in Fig. 2.3.

There are six elements: MS, Node B, RNC, SGSN, GGSN, and GF as shown in Fig. 2.3.

MS: Provides the voice and packet data services. It is also called UE (User Equipment).

Node B: The name for base station in GSM.

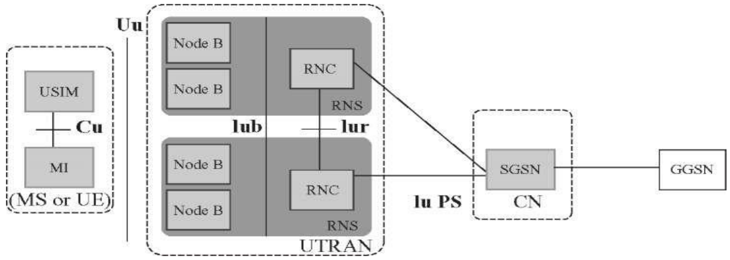


FIGURE 2.3 Cellular packet system.

RNC (Radio Network Controller): Controls the radio resources of the Node Bs that are connected to it. Its function is similar to BSC. A device PCU (Packet Control Unit) converts the data stream into packet format.

SGSN (Service GPRS Support Node): Analogous to MSC/VLR in the circuit-switched system. This includes mobility management, security, and access control functions. It interfaces to HLR.

GGSN (Gateway GPRS Support Node): The point of interface with external packet

data networks such as the Internet.

CGF (Changing Gateway Function): *Mainly for billing.*

PERFORMANCE CRITERIA

1. Voice Quality

Voice quality is very hard to judge without subjective tests for users' opinions. In this technical area, engineers cannot decide how to build a system without knowing the voice quality that will satisfy the users. In military communications, the situation differs: armed forces personnel must use the assigned equipment.

2. Data Quality

There are several ways to measure the data quality such as bit error rate, chip error rate, symbol error rate, and frame error rate. The chip error rate and symbol error rate are measuring the quality of data along the transmission path. The frame error rate and the bit error rate are measuring the quality of data at the throughput.

3.Picture/Vision Quality

There are color acuity, depth perception, flicker perception, motion perception, noise perception, and visual acuity. The percentage of pixel (picture element) loss rate can be characterized in vertical resolution loss and horizontal resolution loss of a pixel.

4.Service Quality

Three items are required for service quality.

1. Coverage. The system should serve an area as large as possible. With radio coverage, however, because of irregular terrain configurations, it is usually not practical to cover 100 percent of the area for two reasons:

a. The transmitted power would have to be very high to illuminate weak spots with sufficient reception, a significant added cost factor.

b. The higher the transmitted power, the harder it becomes to control interference.

Therefore, systems usually try to cover 90 percent of an area in flat terrain and 75 percent of an area in hilly terrain. The combined voice quality and coverage criteria in AMPS cellular systems[3] state that 75 percent of users rate the voice quality between good and excellent in 90 percent of the served area, which is generally flat terrain. The voice quality and coverage criteria would be adjusted as per decided various terrain conditions. In hilly terrain, 90 percent of users must rate voice quality good or excellent in 75 percent of the served area. A system operator can lower the percentage values stated above for a low-performance and low-cost system.

2. **Required grade of service.** For a normal start-up system, the grade of service is specified for a blocking probability of .02 for initiating calls at the busy hour. This is an average value. However, the blocking probability at each cell site will be different. At the busy hour, near freeways, automobile traffic is usually heavy, so the blocking probability at certain cell sites may be higher than 2 percent, especially when car accidents occur. To decrease the blocking probability requires a good system plan and a sufficient number of radio channels.

3. **Number of dropped calls.** During Q calls in an hour, if a call is dropped and Q — 1 calls are completed, then the call drop rate is 1/Q. This drop rate must be kept low. A high drop rate could be caused by either coverage problems or handoff problems related to inadequate channel availability or weak reception.

UNIQUENESS OF MOBILE RADIO ENVIRONMENT

2.3.1 Description of Mobile Radio Transmission Medium

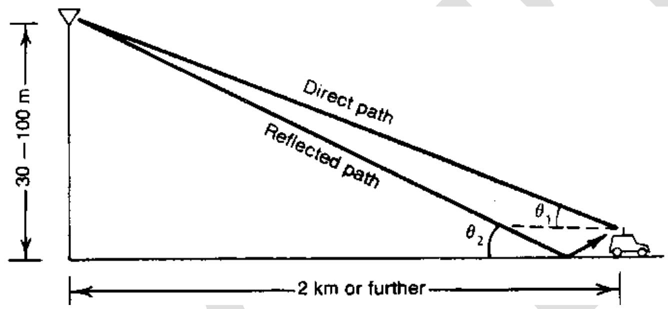
2.3.1.1 The Propagation Attenuation. In general, the propagation path loss increases not only with frequency but also with distance. If the antenna height at the cell site is 30 to 100 m and at the mobile unit about 3 m above the ground, and the distance between the cell site and the mobile unit is usually 2 km or more, then the incident angles of both the direct wave and the reflected wave are very small, as Fig. 2.4 shows. The incident angle of the direct wave is $\mathbf{9_1}$**,** and the incident angle of the reflected wave is $\mathbf{0_2}$**.** $\mathbf{0_1}$ is also called the **elevation angle.** The propagation path loss would be 40 dB/dec,[4] where "dec" is an abbreviation of **decade,** i.e., a period of 10. This means that a 40-dB loss at a signal receiver will be observed by the mobile unit as it moves from 1 to 10 km. Therefore **C** is inversely proportional to **R .**[4]

$$\mathbf{C}\ \mathbf{a}\ R^{-4} = \mathbf{a}R^{-4} \qquad (2.3\text{-}1)$$

where **C =** received carrier power

R = distance measured from the transmitter to the receiver

a = constant



Model of Transmission Medium:

A mobile radio signal **r(t),** illustrated in Fig. 2.6, can be artificially characterized[5] by two components **m(t)** and $r_0(t)$ based on natural physical phenomena.

$$r\,(t) = \mathbf{m(t}\,)ro(t)$$

The component **m(t)** is called **local mean, long-term fading,** or **lognormal fading** and its variation is due to the terrain contour between the base station and the mobile unit. The factor r_0 is called **multipath fading, short-term fading,** or **Rayleigh fading** and its variation is due to the waves reflected from the surrounding buildings and other structures.

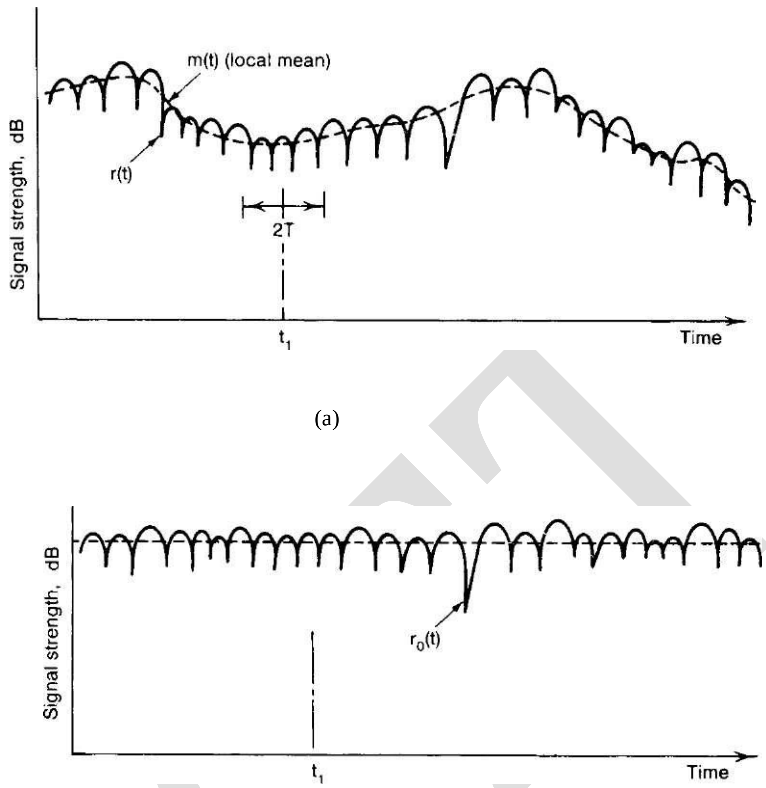
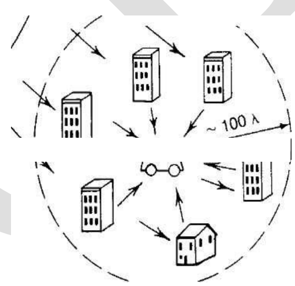


FIGURE 2.6 A mobile radio signal fading representation. **(a)** A mobile signal fading. **(b)** A short-term signal fading.

2.3.3 Mobile Fading Characteristics

Rayleigh fading is also called multipath fading in the mobile radio environment. When these multipath waves bounce back and forth due to the buildings and houses, they form many standing-wave pairs in space, as shown in Fig. 2.7. Those standing-wave pairs are summed together and become an irregular wave-fading structure. When a mobile unit is standing still, its receiver only receives a signal strength at that spot, so a constant signal is observed. When the mobile unit is moving, the fading structure of the wave in the space is received. It is a multipath fading. The recorded fading becomes fast as the vehicle moves faster.

2.3.3.1 **The Radius of the Active Scatterer Region.** The mobile radio multipath fading shown in Fig. 2.7 explains the fading mechanism. The radius of the active scatterer region at 850 MHz can be obtained indirectly as shown in Ref. 7. The radius is roughly 100 wavelengths. The active scatterer region always moves with the mobile unit as its center. It means that some houses were inactive scatterers and became active as the mobile unit approached them; some houses were active scatterers and became inactive as the mobile unit drove away from them.



Unit-2

ELEMENTS OF CELLULAR RADIO SYSTEM DESIGN

CONCEPT OF FREQUENCY CHANNELS:

A radio channel consists of a pair of frequencies, one for each direction of transmission that is used for full-duplex operation. A particular radio channel, say *F*1, used in one geographic zone as named it a cell, say *C*1, with a coverage radius *R* can be used in another cell with the same coverage radius at a distance *D* away.
Frequency reuse is the core concept of the cellular mobile radio system. In this frequency reuse system, users in different geographic locations (different cells) may simultaneously use the same frequency channel (see Fig. 2.13). The frequency reuse system can drastically increase the spectrum efficiency, but if the system is not properly designed, serious interference may occur. Interference due to the common use of the same channel is called *cochannel interference* and is our major concern in the concept of frequency reuse.

2.1 FREQUENCY REUSE SCHEMES:

The frequency reuse concept can be used in the time domain and the space domain. Frequency reuse in the time domain results in the occupation of the same frequency in different time slots. It is called *time-division multiplexing* (TDM). Frequency reuse in the space domain can be divided into two categories.

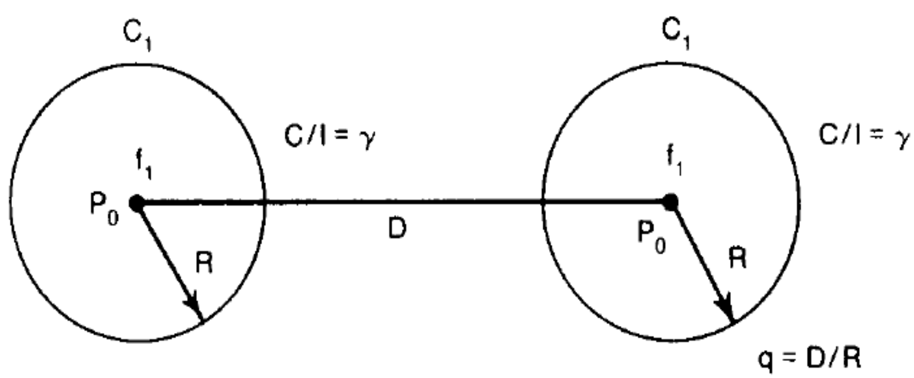
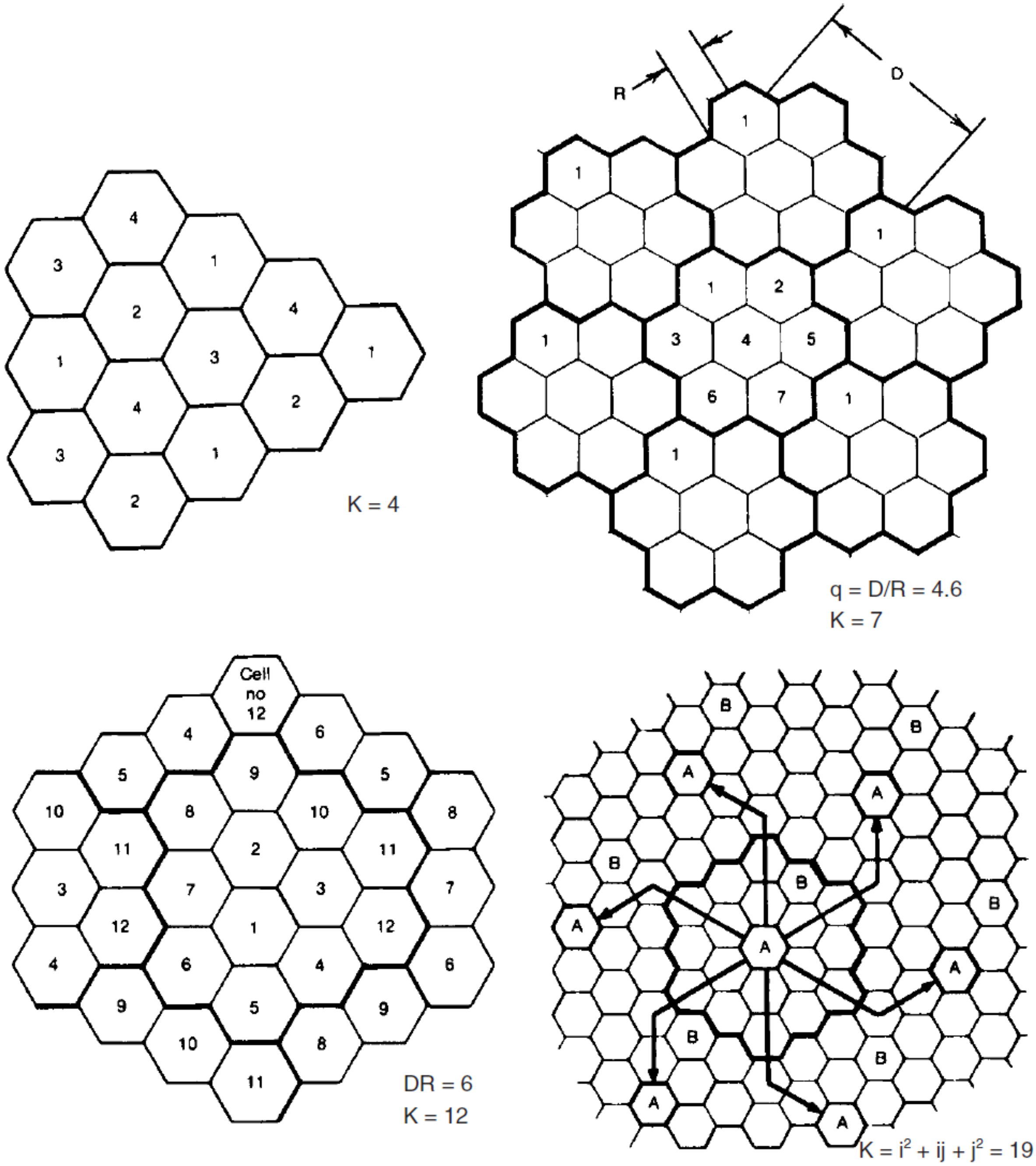


FIGURE 2.13 The ratio of *D/R*.



12 Cell reuse pattern to start-up configuration

Shift parameters i = 3, j = 2

FIGURE 2.14 *N*-cell reuse pattern.

1. Same frequency assigned in two different geographic areas, such as AM or FM radio stations using the same frequency in different cities.
2. Same frequency repeatedly used in a same general area in one system2—the scheme

is used in cellular systems. There are many cochannel cells in the system. The total frequency spectrum allocation is divided into *K* frequency reuse patterns, as illustrated in Fig. 2.14 for *K* = 4, 7, 12, and 19.

FREQUENCY REUSE DISTANCE:

The minimum distance that allows the same frequency to be reused will depend on many factors, such as the number of cochannel cells in the vicinity of the center cell, the type of geographic terrain contour, the antenna height, and the transmitted power at each cell site.

The frequency reuse distance *D* can be determined3,16,17 from

$$D = \sqrt{3K}\,R \qquad (2.5\text{-}1)$$

Where *K* is the frequency reuse pattern shown in Fig. 2.13

If all the cell sites transmit the same power, then *K* increases and the frequency reuse distance *D* increases. This increased *D* reduces the chance that cochannel interference may occur. Theoretically, a large *K* is desired. However, the total number of allocated channels is fixed. When *K* is too large, the number of channels assigned to each of *K* cells becomes small. It is always true that if the total number of channels in *K* cells is divided as *K* increases, trunking inefficiency results.18 The same principle applies to spectrum inefficiency: if the total number of channels are divided into two network systems serving in the same area, spectrum inefficiency increases.

Now the challenge is to obtain the smallest number *K*17 that can still meet our system performance requirements. This involves estimating cochannel interference and selecting the minimum frequency reuse distance *D* to reduce cochannel interference. The smallest value of *K* is *K* = 3, obtained by setting $i = 1$, $j = 1$ in the equation $K = i\,2 + i\,j + j\,2$

NUMBER OF CUSTOMERS IN SYSTEM:

When we design a system, the traffic conditions in the area during a busy hour are some of the parameters that will help determine both the sizes of different cells and the number of channels in them.

The maximum number of calls per hour per cell is driven by the traffic conditions at each particular cell. After the maximum number of frequency channels per cell has been implemented in each cell, then the maximum number of calls per hour can be taken care of in each cell. Now, take the maximum number of calls per hour in each cell Q_i and sum them over all cells. Assume that 60 percent of the car phones will be used during the busy hour, on average, one call per phone ($\eta_c = 0.6$) if that phone is used. The total allowed subscriber traffic M_t can then be obtained.

EXAMPLE *During a busy hour, the number of calls per hour* Q_i *for each of 10 cells is 2000, 1500, 3000, 500, 1000, 1200, 1800, 2500, 2800, 900. Assume that 60 percent of the car phones will be used during this period* ($\eta_c = 0.6$) *and that one call is made per car phone. Summing over all* Q_i *gives the total* Q_t

Qt =10
i=1
Qi = 17,200 *calls per hour*
Because ηc = 0.6, the number of customers in the system is Mt = 17,200

CO-CHANNEL INTERFERENCE REDUCTION FACTOR:

Reusing an identical frequency channel in different cells is limited by cochannel interference between cells, and the cochannel interference can become a major problem. Here we would like to find the minimum frequency reuse distance in order to reduce this cochannel interference.

Assume that the size of all cells is roughly the same. The cell size is determined by the coverage area of the signal strength in each cell. As long as the cell size is fixed, cochannel interference is independent of the transmitted power of each cell. It means that the received threshold level at the mobile unit is adjusted to the size of the cell. Actually, cochannel interference is a function of a parameter *q* defined as

$$q = D/R$$

The parameter *q* is the cochannel interference reduction factor. When the ratio *q* increases, cochannel interference decreases. Furthermore, the separation *D* in Eq. (2.6-1) is a function of *KI* and *C/I* ,

$$D = f\,(KI\ ,C/I\ )$$

where *KI* is the number of cochannel interfering cells in the first tier and *C/I* is the received carrier-to-interference ratio at the desired mobile receiver.3

$$\frac{C}{I} = \frac{C}{\sum_{k=1}^{K_I} I_k}$$

In a fully equipped hexagonal-shaped cellular system, there are always six cochannel interfering cells in the first tier, as shown in Fig. 2.15; that is, *KI* = 6. The maximum number of K*I* in the first tier can be shown as six (i.e., 2*πD/D* ≈ 6). Cochannel interference can be experienced both at the cell site and at mobile units in the center cell. If the interference is much greater, then the carrier-to-interference ratio *C/I* at the mobile units caused by the six interfering sites is (on the average) the same as the *C/I* received at the center cell site caused by interfering mobile units in the six cells. According to both the reciprocity theorem and the statistical summation of radio propagation, the two *C/I* values can be very close. Assume that the local noise is much less than the interference level and can be neglected. *C/I* then can be expressed, from Eq. (2.3-4), as

$$\frac{C}{I} = \frac{R^{-\gamma}}{\sum_{k=1}^{K_I} D_k^{-\gamma}}$$

where γ is a propagation path-loss slope5 determined by the actual terrain environment. In a mobile radio medium, γ usually is assumed to be 4 (see Sec. 2.3.1). *KI* is the number of cochannel interfering cells and is equal to 6 in a fully developed system, as shown in Fig. 2.15. The six cochannel interfering cells in the second tier cause weaker interference than those in the first tier (see Example 2.6 at the end of Sec. 2.7.1).

Therefore, the cochannel interference from the second tier of interfering cells is negligible. Substituting Eq. (2.6-1) into Eq. (2.6-4) yields

$$\frac{C}{I} = \frac{1}{\sum_{k=1}^{K_I} \left(\frac{D_k}{R}\right)^{-\gamma}} = \frac{1}{\sum_{k=1}^{K_I} (q_k)^{-\gamma}}$$

where *qk* is the cochannel interference reduction factor with *k*th cochannel interfering cell

$$q_k = \frac{D_k}{R}$$

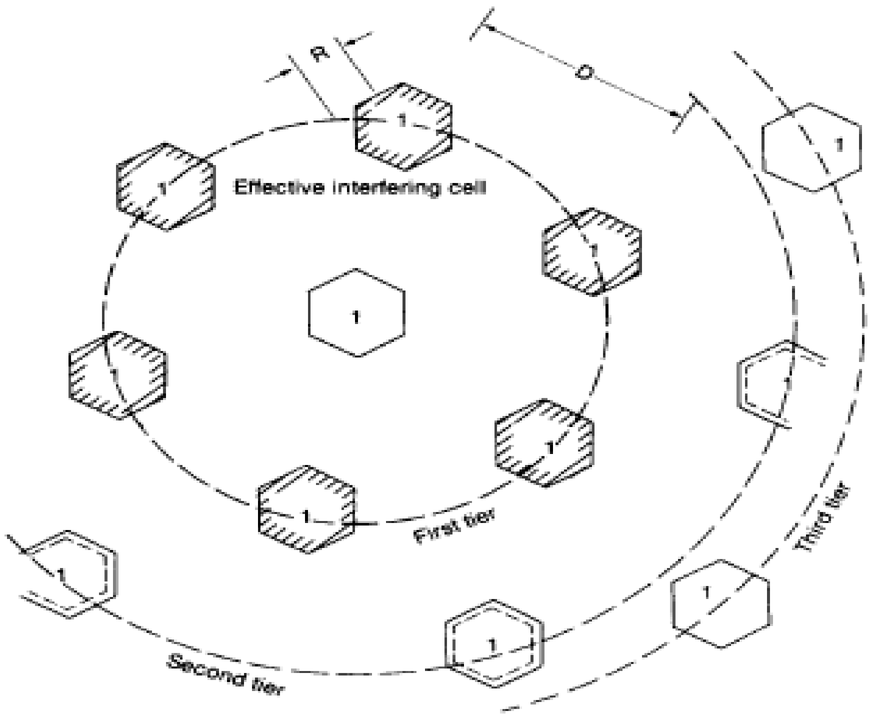


FIGURE 2.15 Six effective interfering cells of cell 1.

DESIRED C/I FROM A NORMAL CASE IN A OMNI DIRECTION ANTENNA SYSTEM:

ANALYTIC SOLUTION:

There are two cases to be considered: (1) the signal and cochannel interference received by the mobile unit and (2) the signal and cochannel interference received by the cell site.

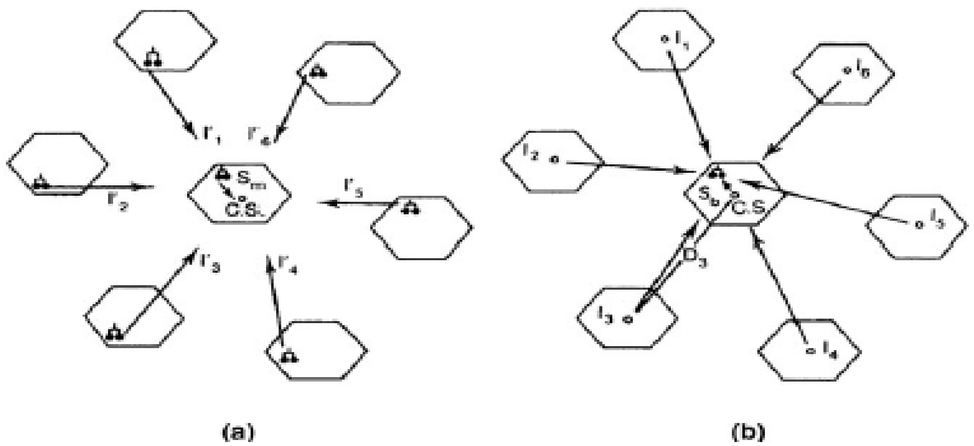


FIGURE 2.16 Cochannel interference from six interferers, (*a*) Receiving at the cell site; (*b*) receiving at the mobile unit.

Both cases are shown in Fig. 2.16. N_m, and N_b are the local noises at the mobile unit and the cell site, respectively. Usually, N_m and N_b are small and can be neglected as compared with the interference level. The effect of the cochannel interference on spectrum efficiency systems will appear in Sec. 15.4. As long as the received carrier-to-interference ratios at both the mobile unit and the cell site are the same, the system is called a *balanced system*. In a balanced system, we can choose either one of the two cases to analyze the system requirement; the results from one case are the same for the others.

Assume that all D_k are the same for simplicity, as shown in Fig. 2.15; then $D = D_k$, and $q = q_k$, and

$$\frac{C}{I} = \frac{R^{-\gamma}}{6D^{-\gamma}} = \frac{q^{\gamma}}{6}$$

Thus

$$q^{\gamma} = 6\frac{C}{I}$$

and

$$q = \left(6\frac{C}{I}\right)^{1/\gamma}$$

the value of *C/I* is based on the required system performance and the specified value of γ is based on the terrain environment. With given values of *C/I* and γ, the cochannel interference reduction factor q can be determined. Normal cellular practice is to specify *C/I* to be 18 dB or higher based on subjective tests and the criterion described in Sec. 2.2. Because a *C/I* of 18 dB is measured by the acceptance of voice quality from present cellular mobile receivers, this acceptance implies that both mobile radio multipath fading and cochannel interference become ineffective at that level. The path-loss slope γ is equal to about 4 in a mobile radio environment.19

$$q = D/R = (6 \times 63.1)^{1/4} = 4.41$$

The 90th percentile of the total covered areawould be achieved by increasing the transmitted power at each cell; increasing the same amount of transmitted power in each cell does not affect the result of Eq. (2.7-4). This is because *q* is not a function of transmitted power. The computer simulation described in the next section finds the value of *q* = 4.6, which is very close to Eq. (2.7-4). The factor *q* can be related to the finite set of cells *K* in a hexagonal-shaped cellular system by

$$q \triangleq \sqrt{3K}$$

Substituting q we get K=7

Equation (2.7-6) indicates that a seven-cell reuse pattern* is needed for a *C/I* of 18 dB. The seven-cell reuse pattern is shown in Fig. 2.14.

Based on *q* = *D/R*, the determination of *D* can be reached by choosing a radius *R* in Eq. (2.7-4). Usually, a value of *q* greater than that shown in Eq. (2.7-4) would be desirable. The greater the value of *q*, the lower the cochannel interference. In a real environment, Eq. (2.6-5) is always true, but Eq. (2.7-1) is not. Because Eq. (2.7-4) is derived from Eq. (2.7-1), the value *q* may not be large enough to maintain a carrier-to-interference ratio of 18 dB. This is particularly true in the worst case.

SOLUTION OBTAINED FROM SIMULATION:

The required cochannel reduction factor *q* can be obtained from the simulation also. Let one main cell site and all six possible cochannel interferers be deployed in a pattern, as shown in Fig. 2.15. The distance *D* from the center cell to the cochannel interferers in the simulation is a variable.

D = 2*R* can be used initially and incremented every 0.5*R* as *D* = 2*R*, 2.5*R*, 3*R*. For every particular value of *D*, a set of simulation data is generated.

First, the location of each mobile unit in its own cell is randomly generated by a random generator. Then the distance *Dk* from each of the six interfering mobile units to the center cell site (assuming *KI* = 6) is obtained. The desired mobile signal as well as six interference levels received at the center cell sitewould be randomly generated following the mobile radio propagation path-loss rule, which is 40 dB/dec, along with a log-normal standard deviation of 8 dB at its mean value.20 Summing up all the data from six simulated interferences,

$$I = \sum_{k=1}^{K_I=6} I_k$$

and dividing it by the simulated main carrier, value *C* becomes *C/I* . This *C/I* is for a particular *D*, the distance between the center cell site and the cochannel cell sites (cochannel interferers). Repeat this process, say 1000 times, for each particular value of *D*, based on the criterion stated in Sec. 2.2.4 (that 75 percent of the users say voice quality is "good" or "excellent" in 90 percent of the total covered area). Then from 75 percent of the users' opinion, *C/I* = 18 dB needs to be achieved18 with a proper value of *D*. Assuming that mobile unit locations are chosen randomly and uniformly, then 90 percent of the area corresponds to 900 out of 1000 mobile unit locations.To find a proper value for *D*, each mobile unit location associates with its received *C/I* . Some *C/I* values are high and some are low. This means that the lowest 100 values of *C/I* should be discarded. The main *C/I* value should be derived from the remaining 900 *C/I* values. This associates a particular *C/I* for a particular separation *D*. Repeating this process for different values of *D*, the corresponding mean *C/I* values are found. The *C/I* versus *D* curve can be plotted, depicting *C/I* = 18 dB as corresponding to *D* = 4.6*R*, as illustrated in the Bell Lab publication.4 Then

$$q = \frac{D}{R} = 4.6$$

Comparing the values of *q* obtained from an analytic solution shown in Eq. (2.7-4) and *q* obtained from a simulation solution shown in Eq. (2.7-7), the results are surprisingly close. Although a simulation (statistical) approach deals with a real-world situation, it does not provide a clear physical picture. The two agreeable solutions illustrated in this section prove that the simple analytic method is implementable in a cellular system based on hexagonal cells.

CELL SPLITTING:

WHY SPLITTING ?

The motivation behind implementing a cellular mobile system is to improve the utilization of spectrum efficiency.19 The frequency reuse scheme is one concept, and cell splitting is another concept. When traffic density starts to build up and the frequency channels *Fi* in each cell *Ci* cannot provide enough mobile calls, the original cell can be split into smaller cells. Usually the new radius is one-half the original radius (see Fig. 2.18). There are two ways of splitting. In Fig. 2.18*a*, the original cell site is not used, while in Fig. 2.18*b*, it is

New cell radius = old cell radius/2

Then, based on Eq. (2.9-1), the following equation is true.

New cell area = old cell area/4

Let each new cell carry the same maximum traffic load of the old cell; then, in theory,
New traffic load/Unit area= 4 × traffic load/unit area

HOW SPLITTING ?

There are two kinds of cell-splitting techniques:

1. *Permanent splitting*. The installation of every new split cell has to be planned ahead of time; the number of channels, the transmitted power, the assigned frequencies, the choosing of the cell-site selection, and the traffic load consideration should all be considered. When ready, the actual service cut-over should be set at the lowest traffic point, usually at midnight on a weekend. Hopefully, only a few calls will be dropped because of this cut-over, assuming that the downtime of the system is within 2 h.

2. *Dynamic splitting*. This scheme is based on using the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a tedious job, as we cannot

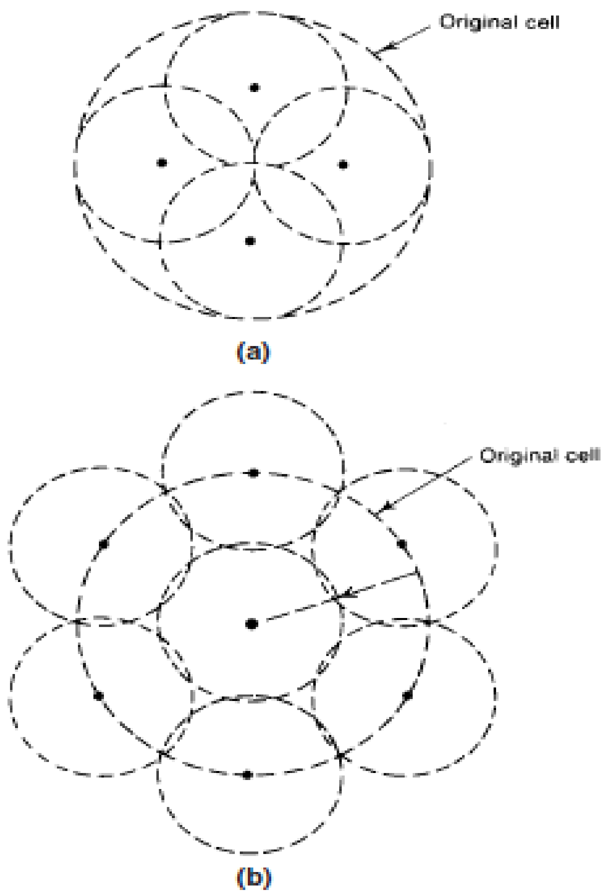


FIGURE 2.

afford to have one single cell unused during cell splitting at heavy t
12.6.2 will discuss this topic in depth.

CONSIDERATION OF THE COMPONENTS OF CELLULAR SYSTEM:

The elements of cellular mobile radio system design have been mentioned in the previous sections. Here we must also consider the components of cellular systems, such as mobile radios, antennas, cell-site, base-station controller, and MTSO. They would affect our system design if we do not choose the right one. The general view of the cellular system is shown in Fig. 2.19. Even though the EIA (Electronic Industries Association) and the FCC have specified standards for radio equipment at the cell sites and the mobile sites, we still needto be concerned about that equipment. The issues affecting choice of antennas, switching equipment, and data links are briefly described here.21−23

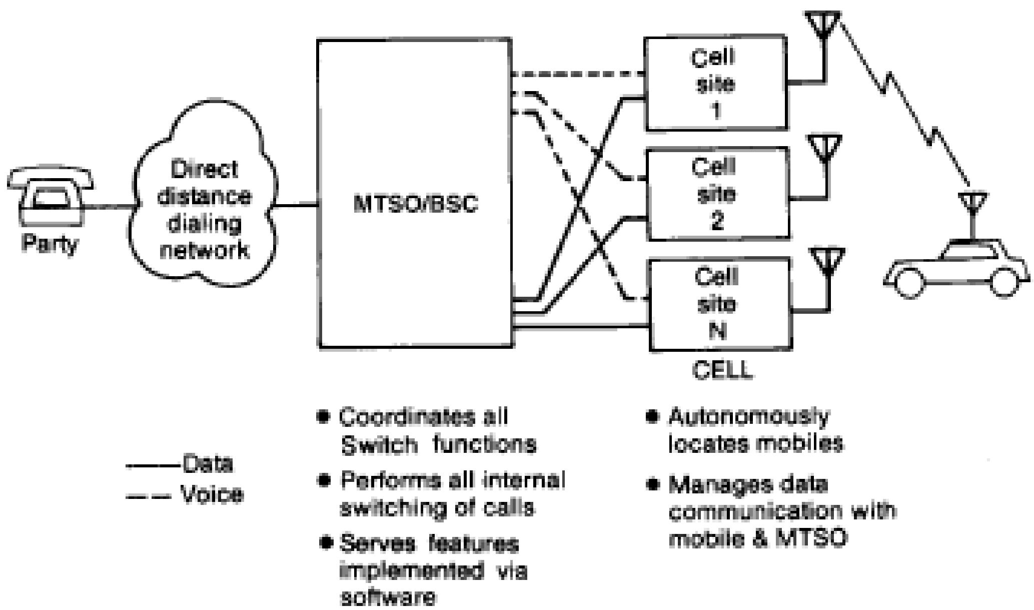


FIGURE 2.19 A general view of cellular telecommunications systems.

Antennas:

Antenna pattern, antenna gain, antenna tilting, and antenna height6 all affect the cellular system design. The antenna pattern can be omnidirectional, directional, or any shape in both the vertical and the horizon planes. Antenna gain compensates for the transmitted power. Different antenna patterns and antenna gains at the cell site and at the mobile units would affect the system performance and so must be considered in the system design. The antenna patterns seen in cellular systems are different from the patterns seen in free space. If a mobile unit travels around a cell site in areas with many buildings, the omnidirectional antenna will not duplicate the omnipattern. In addition, if the front-to-back ratio of a directional antenna is found to be 20 dB in free space, it will be only 10 dB at the cell site. An explanation for these phenomena is given in Chapter 8.

Antenna tilting can reduce the interference to the neighboring cells and enhance the weak spots in the cell. Also, the height of the cell-site antenna can affect the area and shape of the coverage in the system. The effect of antenna height will be described in Chap. 8.

Switching Equipment:

The capacity of switching equipment in cellular systems is not based on the number of switch ports but on the capacity of the processor associated with the switches. In a big cellular system, this processor should be large. Also, because cellular systems are unlike other systems, it is important to consider when the switching equipment would reach the maximum capacity. The service life of the switching equipment is not determined by the life cycle of the equipment but by how long it takes to reach its full capacity. If the switching equipment is designed in modules, or as distributed switches, more modules can be added to increase the capacity of the equipment. For decentralized systems, digital switches may be more suitable. The future trend seems to be the utilization of system handoff. This means that switching equipment can link to other switching equipment so that a call can be carried from one system to another system without the call being dropped. We will discuss these issues in Chap. 13.

Data Links:

The data links are shown in Fig. 2.19. Although they are not directly affected by the cellular system, they are important in the system. Each data link can carry multiple channel data (10 kbps data transmitted per channel) from the cell site to the MTSO. This fast-speed data transmission cannot be passed through a regular telephone line. Therefore, data bank devices are needed. They can be multiplexed, many-data channels passing through a wideband T-carrier wire line or going through a microwave radio link where the frequency is much higher than 850 MHz.

Leasing T1-carrier wire lines through telephone companies can be costly. Although the use of microwaves may be a long-term money saver, the availability of the microwave link has to be considered and is described.

UNIT-3 INTERFERENCE

INTRODUCTION TO CO-CHANNEL INTERFERENCE:

The frequency-reuse method is useful for increasing the efficiency of spectrum usage but results in cochannel interference because the same frequency channel is used repeatedly in different cochannel cells. Application of the cochannel interference reduction factor $q = D/R = 4.6$ for a seven-cell reuse pattern ($K = 7$) is described in Sec.2.7.1

The cochannel interference reduction factor q = 4.6 is based on the system required $C/I = 18$ dB of the AMPS system. From q = 4.6 we can obtain K = 7. Nevertheless, the system required C/I is different from a different system. For those systems with lower required C/I levels, the q values are less.

Here, we use the AMPS system as an example to illustrate the ways of reducing cochannel interference. For other FDMA, TDMA, and OFDMA systems, the same methodology is applied.

In most mobile radio environments, use of a seven-cell reuse pattern is not sufficient to avoid cochannel interference for AMPS systems. Increasing $K > 7$ would reduce the number of cochannels per cell, and that would also reduce spectrum efficiency. Therefore, it might be advisable to retain the same number of radios as the seven-cell system but to sector the cell radially, as if slicing a pie. This technique would reduce cochannel interference and use channel sharing and channel borrowing schemes to increase spectrum efficiency.

REAL TIME AND MEASUREMENT CO-CHANNEL INTERFERENCE:

When the carriers are angularly modulated by the voice signal and the RF frequency difference between them is much higher than the fading frequency, measurement of the signal is

$$e_1 = S(t)\ \sin(\omega t + \phi_1) \tag{9.3-1}$$

and the interference is

$$e_2 = I(t)\ \sin(\omega t + \phi_2) \tag{9.3-2}$$

The received signal is

$$e(t) = e_1(t) + e_2(t) = R\ \sin(\omega t + \psi) \tag{9.3-3}$$

where

$$R = \sqrt{[S(t)\cos\phi_1 + I(t)\cos\phi_2]^2 + [S(t)\sin\phi_1 + I(t)\sin\phi_2]^2} \tag{9.3-4}$$

and

$$\psi = \tan^{-1}\frac{S(t)\sin\phi_1 + I(t)\ \sin\phi_2}{S(t)\cos\phi_1 + I(t)\cos\phi_2} \tag{9.3-5}$$

The envelope R can be simplified in Eq. (9.3-4), and R^2 becomes

$$R^2 = [S^2(t) + I^2(t) + 2S(t)I(t)\cos(\phi_1 - \phi_2)] \tag{9.3-6}$$

Following Kozono and Sakamoto's[2] analysis of Eq. (9.3-6), the term $S^2(t) + I^2(t)$ fluctuates close to the fading frequency V/λ and the term $2S(t)I(t)\cos(\phi_1 - \phi_2)$ fluctuates to a frequency close to $d/dt(\phi_1 - \phi_2)$, which is much higher than the fading frequency. Then the two parts of the squared envelope can be separated as

$$X = S^2(t) + I^2(t) \tag{9.3-7}$$

$$Y = 2S(t)I(t)\ \cos(\phi_1 - \phi_2) \tag{9.3-8}$$

Assume that the random variables $S(t)$, $I(t)$, ϕ_1, and ϕ_2 are independent; then the average processes on X and Y are

$$\overline{X} = \overline{S^2(t)} + \overline{I^2(t)} \tag{9.3-9}$$

$$\overline{Y^2} = 4\overline{S^2(t)I^2(t)}(\tfrac{1}{2}) = 2\overline{S^2(t)I^2(t)} \tag{9.3-10}$$

The signal-to-interference ratio Γ becomes

$$\Gamma = \frac{\overline{S^2(t)}}{\overline{I^2(t)}} = k + \sqrt{k^2 - 1} \tag{9.3-11}$$

where

$$k = \frac{\overline{X^2}}{\overline{Y^2}} - 1 \tag{9.3-12}$$

Because X and Y can be separated in Eq. (9.3-6), the preceding computation of Γ in Eq. (9.3-11) could have been accomplished by means of an envelope detector, analog-to-digital converter, and a microcomputer. The sampling delay time Δt should be small enough to satisfy

$$S(t) \approx S(t + \Delta t), \qquad I(t) \approx I(t + \Delta t) \tag{9.3-13}$$

and

$$\mathrm{E}\left[\cos[\phi_1(t) - \phi_2(t)]\cos[\phi_1(t + \Delta t) - \phi_2(t + \Delta t)]\right] \approx 0 \qquad (9.3\text{-}14)$$

Determining the delay time to meet the requirement of Eq. (9.3-13) for this calculation is difficult and is a drawback to this measurement technique. Therefore, real-time cochannel interference measurement is difficult to achieve in practice.

DESIGN AND PARAMETERS OF ANTENNA SYSTEM:

When the call traffic begins to increase, we need to use the frequency spectrum efficiently and avoid increasing the number of cells K in a seven-cell frequency-reuse pattern. When K increases, the number of frequency channels assigned in a cell must become smaller (assuming a total allocated channel divided by K) and the efficiency of applying the frequency-reuse scheme decreases.

Instead of increasing the number K in a set of cells, let us keep $K = 7$ and introduce a directional-antenna arrangement. The cochannel interference can be reduced by using directional antennas. This means that each cell is divided into three or six sectors and uses three or six directional antennas at a base station. Each sector is assigned a set of frequencies (channels). The interference between two cochannel cells decreases as shown Fig. 9.5.

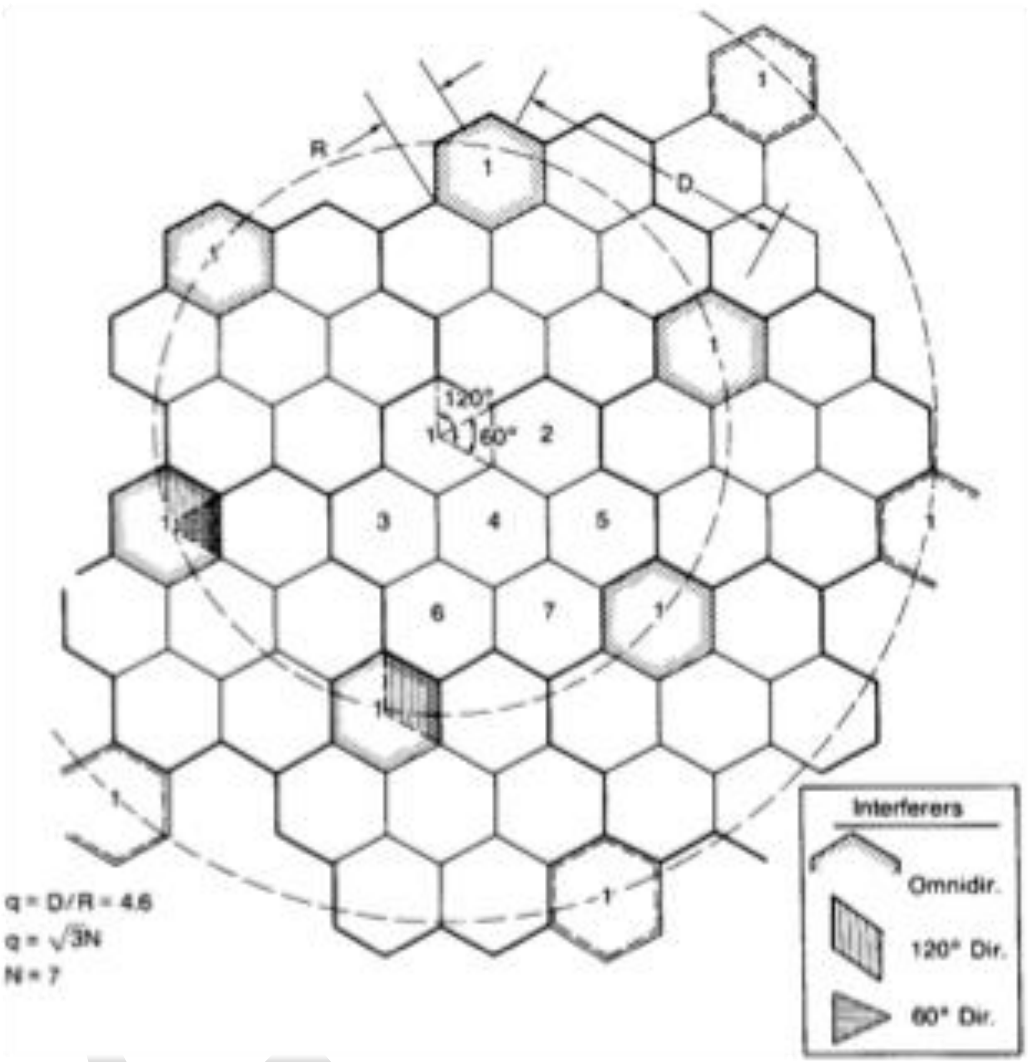
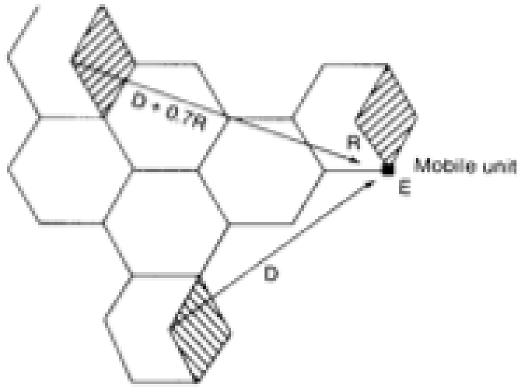


FIGURE 9.5 Interfering cells shown in a seven-cell system (two-tiers).

9.5.1 Directional Antennas In K = 7 Cell Patterns :

9.5.1.1 Three-Sector Case. The three-sector case is shown in Fig. 9.5. To illustrate the worst-case situation, two cochannel cells are shown in Fig. 9.6*a*. The mobile unit at position *E* will experience greater interference in the lower shaded cell sector than in the upper shaded cell-sector site. This is because the mobile receiver receives the weakest signal from its own cell but fairly strong interference from the interfering cell. In a three-sector case, the interference is effective in only one direction because the front-to-back ratio of a cell-site directional antenna is at least 10 dB or more in a mobile radio environment. The worst-case cochannel interference in the directional-antenna sectors in which interference occurs may be calculated. Because of the use of directional antennas, the number of principal interferers is reduced from six to two (Fig. 9.5). The worst case of C / I occurs when the mobile unit is at position E, at which point the distance between the mobile unit and the two interfering antennas is roughly $D + (R/2)$; however, C / I can be calculated more precisely as follows.



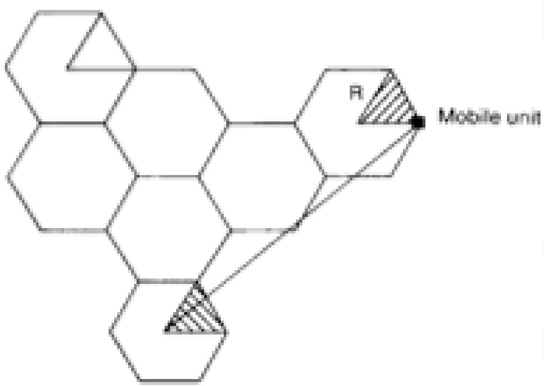


FIGURE 9.6 Determination of carrier-to-interference ratio C/I in a directional antenna system. (*a*) Worst case in a 120° directional antenna system ($N = 7$); (*b*) worst case in a 60° directional antenna system ($N = 7$).

The value of C/I can be obtained by the following expression (assuming that the worst case is at position E at which the distances from two interferers are $D + 0.7$ and D).

$$\frac{C}{I}(\text{worst case}) = \frac{R^{-4}}{(D + 0.7R)^{-4} + D^{-4}}$$

$$= \frac{1}{(q + 0.7)^{-4} + q^{-4}} \qquad (9.5\text{-}1)$$

Let $q = 4.6$; then Eq. (9.5-1) becomes

$$\frac{C}{I}(\text{worst case}) = 285\ (=)\ 24.5\ \text{dB} \qquad (9.5\text{-}2)$$

The C/I received by a mobile unit from the 120° directional antenna sector system expressed in Eq. (9.5-2) greatly exceeds 18 dB in a worst case. Equation (9.5-2) shows that using directional antenna sectors can improve the signal-to-interference ratio, that is, reduce the cochannel interference. However, in reality, the C/I could be 6 dB weaker than in Eq. (9.5-2) in a heavy traffic area as a result of irregular terrain contour and imperfect site locations. The remaining 18.5 dB is still adequate.

9.5.1.2 *Six-Sector Case.* We may also divide a cell into six sectors by using six 60°-beam directional antennas as shown in Fig. 9.6*b*. In this case, only one instance of interference can occur in each sector as shown in Fig. 9.5. Therefore, the carrier-to-interference ratio in this case is

$$\frac{C}{I} = \frac{R^{-4}}{(D + 0.7R)^{-4}} = (q + 0.7)^4 \tag{9.5-3}$$

For $q = 4.6$, Eq. (9.5-3) becomes

$$\frac{C}{I} = 794\,(=)\,29 \text{ dB} \tag{9.5-4}$$

which shows a further reduction of cochannel interference. If we use the same argument as we did for Eq. (9.5-2) and subtract 6 dB from the result of Eq. (9.5-4), the remaining 23 dB is still more than adequate. When heavy traffic occurs, the 60◦ -sector configuration can be used to reduce cochannel interference. However, fewer channels are generally allowed in a 60◦ sector and the trunking efficiency decreases. In certain cases, more available channels could be assigned in a 60◦ sector.

9.5.2 Directional Antenna in $K = 4$ Cell Pattern

9.5.2.1 Three-Sector Case. To obtain the carrier-to-interference ratio, we use the same procedure as in the $K = 7$ cell-pattern system. The 120° directional antennas used in the sectors reduced the interferers to two as in $K = 7$ systems, as shown in Fig. 9.7. We can apply Eq. (9.5-1) here. For $K = 4$, the value of $q = \sqrt{3K} = 3.46$; therefore, Eq. (9.5-1) becomes

$$\frac{C}{I}\,(\text{worst case}) = \frac{1}{(q+0.7)^{-4} + q^{-4}} = 97 = 20\,\text{dB} \tag{9.5-5}$$

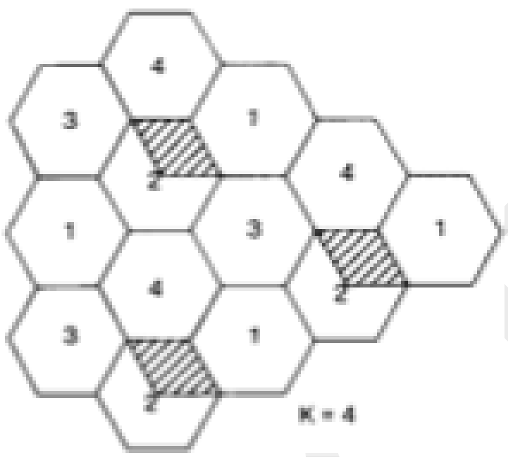


FIGURE 9.7 Interference with frequency-reuse pattern $K = 4$.

If, using the same reasoning used with Eq. (9.5-4), 6 dB is subtracted from the result of Eq. (9.5-5), the remaining 14 dB is unacceptable.

9.5.2.2 Six-Sector Case. There is only one interferer at a distance of $D + R$ shown in Fig. 9.7. With $q = 3.46$, we can obtain

$$\frac{C}{I}\,(\text{worst case}) = \frac{R^{-4}}{(D+R)^{-4}} = \frac{1}{(q+1)^{-4}} = 355 = 26\,\text{dB} \tag{9.5-6}$$

If 6 dB is subtracted from the result of Eq. (9.5-6), the remaining 21 dB is adequate. Under heavy traffic conditions, there is still a great deal of concern over using a $K = 4$ cell pattern in a 60◦ sector. An explanation of this point is given in the next section.

9.5.3 Comparing K = 7 and K = 4 systems A $K = 7$ cell-pattern system is a logical way to begin an omnicell system. The cochannel reuse distance is more or less adequate, according to the designed criterion. When the traffic increases, a three-sector system should be implemented, that is, with three 120° directional antennas in place. In certain hot spots, 60° sectors can be used locally to increase the channel utilization.

If a given area is covered by both $K = 7$ and $K = 4$ cell patterns and both patterns have a six-sector configuration, then the $K = 7$ system has a total of 42 sectors, but the $K = 4$ system has a total of only 26 sectors and, of course, the system of $K = 7$ and six sectors has less cochannel interference.

One advantage of 60° sectors with $K = 4$ is that they require fewer cell sites than 120° sectors with $K = 7$. Two disadvantages of 60° sectors are that (1) they require more antennas to be mounted on the antenna mast and (2) they often require more frequent handoffs because of the increased chance that the mobile units will travel across the six sectors of the cell. Furthermore, assigning the proper frequency channel to the mobile unit in each sector is more difficult unless the antenna height at the cell site is increased so that the mobile unit can be located more precisely. In reality the terrain is not flat, and coverage is never uniformly distributed; in addition, the directional antenna front-to-back power ratio in the field is very difficult to predict (see Sec. 8.4.2). In small cells, interference could become uncontrollable; thus the use of a $K = 4$ pattern with 60° sectors in small cells needs to be considered only for special implementations such as portable cellular systems (Sec. 15.6) or narrowbeam applications (Sec. 12.8). For small cells, a better alternative scheme is to use a $K = 7$ pattern with 120° sectors plus the underlay-overlay configuration described .

UNIT-IV

NON-CO-CHANNEL INTERFERENCE-DIFFERENT TYPES:

10.2 ADJACENT-CHANNEL INTERFERENCE

The scheme discussed in Chap. 9 for reduction of cochannel interference can be used to reduce adjacent-channel interference. However, the reverse argument is not valid here. In addition, adjacent-channel interference can be eliminated on the basis of the channel assignment, the filter characteristics, and the reduction of near-end–far-end (ratio) interference.

"Adjacent-channel interference" is a broad term. It includes next-channel (the channel next to the operating channel) interference and neighboring-channel (more than one channel away from the operating channel) interference. Adjacent-channel interference can be reduced by the frequency assignment.

10.2.1 Next-Channel Interference

Next-channel interference in an AMPS system affecting a particular mobile unit cannot be caused by transmitters in the common cell site but must originate at several other cell sites. This is because any channel combiner at the cell site must combine the selected channels, normally 21 channels (630 kHz) away, or at least 8 or 10 channels away from the desired one. Therefore, next-channel interference will arrive at the mobile unit from other cell sites if the system is not designed properly. Also, a mobile unit initiating a call on a control channel in a cell may cause interference with the next control channel at another cell site. The methods for reducing this next-channel interference use the receiving end. The channel filter characteristics4 are a 6 dB/oct slope in the voice band and a 24 dB/oct falloff outside the voice-band region (see Fig. 10.3).

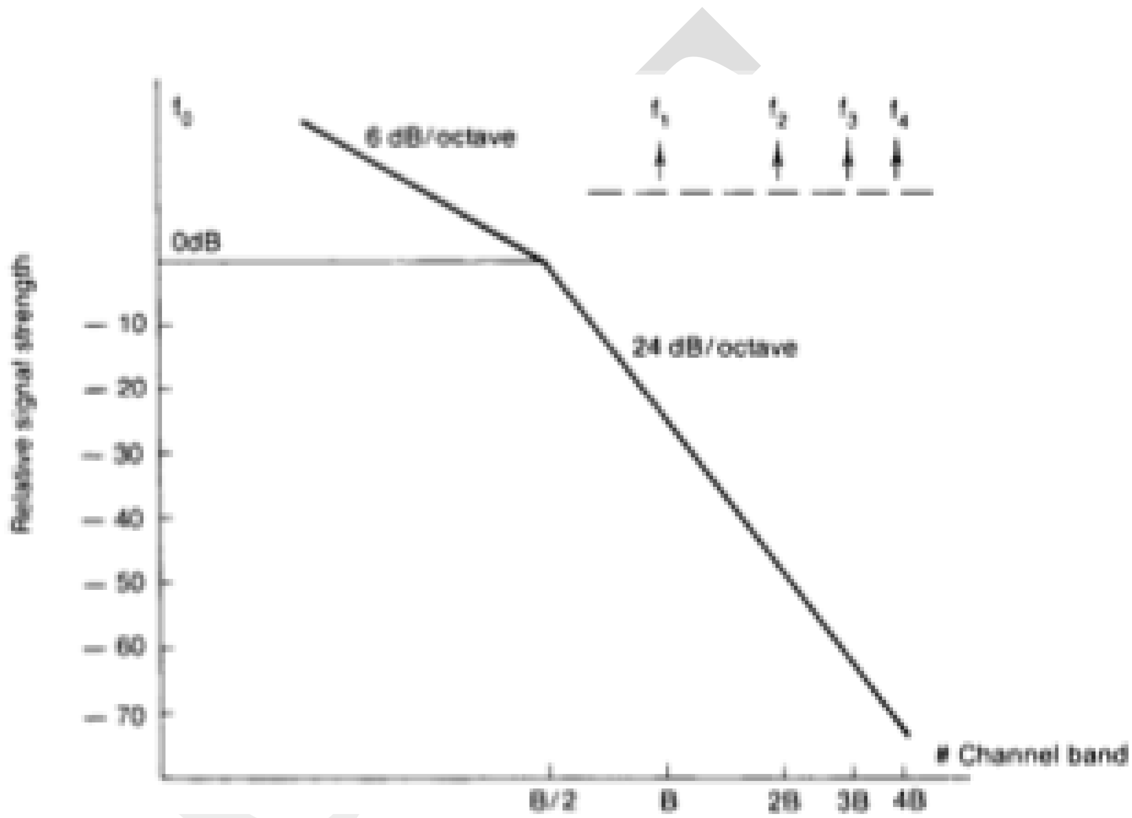


FIGURE 10.3 Characteristics of channel-band filter.

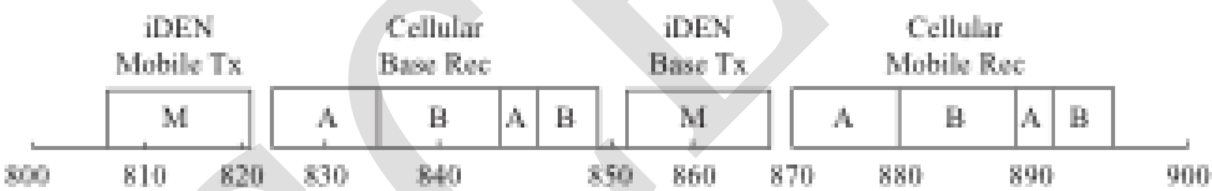
10.2.2 Neighboring-Channel Interference

The channels that are several channels away from the next channel will cause interference with the desired signal. Usually, a fixed set of serving channels is assigned to each cell site. If all the channels are simultaneously transmitted at one cell-site antenna, a sufficient amount of band isolation between channels is required for a multichannel combiner (see Sec. 10.7.1) to reduce intermodulation products. This requirement is no different from other non mobile radio systems. Assume that band separation requirements can be resolved, for example, by using multiple antennas instead of one antenna at the cell site. There will be no intermodulation products. A truly linear broadband amplifier can realize this idea. However, it is a new evolving technology.

Another type of adjacent-channel interference is unique to the mobile radio system. In the mobile radio system, most mobile units are in motion simultaneously. Their relative positions change from time to time. In principle, the optimum channel assignments that avoid adjacent-channel interference must also change from time to time. One unique station that causes adjacent-channel interference in mobile radio systems is described in the next section.

10.2.3 Transmitting and Receiving Channels Interference

In FDMA and TDMA systems, the transmitting channels and receiving channels have to be separated by a guard band mostly 20 MHz. It is because the transmitting channels are so strong that they can mask the weak signals received from the receiving channels. The duplexer can only provide 30 dB to 40 dB isolation. The band isolation is the other means to reduce the interference.



		Mobile Tx	Base Tx
A	Cellular band A	824-835, 845-846.5 MHz	869-880, 890-891.5 MHz
B	Cellular band B	835-845, 846.5-849 MHz	880-890, 891.5-894 MHz
	iDEN	806-821 MHz	851-866 MHz

FIGURE 10.4 Cellular and iDEN spectrum in 800 MHz.

10.2.4 Interference from Adjacent Systems

The frequency bands allocated between AMPS and iDEN in800-MHzsystems are shown inFig.10.4.In1993, iDEN transmitted in the band 851–866MHz, using several broadband amplifiers to cover this band. The IM(2A-B) generated from the non linear amplifiers interfered with the cellular base received signals. Then, the broadband amplifiers were removed.

10.3 NEAR-END–FAR-ENDINTERFERENCE

10.3.1 In One Cell

Because motor vehicles in a given cell are usually moving, some mobile units are close to the cell site and some are not. The close-in mobile unit has a strong signal that causes adjacent-channel interference (see Fig. 10.5*a*). Near-end–far-end interference can occur only at the reception point in the cell site.

If a separation of 5*B* (five channel bandwidths) is needed for two adjacent channels in a cell in order to avoid the near-end–far-end interference, it is then implied that a minimum separation of 5*B i*s required between each adjacent channel used with one cell.

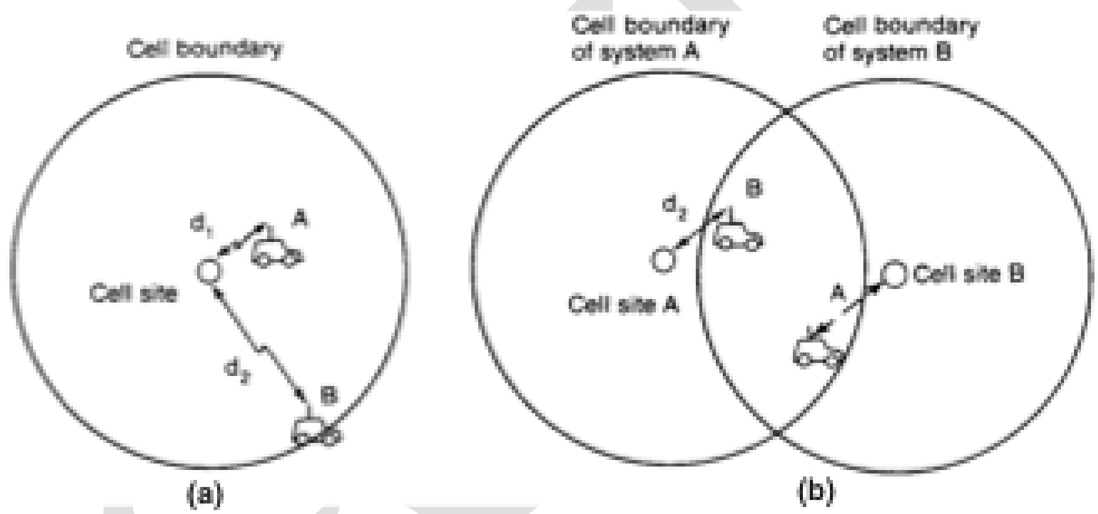


FIGURE 10.5 Near-end–far-end (ratio) interference. (*a*) In one cell; (*b*) in two-system cells.

Because the total frequency channels are distributed in a set of *N* cells, each cell only has 1/ *N* of the total frequency channels. We denote { *F*1 }, { *F*2 }, { *F*3 }, { *F*4 } for the sets of frequency channels assigned in their corresponding cells *C*1 , *C*2 , *C*3 , *C*4 . The issue here is how we can construct a good frequency management chart to assign the *N* sets of frequency channels properly and thus avoid the problems indicated above. The following section addresses how cellular system engineers solve this problem in two different systems.

10.3.2 In Cells of Two Systems

Adjacent-channel interference can occur between two systems in a duopoly-market system. In this situation, adjacent-channel interference can occur at both the cell site and the mobile unit. For instance, mobile unit A can be located at the boundary of its own home cell A in system A but very close to cell B of system B as shown in Fig 10.5*b*. The other situation would occur if mobile unit B were at the boundary of cell B of system B but very close to cell A of system A. Following the definition of near-end–far-end interference given in Sec. 10.3.1, the solid arrow indicates that interference may occur at cell site A and the dotted arrow indicates that interference may occur at mobile unit A. Of course, the same interference will be introduced at cell site B and mobile unit B.

Thus, the frequency channels of both cells of the two systems must be coordinated in the neighborhood of the two-system frequency bands. This phenomenon causes a great concern as indicated in the additional frequency-spectrum allocation charts in Fig. 10.6 as an example.

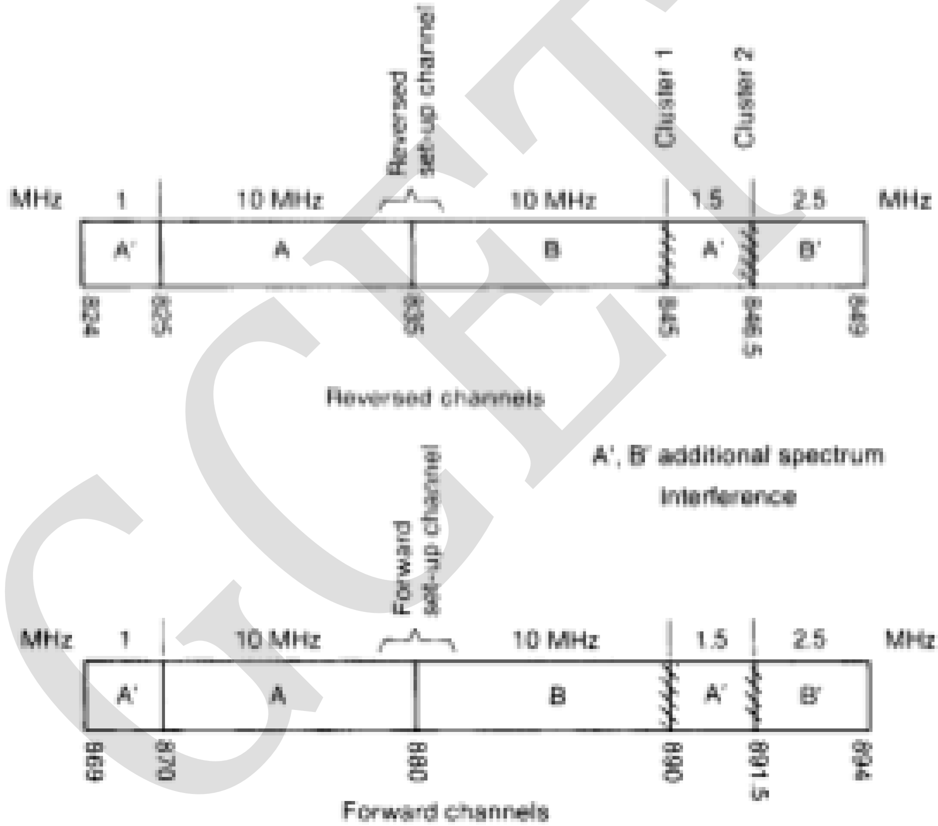


FIGURE 10.6 Spectrum allocation with new additional spectrum.

The two causes of near-end–far-end interference of concern here are :

1. *Interference caused on the set-up channels.* Two systems try to avoid using the neighborhood of the set-up channels as shown in Fig. 10.6.

2. *Interference caused on the voice channels.* There are two clusters of frequency sets as shown in Fig. 10.6 that may cause adjacent-channel interference and should be avoided. The cluster can consist of 4 to 5 channels on each side of each system, that is, 8 to 10 channels in each cluster. The channel separation can be based on two assumptions.

a. *Received interference at the mobile unit.* The mobile unit is located away from its own cell site but only 0.25 mi away from the cell site of another system.

b. *Received interference at the cell site.* The cell site is located 10 mi away from its own mobile unit but only 0.25 mi from the mobile unit of another system.

These assumptions are discussed in the next section. If the two system operators do not agree to coordinate their use of frequency channels and some of the cell sites of system B are at the coverage boundaries of the cells of system A, then the two groups of frequencies shown in Fig. 10.6 must not be used if interference has to be avoided. Of course, if the two systems do coordinate their use of frequency channels, adjacent channels in the two clusters can be used with no interference. These observations regarding adjacent-channel interference lead the author to conclude that the existence of two systems having all co-location cell sites in a city is desirable since near-end–far-end ratio interference might be easy to control or might not occur if frequency channel use is coordinated.

UNIT-V

CELL COVERAGE FOR SIGNAL AND TRAFFIC

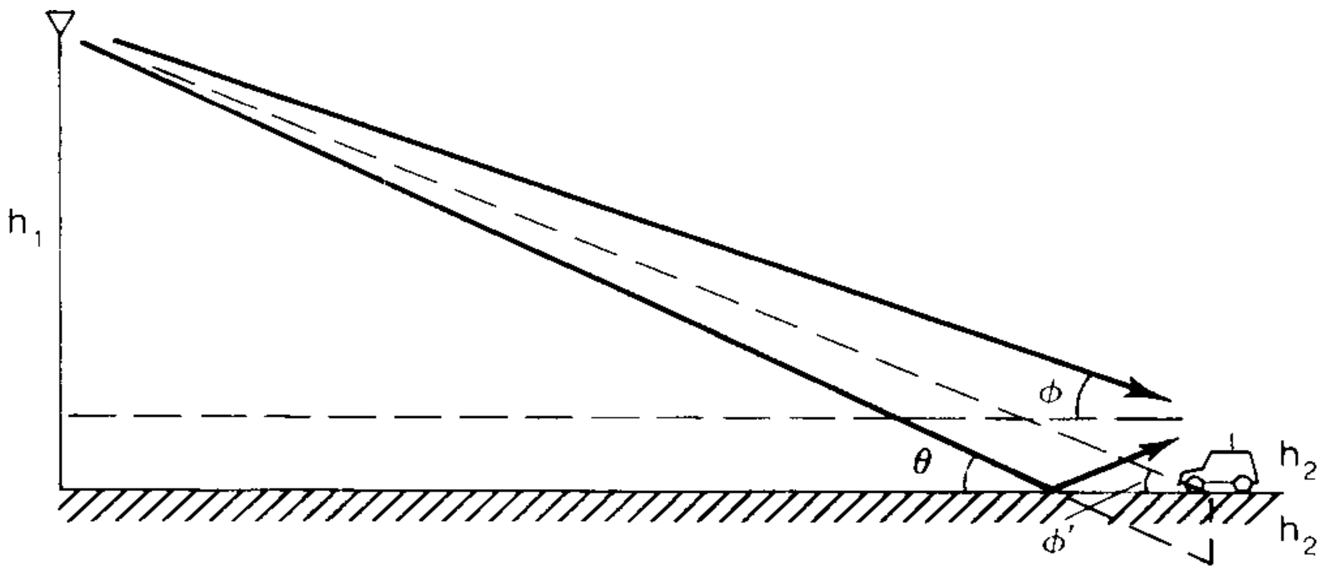
SIGNAL REFLECTION IN FLAT AND HILLY TERRAIN:

Cell coverage can be based on signal coverage or on traffic coverage. Signal coverage can be predicted by coverage prediction models and is usually applied to a start-up system. The task is to cover the whole area with a minimum number of cell sites. Because 100 percent cell coverage of an area is not possible, the cell sites must be engineered so that the holes are located in the no-traffic locations. The prediction model is a point-to-point model that is discussed in this chapter. We have to examine the service area as occurring in one of the following environments:

Human-made structures

In a building area
In an open area
In a suburban area
In an urban area
Natural terrains
Over flat terrain
Over hilly terrain
Over water
Through foliage areas

The results generated from the prediction model will differ depending on which service area is used. There are many field-strength prediction models in the literature.1−28 They all provide more or less an area-to-area prediction. As long as 68 percent of the predicted values from a model are within 6 to 8 dB (one standard deviation) of their corresponding measured value, the model is considered a good one. However, we cannot use area-to-area prediction models for cellular system design because of the large uncertainty of the prediction. The model being introduced here is the point-to-point prediction model, which would provide a standard deviation from the predicted value of less than 3 dB. An explanation of this model appears . Many tools can be developed based upon this model, such as cell-site choosing interference reduction, and traffic handling



GROUND INCIDENT ANGLE AND GROUND ELEVATION ANGLE:

The ground incident angle and the ground elevation angle over a communication link are described as follows. The ground incident angle θ is the angle of wave arrival incidently pointing to the ground as shown in Fig. 8.1. The ground elevation angle φ is the angle of wave arrival at the mobile unit as shown in Fig.

EXAMPLE

In a mobile radio environment, the average cell-site antenna height is about 50 m, the mobile antenna height is about 3 m, and the communication path length is 5 km. The incident angle is

$$\theta = \tan^{-1} \frac{50 \text{ m} + 3 \text{ m}}{5 \text{ km}} = 0.61^\circ$$

The elevation angle at the antenna of the mobile unit is

$$\phi = \tan^{-1} \frac{50 \text{ m} - 3 \text{ m}}{5 \text{ km}} = 0.54^\circ$$

The elevation angle at the location of the mobile unit is

$$\phi' = tan^{-1} \frac{50 \text{ m}}{5 \text{ km}} = 0.57^\circ$$

GROUND REFLECTION ANGLE AND REFLECTION POINT:

Based on Snell's law, the reflection angle and incident angle are the same. Because in graphical display we usually exaggerate the hilly slope and the incident angle by enlarging the vertical scale, as shown in Fig. 8.2, then as long as the actual hilly slope is less than 10◦, the reflection point on a hilly slope can be obtained by following the same method as if the reflection point were on flat ground. Be sure that the two antennas (base and mobile) have been placed vertically, not perpendicular to the sloped ground. The reason is that the actual slope of the hill is usually very small and the vertical stands for two antennas are correct. The scale drawing in Fig. 8.2 is somewhat misleading; however, it provides a clear view of the situation.

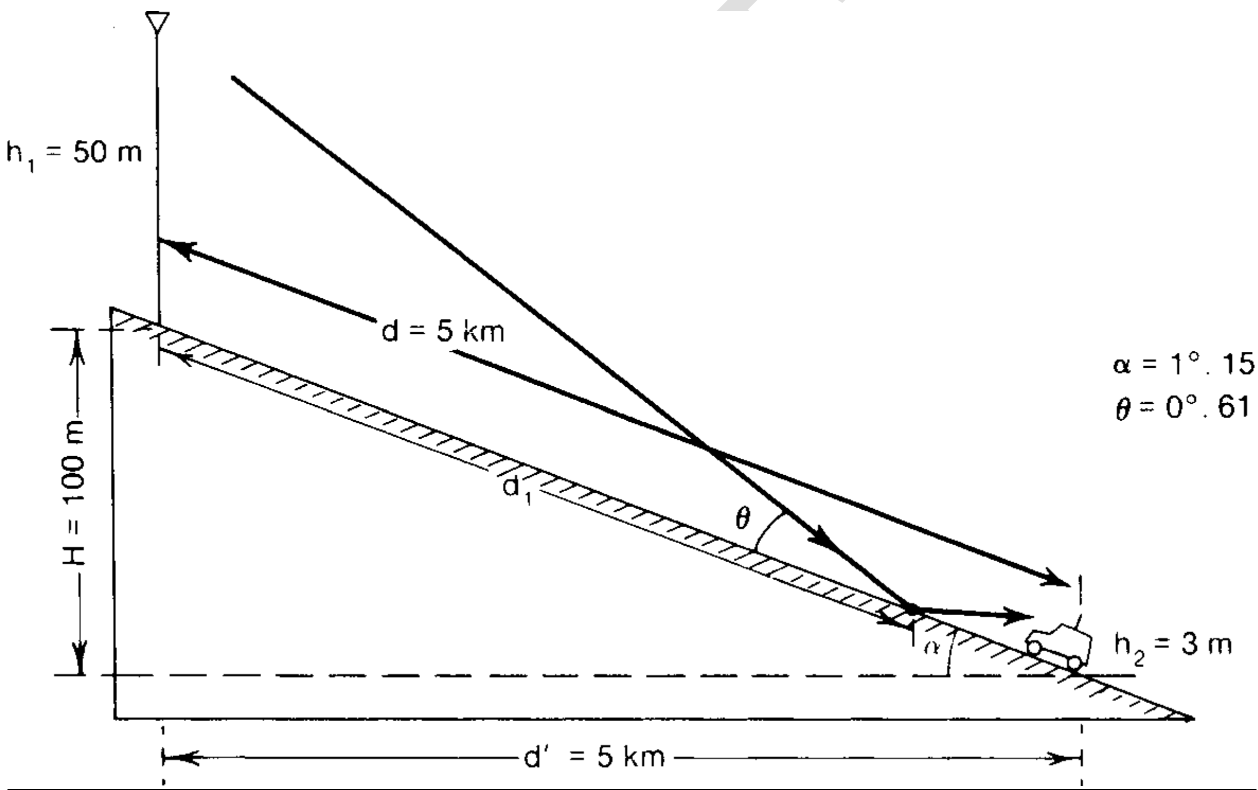


FIG: A coordinate sketch in a hilly terrain.

Effect of the Human-Made Structures:

Because the terrain configuration of each city is different, and the human-made structure of each city is also unique, we have to find a way to separate these two. The way to factor out the effect due to the terrain configuration from the man-made structures is to work out a way to obtain the path loss curve for the area as if the area were flat, even if it is not. The path loss curve obtained on virtually flat ground indicates the effects of the signal loss due to solely human-made structures. This means that the different path loss curves obtained in each city show the different human-made structure in that city. To do this, we may have to measure signal strengths at those high spots and also at the low spots surrounding the cell sites, as shown in Fig. 8.3*a*. Then the average path loss slope , which is a combination of measurements from high spots and low spots along different radio paths in a general area, represents the signal received as if it is from a flat area affected only by a different local human-made structured environment. We are using 1-mi intercepts (or, alternatively, 1-km intercepts) as a starting point for obtaining the path loss curves.

Therefore, the differences in area-to-area prediction curves are due to the different manmade structures. We should realize that measurements made in urban areas are different from those made in suburban and open areas. The area-to-area prediction curve is obtained from the mean value of the measured data and used for future predictions in that area.

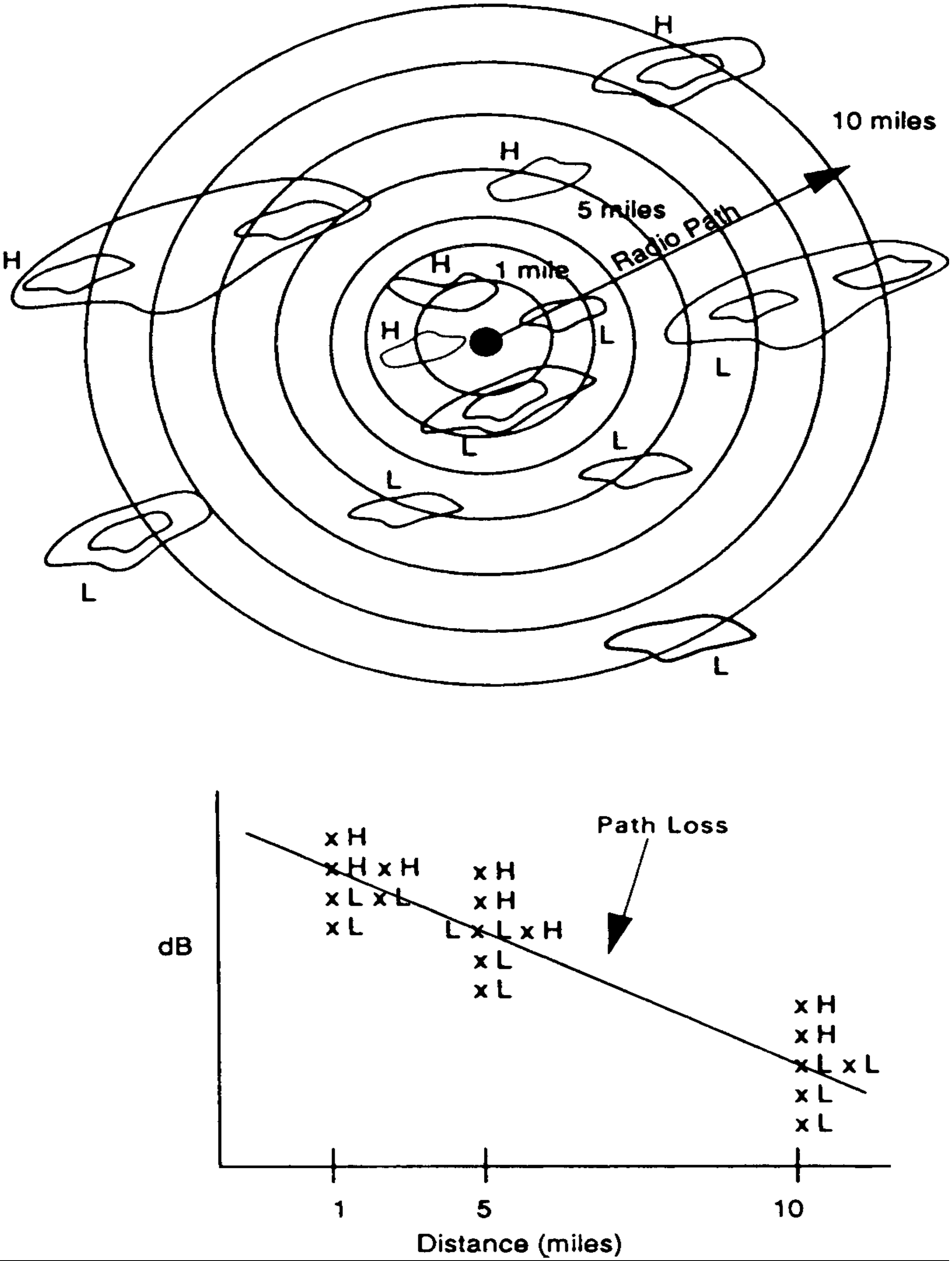


FIG-1 : For selecting measurement areas

FIG-2 : path loss phenomenon

Any area-to-area prediction model1−28 can be used as a first step toward achieving the point-to-point prediction model. One area-to-area prediction model which is introduced here10 can be represented by two parameters: (1) the 1-mi (or 1-km) intercept point and (2) the path-loss slope. The 1-mi intercept point is the power received at a distance of 1 mi from the transmitter. There are two general approaches to finding the values of the two parameters experimentally.

1. Compare an area of interest with an area of similar human-made structures which presents a curve such as that shown in Fig. 8.3*c*. The suburban area curve is a commonly used curve. Because all suburban areas in the United States look alike, we can use this curve for all suburban areas. If the area is not suburban but is similar to the city of Newark, then the curve for Newark should be used.

2. If the human-made structures of a city are different from the cities listed in Fig. 8.8*c*, a simple measurement should be carried out. Set up a transmitting antenna at the center of a general area. As long as the building height is comparable to the others in the area, the antenna location is not critical. Take six or seven measured data points around the 1-mi intercept and around the 10-mi boundary based on the high and low spots. Then compute the average of the 1 mi data points and of the 10 mi data points. By connecting the two values, the path-loss slope can be obtained. If the area is very hilly, then the data points measured at a given distance from the base station in different locations can be far apart. In this case, we may take more measured data points to obtain the average path-loss slope. If the terrain of the hilly area is generally sloped, then we have to convert the data points that were measured on the sloped terrain to a fictitiously flat terrain in that area. The conversion is based on the effective antenna-height gain as *G* = effective antenna-height gain = 20 log HE /HI

where *h*1 is the actual height and *he* is the effective antenna height at either the 1- or 10-mi locations. The method for obtaining *he* is shown in the following section.

3. An explanation of the path-loss phenomenon is as follows. The plotted curves shown in Fig. 8.3*c* have different 1-mi intercepts and different slopes. The explanation can be seen in Fig. 8.3*d*. When the base station antenna is located in the city, then the 1-mi intercept could be very low and the slope is flattened out, as shown by Tokey's curve. When the base station is located outside the city, the intercept could be much higher and the slope is deeper, as shown by the Newark curve. When the structures are uniformly distributed, depending on the density (average separation between buildings) *s* shown in Fig. 8.3*d*,
the 1-mi intercept could be high or low, but the slope may also keep at 40 dB/dec.

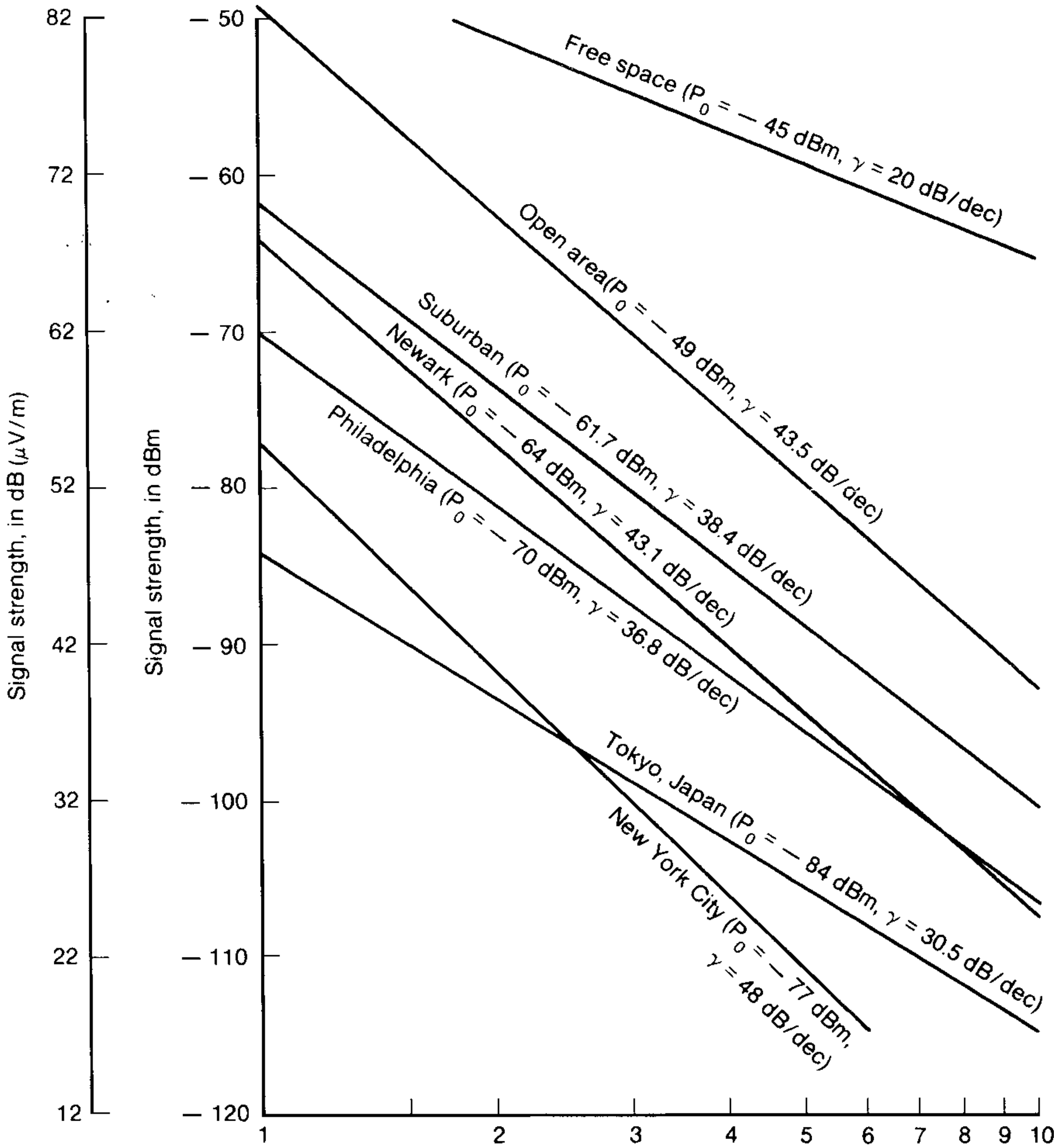


FIG-Propagation path loss in different cities.

The Phase Difference between a Direct Path and a Ground-Reflected Path:

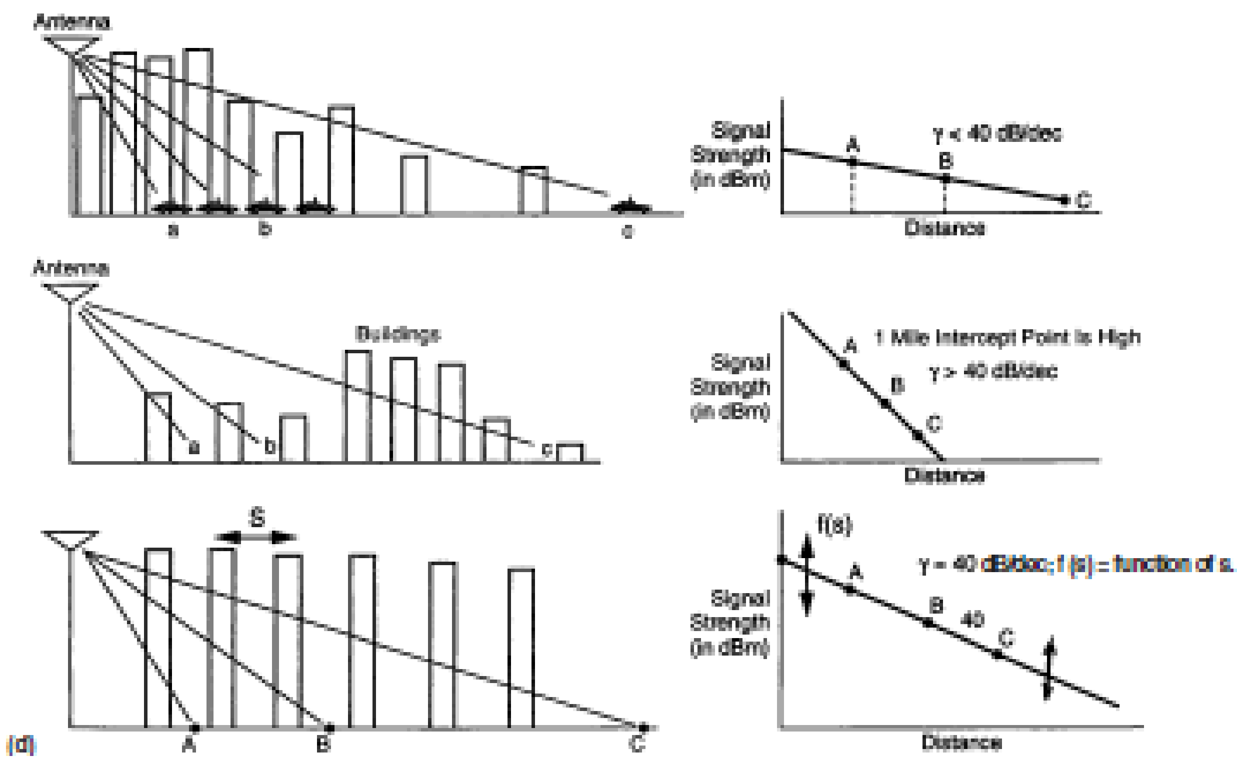
Based on a direct path and a ground-reflected path , where a direct path is a line-of-sight (LOS) path with its received poweR

$$P_{LOS} = P_0 \left(\frac{1}{4\pi d/\lambda} \right)^2$$

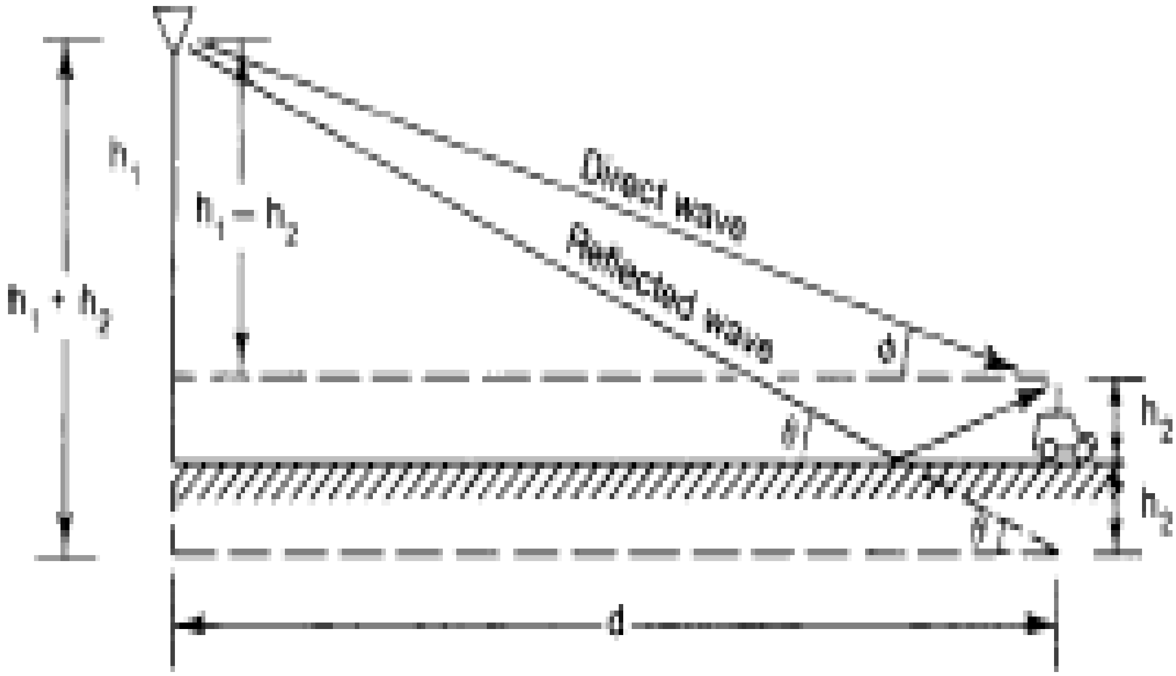
and a ground-reflected path with its reflection coefficient and phase changed after reflection, the sum of the two wave paths can be expressed as:

$$P_r = P_0 \left(\frac{1}{4\pi d/\lambda} \right)^2 \left| 1 + a_v e^{j\Delta\phi} \right|^2$$

where *av* = the reflection coefficient
_*φ* = the phase difference between a direct path and a reflected path



(*Continued*) (***d***) Explanation of the path-loss phenomenon.



A simple model.

P_0 = the transmitted power
d = the distance
λ = the wavelength
Equation (8.2-2) indicates a two-wave model, which is used to understand the pathloss phenomenon in a mobile radio environment. It is not the model for analyzing the multipath fading phenomenon. In a mobile environment $a_e = -1$ because of the small incident angle of the ground wave caused by a relatively low cell-site antenna height.
Thus29

$$P_r = P_0\left(\frac{1}{4\pi d/\lambda}\right)^2 \left|1 - \cos\Delta\phi - j\sin\Delta\phi\right|^2$$

$$= P_0\frac{2}{(4\pi d/\lambda)^2}(1 - \cos\Delta\phi) = P_0\frac{4}{(4\pi d/\lambda)^2}\sin^2\frac{\Delta\phi}{2}$$

where

$$\Delta\phi = \beta\Delta d$$

and Δd is the difference, $\Delta d = d_1 - d_2$ from Fig. 8.4.

$$d_1 = \sqrt{(h_1 + h_2)^2 + d^2}$$

and

$$d_2 = \sqrt{(h_1 - h_2)^2 + d^2}$$

Because Δd is much smaller than either d_1 or d_2,

$$\Delta\phi = \beta\Delta d \approx \frac{2\pi}{\lambda}\frac{2h_1h_2}{d}$$

Then the received power of Eq. (8.2-3) becomes

$$P_r = P_0 \frac{\lambda^2}{(4\pi)^2 d^2} \sin^2 \frac{4\pi h_1 h_2}{\lambda d}$$

If $\Delta\phi$ is less than 0.6 rad, then $\sin(\Delta\phi/2) \approx \Delta\phi/2$, $\cos(\Delta\phi/2) \approx 1$ and I
plifies to

$$P_r = P_0 \frac{4}{16\pi^2 (d/\lambda)^2} \left(\frac{2\pi h_1 h_2}{\lambda d}\right)^2 = P_0 \left(\frac{h_1 h_2}{d^2}\right)^2$$

From Eq. (8.2-9), we can deduce two relationships as follows:

$$\Delta P = 40 \log \frac{d_1}{d_2} \quad \text{(a 40 dB/dec path loss)}$$

$$\Delta G = 20 \log \frac{h_1'}{h_1} \quad \text{(an antenna height gain of 6 dB/oct)}$$

where _P is the power difference in decibels between two different path lengths and _G
is the gain (or loss) in decibels obtained from two different antenna heights at the cell site.
From these measurements, the gain from a mobile antenna height is only 3 dB/oct, which
is different from the 6 dB/oct for *h*

_
1 shown in Eq. (8.2-10*b*). Then

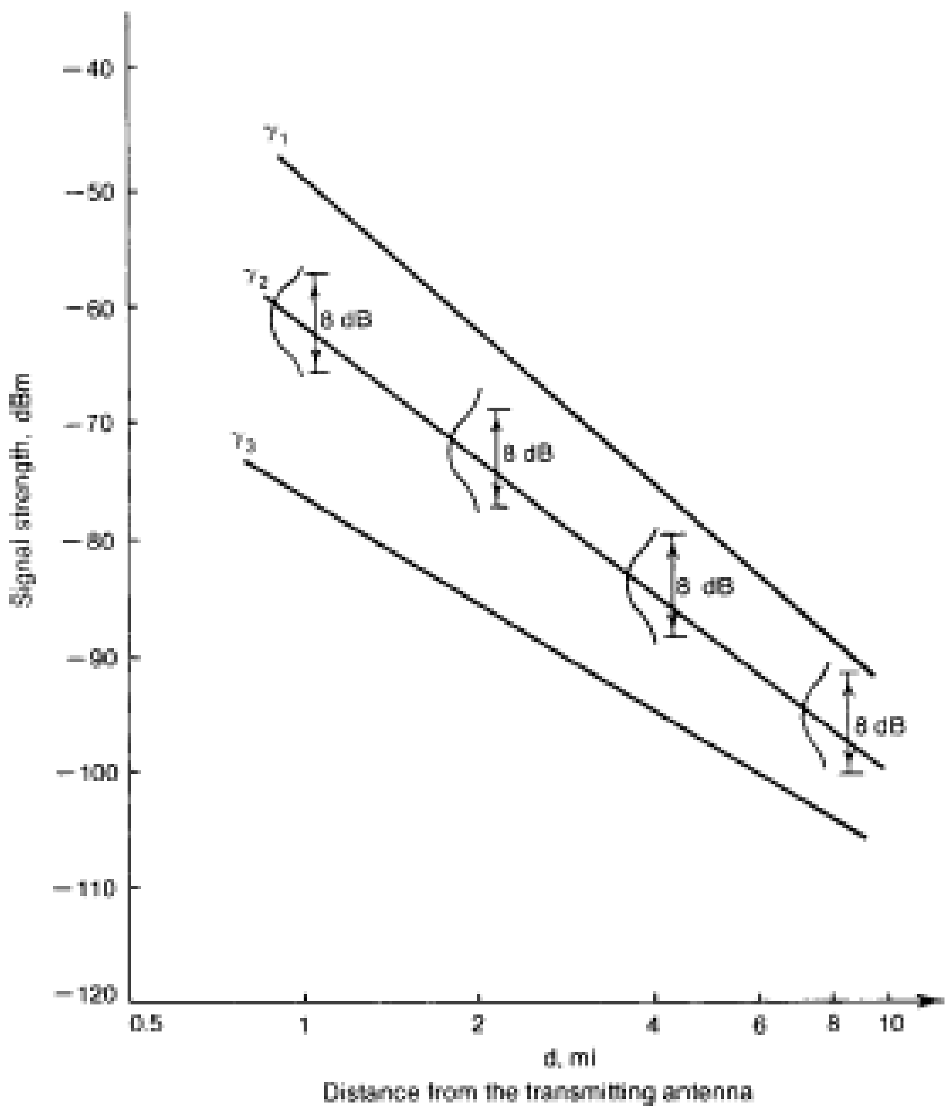
$$\Delta G' = 10 \log \frac{h_2'}{h_2} \quad \text{(an antenna-height gain of 3 dB/oct)}$$

WHY THERE IS A CONSTANT STANDARD DEVIATION ALONG A PATH –LOSS CURVE:

When plotting signal strengths at any given radio-path distance, the deviation from predicted values is approximately 8 dB.10,12 This standard deviation of 8 dB is roughly true in many different areas. The explanation is as follows. When a line-of-sight path exists, both the direct wave path and reflected wave path are created and are strong (see Fig. 8.2). When an out-of-sight path exists, both the direct wave path and the reflected wave path are weak. In either case, according to the theoretical model, the 40-dB/dec
path-loss slope applies. The difference between these two conditions is the 1-mi intercept (or 1-km intercept) point. It can be seen that in the open area, the 1-mi intercept is high. In the urban area, the 1-mi intercept is low. The standard deviation obtained from the measured data remains the same along the different path-loss curves regardless of environment. Support for the above argument can also be found from the observation that the standard deviation obtained from the measured data

along the predicted path-loss curve is approximately 8 dB. The explanation is that at a distance from the cell site, some mobile
unit radio paths are line-of-sight, some are partial line-of-sight, and some are out-of-sight.

Thus, the received signals are strong, normal, and weak, respectively. At any distance, the above situations prevail. If the standard deviation is 8 dBat one radio-path distance, the same 8 dB will be found at any distance. Therefore a standard deviation of 8 dB is always found along the radio path as shown in Fig. 8.5. The standard deviation of 8 dB from the measured data near the cell site is due mainly to the close-in buildings around the cell site. The same standard deviation from the measured data at a distant location is due to the great variation
along different radio paths.



An 8-dB local mean spread.

STRAIGHT LINE PATH LOSS SLOPE:

As we described earlier, the path-loss curves are obtained from many different runs at many different areas. As long as the distances of the radio path from the cell site to the mobile unit are the same in different runs, the signal strength data measured at that distance would be used to calculate the mean value for the path loss at that distance. In the experimental data, the path-loss deviation is 8 dB across the distance from 1.6 to 15 km (1 to 10 mi) where the general terrain contours are not generally flat. Figure 8.5 depicts this. The path-loss curve is γ . The received power can be expressed as

$$P_r = P_0 - \gamma \log \frac{r}{r_0}$$

The slope γ is different in different areas, but it is always a straight line in a log scale. If γ = 20 is a free-space path loss, γ = 40 is a mobile path loss.

CONFIDENCE LEVEL:

A confidence level can only be applied to the path-loss curve when the standard deviation σ is known. In American suburban areas, the standard deviation σ = 8 dB. The values at any given distance over the radio path are concentrated close to the mean and have a bell-shaped (normal) distribution. The probability that 50 percent of the measured data are equal to or below a given level is

$$P(x \geq C) = \int_C^\infty \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-A)^2/2\sigma^2} dx = 50\%$$

where A is the mean level obtained along the path-loss slope, which is shown in Eq as

$$A = P_0 - \gamma \log \frac{r_1}{r_0}$$

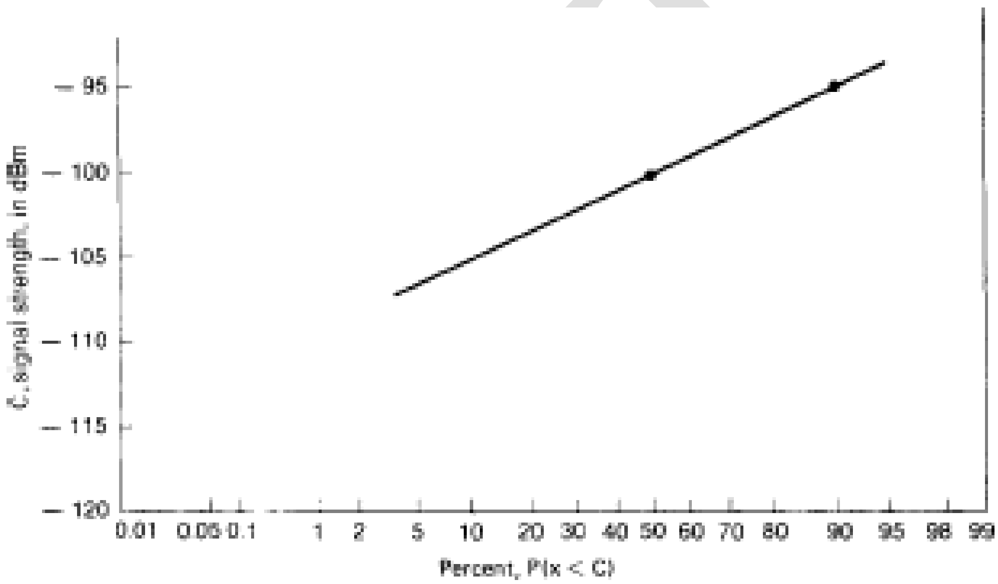
Thus, level A corresponds to the distance r_1. If level A increases, the confide decreases, as shown in Eq. (8.2-12).

$$P(x \geq C) = P\left(\frac{x-A}{\sigma} \geq B\right)$$

Let $C = B\sigma + A$. The different confidence levels are shown in Table 8.2. We can see how to use confidence levels from the following example.

DIFFERENT CONFIDENCE LEVELS

$P(x \le C)$, %	$C = B\sigma + A$
80	$-0.85\sigma + A$
70	$-0.55\sigma + A$
60	$-0.25\sigma + A$
50	A
40	$0.25\sigma + A$
30	$0.55\sigma + A$
20	$0.85\sigma + A$
16	$1\sigma + A$
10	$1.3\sigma + A$
2.28	$2\sigma + A$



A LOG NORMALL CURVE

$$P\left(\frac{x - A}{\sigma} \ge B\right) = 20\% \qquad x \ge B\sigma + A$$

or from Table 8.2 we obtain

$$x \ge 0.85 \times 8 + (-100) = -93.2\,\text{dBm}$$

The log normal curve with a standard deviation of 8 dB is shown in Fig.

A General Formula for Mobile Radio Propagation:

radio environment, which could be a suburban area. The 1-mi intercept level in a suburban area is −61.7 dBm under the standard conditions listed in Table 8.1. Combining these data with the equation shown in Eq. (8.2-10*b*) from the theoretical prediction model, and Eqs. (8.2-10*c*) and (8.2-11) from the measured data, the received power P_r at the suburban area can be expressed as

$$P_r = (P_t - 40) - 61.7 - 38.4 \log \frac{r_1}{1\ \text{mi}} + 20 \log \frac{h_1}{100\ \text{ft}} + 10 \log \frac{h_2}{10\ \text{ft}} + (G_t - 6) + G_m$$

can be simplified as

$P_r = P_t - 157.7 - 38.4 \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m$

where P_t is in decibels above 1 mW, r_1 is in miles, h_1 and h_2 are in feet, and G_t and G_m are in decibels. Equation (8.2-18) is used for suburban areas. We may like to change Eq. (8.2-18) to a general formula by using P_r at 10 mi as a reference which is −100 dBm, as shown in Fig. 8.3*c*. Also the 40 dB/oct slope used is generous. Then Eq. changes to

$P_r = P_t - 156 - 40 \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m$

where the units of P_t , r_1, h_1, h_2, G_t , and G_m are stated below Eq Equation can be used as a general formula in a mobile radio environment. The most general formula is expressed as follows

$P_r = P_t - K - \gamma \log r_1 + 20 \log h_1 + 10 \log h_2 + G_t + G_m$

where $P_r = P_t - K$ at $r_1 = 1$ mile, $h_1 = h_2 = 1$_ , and $G_t = G_m = 0$. The value of K and γ will be different and need to be measured in different human-made environment.

Propagation over water or flat open area is becoming a big concern because it is very easy to interfere with other cells if we do not make the correct arrangements. Interference resulting from propagation over the water can be controlled if we know the cause.

In general, the permittivities _r of seawater and fresh water are the same, but the conductivities of seawater and fresh water are different. We may calculate the dielectric constants _c, where _c = _$r - j60\sigma\lambda$. The wavelength at 850 MHz is 0.35 m. Then _c (seawater) = $80 - j84$ and _c (fresh water) = $80 - j0.021$.

However, based upon the reflection coefficients formula33,34 with a small incident angle, both the reflection coefficients for horizontal polarized waves and vertically polarized waves approach 1. Because the 180◦ phase change occurs at the ground reflection point, the reflection coefficient is −1. Now we can establish a scenario, as shown in Fig. 8.7. Because the two antennas, one at the cell site and the other at the mobile unit, are well above sea level, two reflection points are generated. The one reflected from the ground is close to the mobile unit; the other reflected from the water is away from the mobile unit. We recall that the only reflected wave we considered in the land mobile propagation is the one reflection point

which is always very close to the mobile unit.We are now using the formula to find the field

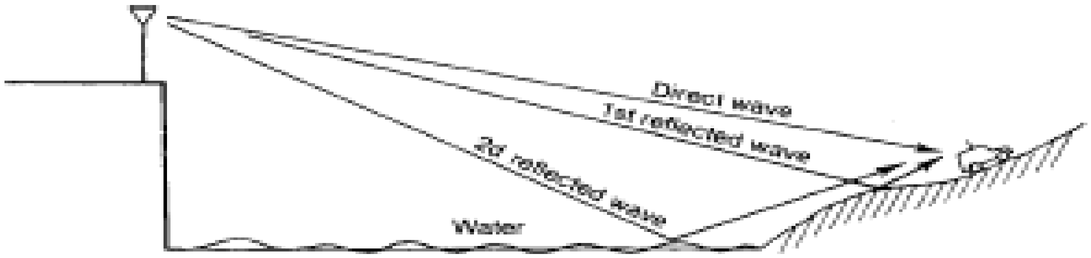


FIGURE 8.7 A model for propagation over water.

strength under the circumstances of a fixed point-to-point transmission and a land-mobile transmission over a water or flat open land condition.

8.3.1 Between Fixed Stations

The point-to-point transmission between the fixed stations over the water or flat open land can be estimated as follows. The received power P_r can be expressed as (see Fig. 8.8)

$$P_r = P_t\left(\frac{1}{4\pi d/\lambda}\right)^2\left|1 + a_v e^{-j\phi_v}\exp(j\Delta\phi)\right|^2 \tag{8.3-1}$$

where P_t = the transmitted power

d = distance between two stations

λ = wavelength

a_v, ϕ_v = amplitude and phase of a complex reflection coefficient, respectively

$\Delta\phi$ is the phase difference caused by the path difference Δd between the direct wave and the reflected wave, or

$$\Delta\phi = \beta\Delta d = \frac{2\pi}{\lambda}\Delta d \tag{8.3-2}$$

The first part of Eq. (8.3-1) is the free-space loss formula which shows the 20 dB/dec slope; that is, a 20-dB loss will be seen when propagating from 1 to 10 km.

$$P_0 = \frac{P_t}{(4\pi d/\lambda)^2} \tag{8.3-3}$$

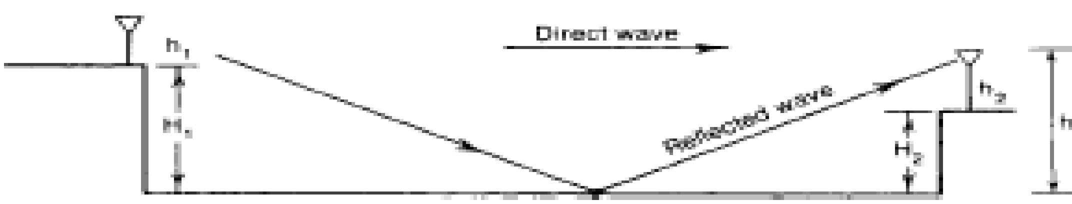


FIGURE 8.8 Propagation between two fixed stations over water or flat open land.

The $a_v e^{-j\phi_v}$ are the complex reflection coefficients and can be found from the for

$$a_v e^{-j\phi_v} = \frac{\epsilon_c \sin\theta_1 - (\epsilon_c - \cos^2\theta_1)^{1/2}}{\epsilon_c \sin\theta_1 + (\epsilon_c - \cos^2\theta_1)^{1/2}}$$

When the vertical incidence is small, θ is very small and

$$a_v \approx -1 \quad \text{and} \quad \phi_v = 0$$

can be found from Eq. (8.3-4), ϵ_c is a dielectric constant that is different for differer However, when $a_v e^{-j\phi_v}$ is independent of ϵ_c, the reflection coefficient remains -1 re of whether the wave is propagated over water, dry land, wet land, ice, and so fc wave propagating between fixed stations is illustrated in Fig. 8.8. Equation (8.3 becomes

$$P_r = \frac{P_t}{(4\pi d/\lambda)^2}\left|1 - \cos\Delta\phi - j\sin\Delta\phi\right|^2$$

$$= P_0(2 - 2\cos\Delta\phi)$$

as $\Delta\phi$ is a function of Δd and Δd can be obtained from the following calculat effective antenna height at antenna 1 is the height above the sea level.

$$h_1' = h_1 + H_1$$

The effective antenna height at antenna 2 is the height above the sea level.

$$h_2' = h_2 + H_2$$

as shown in Fig. 8.8, where h_1 and h_2 are actual heights and H_1 and H_2 are the h hills. In general, both antennas at fixed stations are high, so the reflection point of t will be found toward the middle of the radio path. The path difference Δd can be from Fig. 8.8 as

$$\Delta d = \sqrt{(h_1' + h_2')^2 + d^2} - \sqrt{(h_1' - h_2')^2 + d^2}$$

Because $d \gg h_1'$ and h_2', then

$$\Delta d \approx d\left[1 + \frac{(h_1' + h_2')^2}{2d^2} - 1 - \frac{(h_1' - h_2')^2}{2d^2}\right] = \frac{2h_1'h_2'}{d}$$

Then, Eq. (8.3-2) becomes

$$\Delta\phi = \frac{2\pi}{\lambda}\frac{2h_1'h_2'}{d} = \frac{4\pi h_1'h_2'}{\lambda d}$$

Examining Eq. (8.3-6), we can set up five conditions:

1. $P_r < P_0$. The received power is less than the power received in free space; that

$$2 - 2\cos\Delta\phi < 1 \quad \text{or} \quad \Delta\phi < \frac{\pi}{3}$$

3. $P_r = P_0$; that is,

$$2 - 2\cos\Delta\phi = 1 \quad \text{or} \quad \Delta\phi = \pm 60^\circ = \pm\frac{\pi}{3}$$

4. $P_r > P_0$; that is,

$$2 - 2\cos\Delta\phi > 1 \quad \text{or} \quad \frac{\pi}{3} < \Delta\phi < \frac{5\pi}{3}$$

5. $P_r = 4P_0$; that is,

$$2 - 2\cos\Delta\phi = \max \quad \text{or} \quad \Delta\phi = \pi$$

The value of $\Delta\phi$ can be found from Eq. (8.3-9). Now we can examine the situations r
from Eq. (8.3-9) in the following examples.

EXAMPLE 8.7 *Let a distance between two fixed stations be 30 km. The effective height at one and h_1 is 150 m above sea level. Find the h_2 at the other end so received power always meets the condition $P_r < P_0$ at 850-MHz transmission (λ =*

Solution

$$\frac{4\pi h_1' h_2'}{\lambda d} \le \frac{\pi}{3}$$

or

$$h_1' \le \frac{d\lambda}{12h_1'} = \frac{30{,}000 \times 0.35}{12 \times 150} = 6 \text{ m}$$

EXAMPLE 8.8 *Using the same parameters given in Example 8.7, find the ran which would keep $P_r > P_0$, and find the maximum received power P_r for $P_r = 4P$*

Solution

a. $$\frac{\pi}{3} \le \frac{4\pi h_1' h_2'}{\lambda d} \le \frac{5\pi}{3} \quad \text{the range of } h_2 \text{ for } P_r > P_0$$

Substituting the values given in Example 8.7, we obtain

$$6 \text{ m} < h_2 < 30 \text{ m} \quad 42 \text{ m} < h_2 < 66 \text{ m}$$

b. *$\Delta\phi = \pi$ for the maximum received power.*

$$h_2 = 18 \text{ m} \qquad h_2 = 54 \text{ m} \qquad h_2 = 6 \text{ m}\,[3(2n-1)]$$

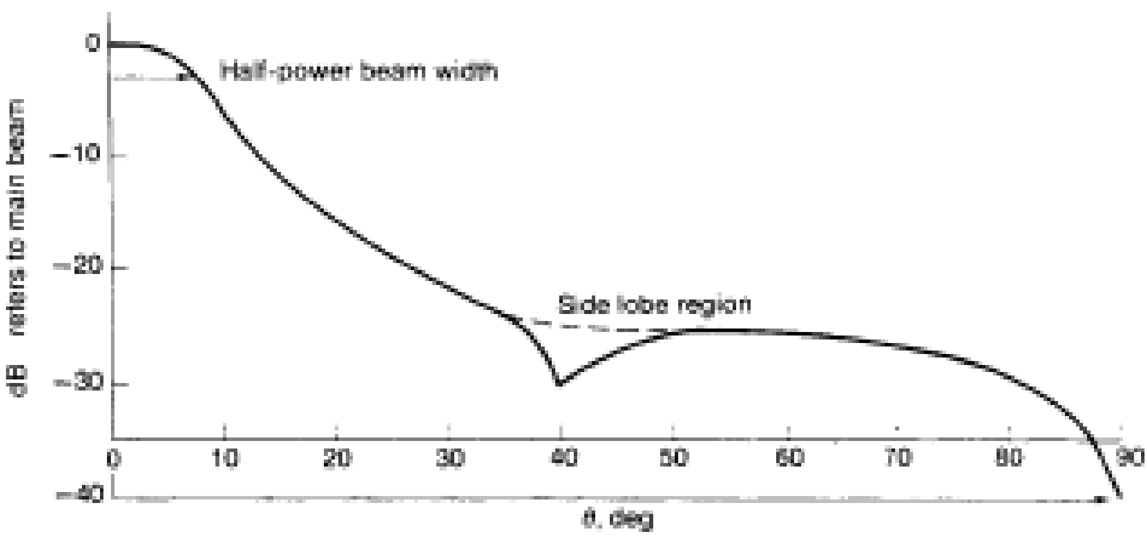
where n is any integer.

Near-in Propagation:

We usually worry about propagation at the far distance for coverage purposes. Now we also should investigate the near-in distance propagation. We may use the suburban area as an example. At the 1-mi intercept, the received level is −61.7 dBm based on the reference set of parameters; that is, the antenna height is 30 m (100 ft). If we increase the antenna height to 60 m (200 ft), a 6-dB gain is obtained. From 60 to 120 m (20 to 400-ft), another 6 dB is obtained. At the 120-m (400-ft) antenna height, the mobile received signal is the same as that received at the free space.

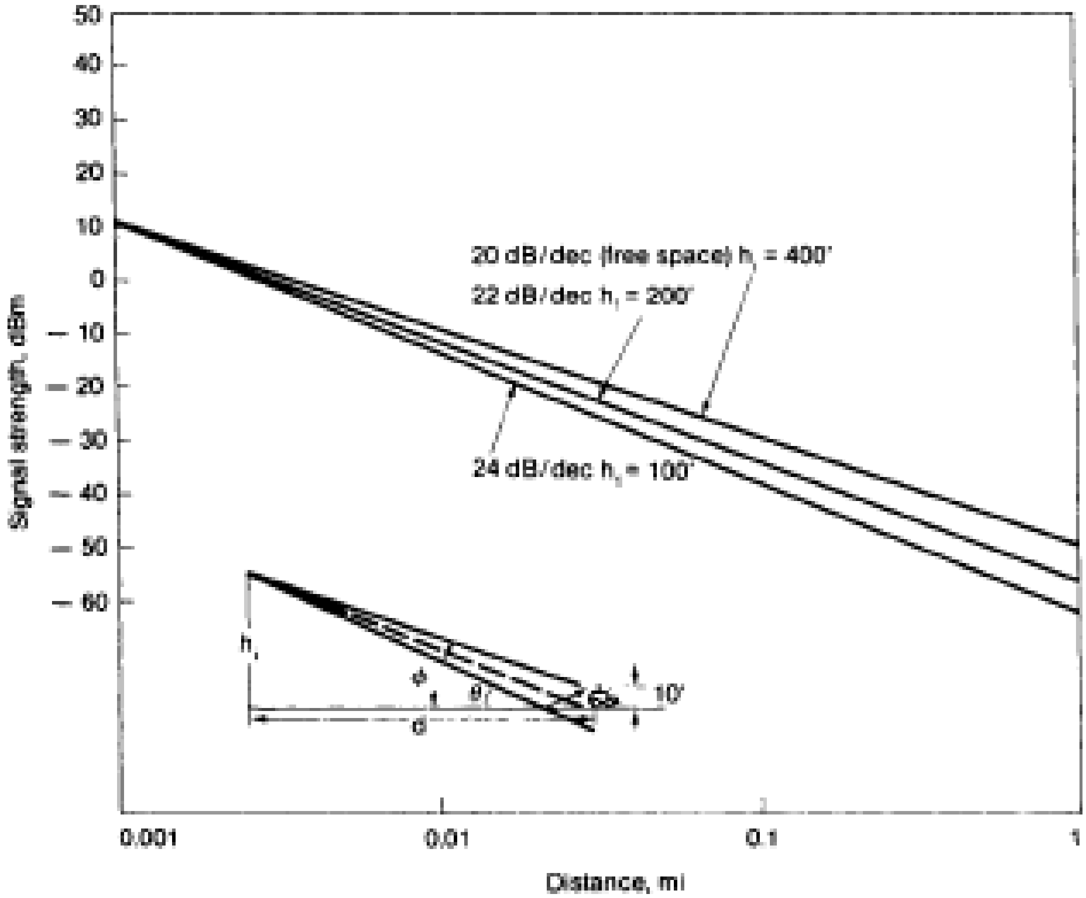
The antenna pattern is not isotropic in the vertical plane. A typical 6-dB omnidirectional antenna vertical beamwidth is shown in Fig. 8.12. The reduction in signal reception can be found in the figure and is listed in the table below. At *d* = 100 m (328 ft) [mobile antenna height = 3 m (10 ft)], the incident angles and
elevation angles are 11.77◦ and 10.72◦, respectively.

Antenna Height h_1, m (ft)	Incident Angle θ, Degrees	Elevation Angle ϕ, Degrees	Attentuation α, dB
90 (300)	30.4	29.6	21
60 (200)	21.61	20.75	16
30 (100)	11.77	10.72	6



A typical 6-dB omnidirectional antenna beamwidth.

Because the incident angle becomes larger, the 40-dB/dec slope is no longer valid. If the antenna beam is aimed at the mobile unit, we will observe 24 dB/dec for an antenna height of 100 ft, 22 dB/dec for an antenna height of 200 ft, and 20 dB/dec for an antenna height of 400 ft or higher. The slope of 20 dB/dec is the free-space loss as shown in Fig. 8.13. The power of 11 dBm received at 0.001 mi is obtained from the free-space formula with an ERP of 46 dBm at the cell site as the standard condition



CURVES FOR NEAR IN PROPOGATION

LONG DISTANCE PROPOGATION:

The advantage of a high cell site is that it covers the signal in a large area, especially in a noise-limited system where usually different frequencies are repeatedly used in different areas. However, we have to be aware of the long-distance propagation phenomenon.

A noise-limited system gradually becomes an interference-limited system as the traffic increases.40−41 The interference is due to not only the existence of many cochannels and adjacent channels in the system, but the long-distance propagation also affects the interference.

Within an Area of 50-mi Radius

For a high site, the low-atmospheric phenomenon would cause the ground wave path to propagate in a non-straight-line fashion. The phenomenon is usually more pronounced over seawater because the atmospheric situation over the ocean can be varied based on the different altitudes. The wave path can bend either upward or downward. Then we may have the experience that at one spot the signal may be strong at one time but weak at another.

At a Distance of 320 km (200 mi)

Tropospheric wave propagation prevails at 800 MHz for long-distance propagation; sometimes the signal can reach 320 km (200 mi) away. Thewave is received 320 km away because of an abrupt change in the effective dielectric constant of the troposphere (10 km above the surface of the earth). The dielectric constant changes with temperature, which decreases with height at a rate of about 6.5°C/km and reaches -50°C at the upper boundary of the troposphere. In tropospheric propagation, the wave may be divided by refraction and reflection. *Tropospheric refraction*.40 This refraction is a gradual bending of the rays due to the changing effective dielectric constant of the atmosphere through which the wave is passing.

Tropospheric reflection. This reflection will occur where there are abrupt changes in the dielectric constant of the atmosphere. The distance of propagation is much greater than the line-of-sight propagation. *Moistness*. Actually water content has much more effect than temperature on the dialectric constant of the atmosphere and on the manner in which the radio waves are affected.

The water vapor pressure decreases as the height increases. If the refraction index decreases with height over a portion of the range of height, the rays will be curved downward, and a condition known as *trapping*, or *duct propagation*, can occur. There are surface ducts and elevated ducts. Elevated ducts are due to large air masses and are common in southern California. They can be found at elevations of 300 to 1500 m (1000 to 5000 ft) and may vary in thickness from a few feet to a thousand feet. Surface ducts appear over the sea and are about 1.5 m (5 ft) thick. Over land areas, surface ducts are produced by the cooling air of the earth. Tropospheric wave propagation does cause interference and can only be reduced by umbrella antenna beam patterns, a directional antenna pattern, or a low-power low-antennamast approach.

POINT- TO POINT MAODEL:

In this condition, the direct path from the cell site to the mobile unit is not obstructed by the terrain contour. Here, two general terms should be distinguished. The *nonobstructive direct path* is a path unobstructed by the terrain contour. The *line-of-sight path* is a path that is unobstructed by the terrain contour and by man-made structures. In the former case, the cell-site antenna cannot be seen by the mobile user whereas in the latter case, it can be. Therefore, the signal reception is very strong in the line-of-sight case, which is not the case we are worrying about. In the mobile environment, we do not often have line-of-sight conditions. Therefore, we use direct-path conditions, which are unobstructed by the terrain contour. Under these conditions, the antenna-height gain will be calculated for every location in which the mobile unit travels, as illustrated in Fig. 8.14. The method for finding the antenna-height gain is as follows.

***Finding the Antenna-Height Gain*43**

1. Find the specular reflection point. Take two values from two conditions stated as follows.

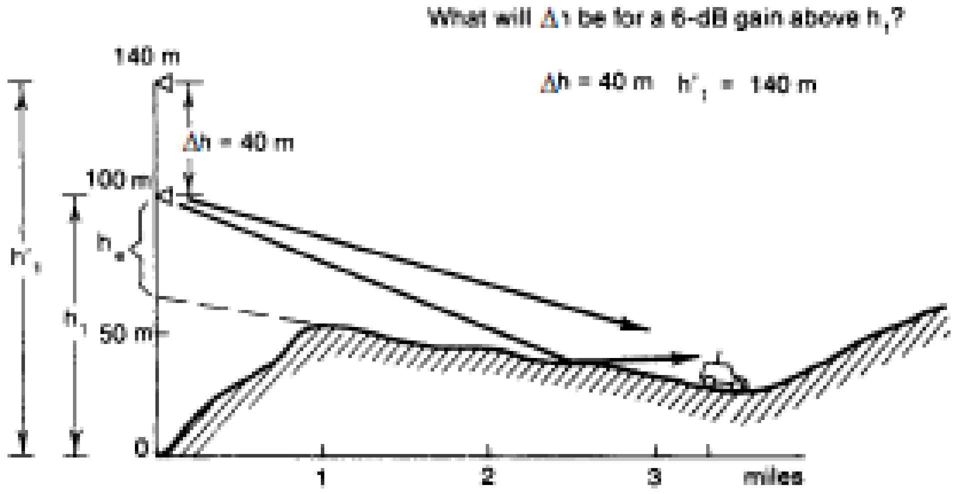
a. Connect the image antenna of the cell-site antenna to the mobile antenna; the intercept point at the ground level is considered as a potential reflection point.

b. Connect the image antenna of the mobile antenna to the cell-site antenna; the intercept point at the ground level is also considered as a potential reflection point. Between two potential reflection points we choose the point which is close to the mobile unit to be the real one because more energy would be reflected to the mobile unit at that point.

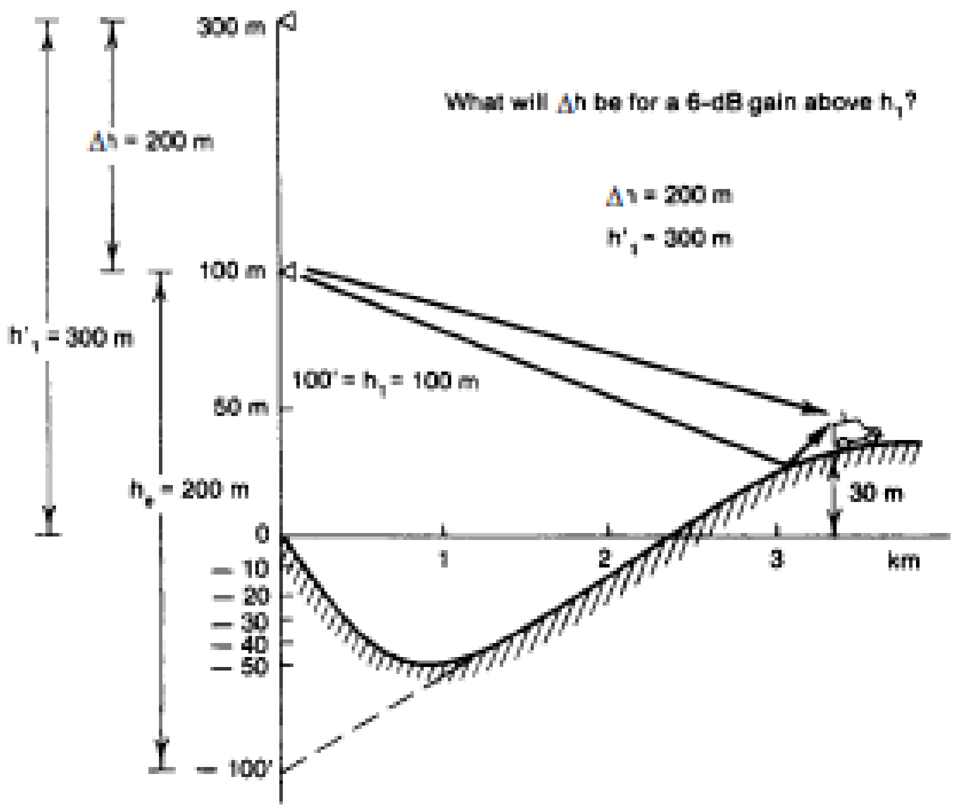
2. Extend the reflected ground plane. The reflected ground plane which the reflection point is on can be generated by drawing a tangent line to the point where the ground curvature is, then extending the reflected ground plane to the location of the cell-site antenna.

CALCULATION OF EFFECTIVE ANTENNA

HEIGHT



(a)



(b)

CALCULATION OF EFFECTIVE ANTENNA HEIGHT

3. Measure the effective antenna height. The effective antenna height is measured from the point where the reflected ground plan and the cell-site antenna location meet. Between these two cases shown in Fig. 8.14, *he* equals 40 m in Fig. 8.14*a* and 200 m in Fig. 8.14*b*. The actual antenna height *h*1 is 100 m.

4. Calculate the antenna-height gain _*G*. The formula of _*G* is expressed as

$$G = 20 \log \frac{h_e}{h_1}$$

Then the ΔG from Fig. 8.14*a* is

$$\Delta G = 20 \log \frac{40}{100} = -8 \text{ dB} \qquad \text{(a negative gair}$$

The ΔG from Fig. 8.14*b* is

$$\Delta G = 20 \log \frac{200}{100} = 6 \text{ dB} \qquad \text{(a positive gain i}$$

We have to realize that the antenna-height gain _*G* changes as the mobile unit moves along the road. In other words, the effective antenna height at the cell site changes as the mobile unit moves to a new location, although the actual antenna remains unchanged.

UNIT-VI

CELL SITE AND MOBILE ANTENNAS

SUM AND DIFFERENCE PATTERNS AND THEIR SYNTHESIS:

5.1 GENERAL INTRODUCTION

Cell coverage can be based on signal coverage or on traffic coverage. Signal coverage can be predicted by coverage prediction models and is usually applied to a start-up system. The task is to cover the whole area with a minimum number of cell sites. Because 100 percent cell coverage of an area is not possible, the cell sites must be engineered so that the holes are located in the no-traffic locations. The prediction model is a point-to-point model that is discussed in this chapter. We have to examine the service area as occurring in one of the following environments:

Human-made structures

In a building area

In an open area

In a suburban area
In an urban area
Natural terrains
Over flat terrain
Over hilly terrain
Over water
Through foliage areas
The results generated from the prediction model will differ depending on which service area is used.
There are many field-strength prediction models in the literature.1−28 They all provide more or less an area-to-area prediction. As long as 68 percent of the predicted values from a model are within 6 to 8 dB (one standard deviation) of their corresponding measured value, the model is considered a good one. However, we cannot use area-to-area prediction models for cellular system design because of the large uncertainty of the prediction.
The model being introduced here is the point-to-point prediction model, which would provide a standard deviation from the predicted value of less than 3 dB. An explanation of this model appears in Refs. 23 and 24. Many tools can be developed based upon this model, such as cell-site choosing, interference reduction, and traffic handling.

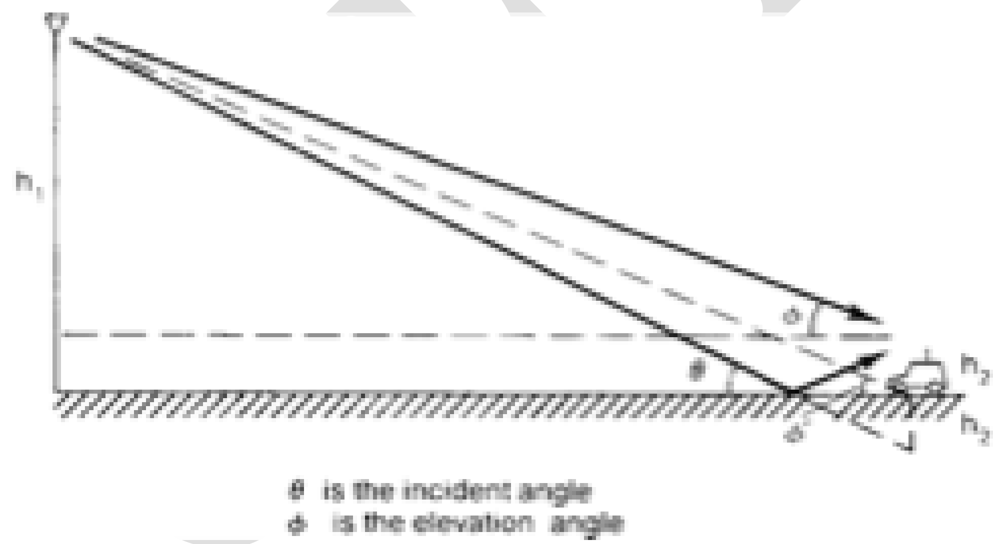


Fig:5.1 A coordinate sketch in a flat terrain

5.1.1 Ground Incident Angle and Ground Elevation Angle
The ground incident angle and the ground elevation angle over a communication link are described as follows. The ground incident angle θ is the angle of wave arrival incidently pointing to the ground as shown in Fig. 8.1. The ground elevation angle φ is the angle of wave arrival at the mobile unit as shown in Fig. 8.1.
EXAMPLE 5.1 *In a mobile radio environment, the average cell-site antenna height is about*

50 m, the mobile antenna height is about 3 m, and the communication path length is 5 km. The incident angle is (see Fig.5.1)

$$\theta = \tan^{-1} \frac{50 \text{ m} + 3 \text{ m}}{5 \text{ km}} = 0.61^{\circ}$$

The elevation angle at the antenna of the mobile unit is

$$\phi = \tan^{-1} \frac{50 \text{ m} - 3 \text{ m}}{5 \text{ km}} = 0.54^{\circ}$$

The elevation angle at the location of the mobile unit is

$$\phi' = tan^{-1} \frac{50 \text{ m}}{5 \text{ km}} = 0.57^{\circ}$$

5.1.2 Ground Reflection Angle and Reflection Point

Based on Snell's law, the reflection angle and incident angle are the same. Because in graphi-
cal display we usually exaggerate the hilly slope and the incident angle by enlarging the verti-
cal scale, as shown in Fig. 8.2, then as long as the actual hilly slope is less than 10◦ , the reflec-
tion point on a hilly slope can be obtained by following the same method as if the reflection point were on flat ground. Be sure that the two antennas (base and mobile) have been placed
vertically, not perpendicular to the sloped ground. The reason is that the actual slope of the hill is usually very small and the vertical stands for two antennas are correct. The scale draw-
ing in Fig. 5.2 is somewhat misleading; however, it provides a clear view of the situation.

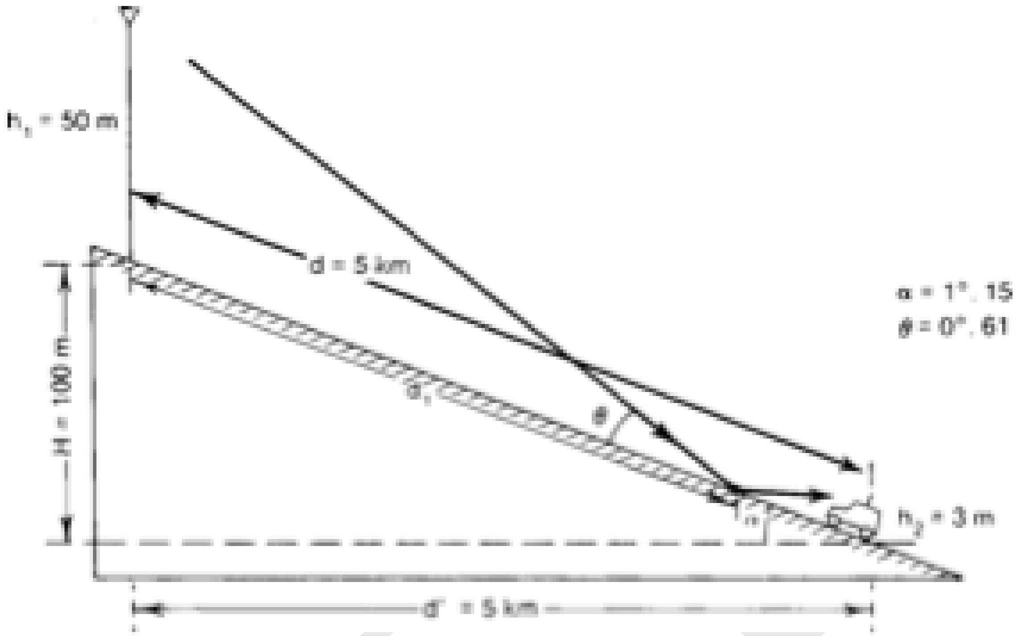


FIGURE 5.2 A coordinate sketch in a hilly terrain.

EXAMPLE 8.2 *Let* $h_1 = 50$ *m,* $h_2 = 3$ *m, d = 5 km, and H =* 100 *m as shown in Fig. 5.2.*

(*a*) *Using the approximate method (*$d = d'$ *= 5 km), the slope angle* α *of the hill is*

$$\alpha = \tan^{-1}\frac{100\text{ m}}{5\text{ km}} = 1.14576^\circ$$

the incident angle is

$$\theta = \tan^{-1}\frac{50\text{ m} + 3\text{ m}}{5\text{ km}} = 0.61$$

and the reflection point location from the cell-site antenna

$$d_1 = 50/\tan\theta = 4.717\text{ km}.$$

(b) Using the accurate method, the slope angle α of the hill is

$$\alpha = \tan^{-1}\frac{100\text{ m}}{\sqrt{(5\text{ km})^2 - (100\text{ m})^2}} = \tan^{-1}\frac{100}{4999} = 1.14599^\circ$$

The incident angle θ *and the reflection point location* $d1$ *are the same as above.*

5.3 Omnidirectional Antenna

As it is necessary to cover not only the highway but also areas in the vicinity of the highway,
the omnidirectional antenna is used. When the cell sites are chosen and put up along the highway (see Fig. 12.23), the line-of-sight situation is usually assumed.
Although the general area around the highway could be suburban, because of the line-of-sight situation the path loss should be calculated using an open-area curve instead of the suburban-area curve shown in Fig. 8.3*c*. The differences between highway cell-site separation and normal cell-site separation us- ing path-loss values from the suburban and the open-area curves (see Fig. 8.3*c*), respectively, are plotted in Fig. 12.24. The curve is labeled “Noise condition of human origin.” Traffic along highways away from densely populated areas is usually light and the level of automotive noise is low, perhaps 2 dB lower than the average human-made noise-level condition. Based on the 2-dB noise quieting assumption, another curve labeled “Low noise condition of human origin” is also shown in Fig. 12.24.
From Fig. 12.24 we can obtain the following data.
Average Cell-Site Separation, mi;
Normal Human-Made Normal Human-Made Low Human-Made
Noise Condition Noise Condition Noise Condition

Highway Cell-Site Separation, mi 6 9.5 11 10 15 17
The purpose of using the omni directional antenna at the cell sites along the highway is to cover the area in the vicinity of the highway where residential areas are usually located.

5.4 For Interference Reduction Use: Directional Antennas

When the frequency reuse scheme must be used in AMPS, cochannel interference will occur.
The cochannel interference reduction factor $q = D/R = 4.6$ is based on the assumption that the terrain is flat. Because actual terrain is seldom flat, we must either increase q or use directional antennas.

5.4.1 Directional Antennas. A 120◦ -corner reflector or 120◦ -plane reflector can be used in a 120◦ -sector cell. A 60◦ -corner reflector can be used in a 60◦ -sector cell. A typical pattern for a directional antenna of 120◦ beamwidth is shown in Fig. 5.3.

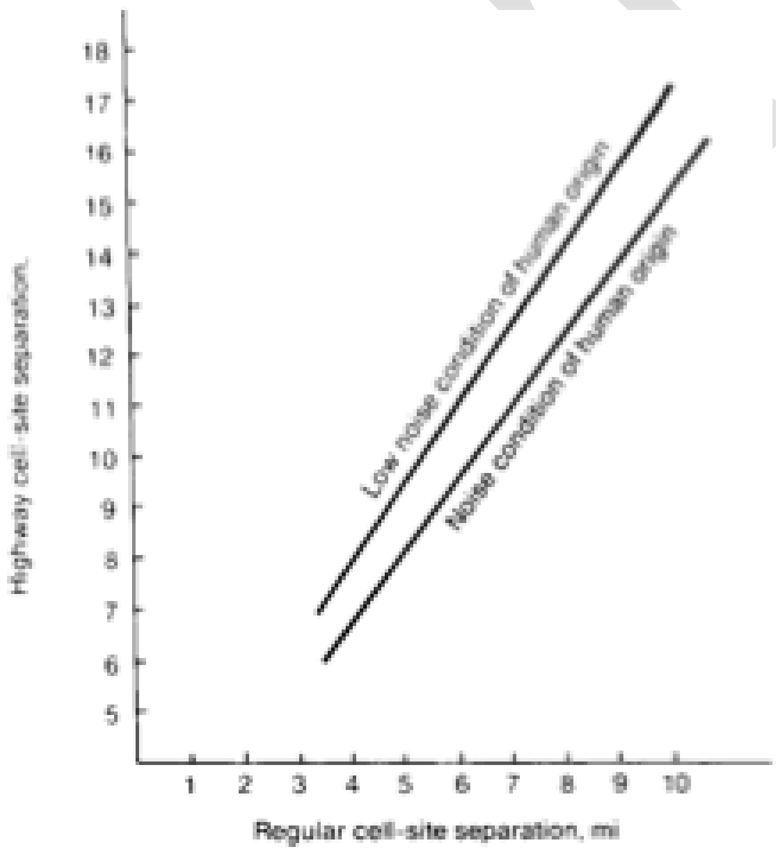
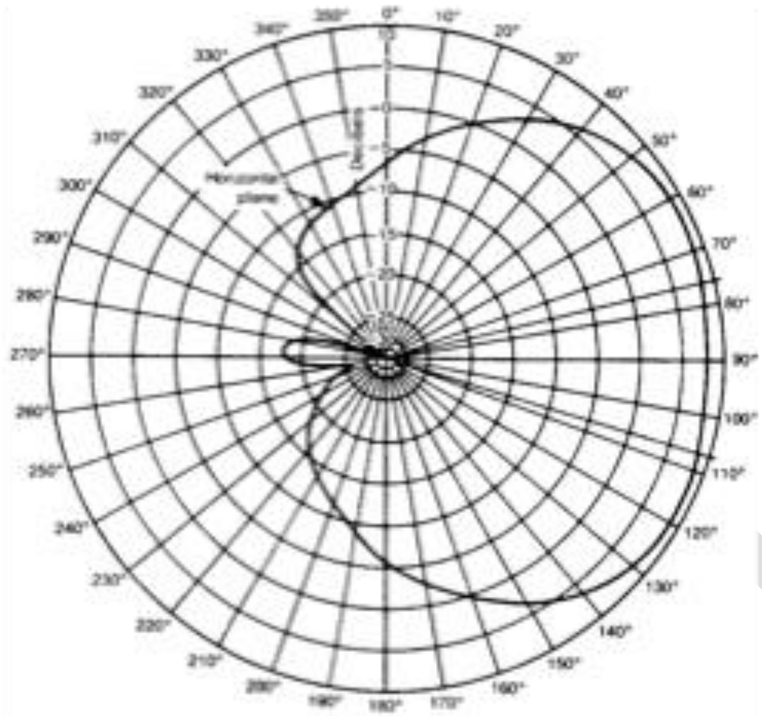
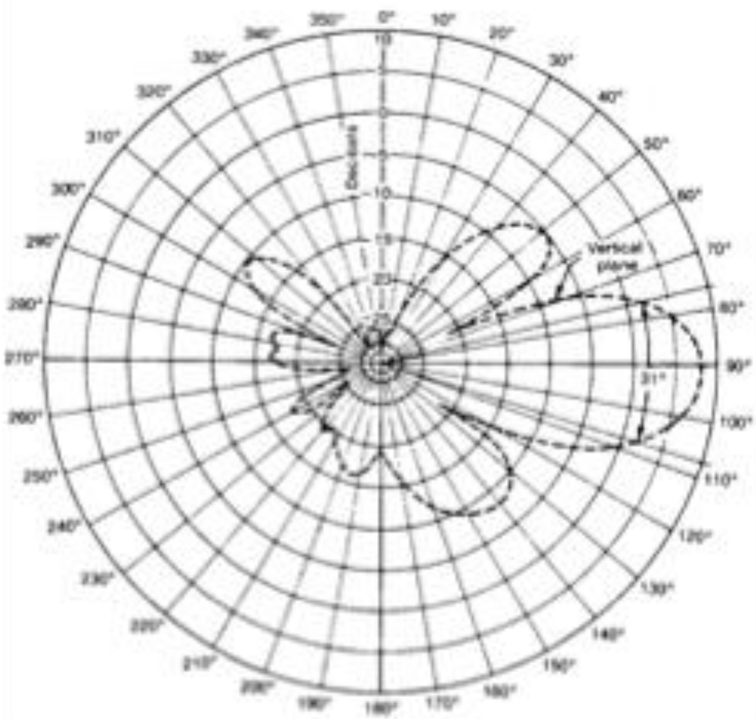


FIGURE 5.3 Highway cell-site separation.



(a)



(b)

FIGURE 5.3 A typical 8-dB directional antenna pattern. (*Reprinted from Bell System Technical Journal, Vol. 58, January 1979, pp. 224–225.)* (***a***) Azimuthal pattern of 8-dB directional antenna. (***b***) Vertical pattern of 8-dB directional antenna.

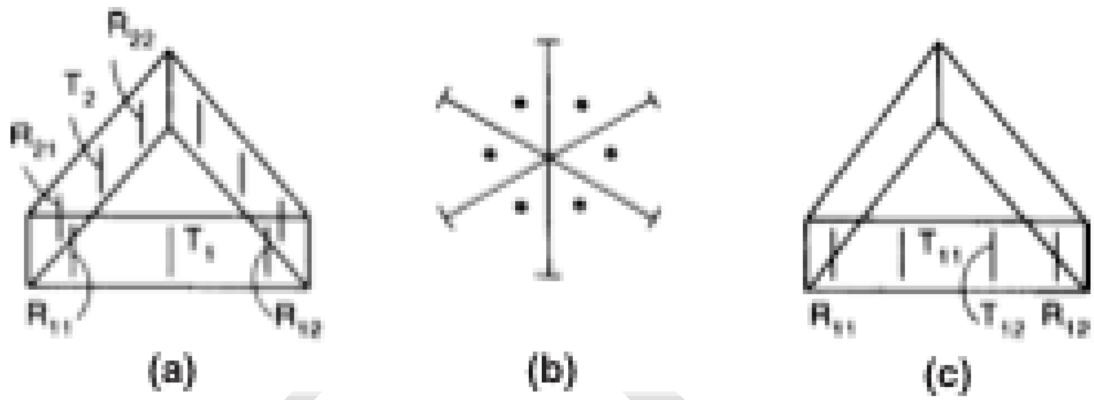


FIGURE 5.4 Directional antenna arrangement: (***a***) 120◦ sector (45 radios); (***b***) 60◦ sector; (***c***) 120◦ sector (90 radios).

5.3.2 Normal Antenna (Mature System) Configuration

1. *K* = 7 cell pattern (120◦ sectors). In a *K* = 7 cell pattern for frequency reuse, if 333 channels are used, each cell would have about 45 radios. Each 120◦ sector would have one transmitting antenna and two receiving antennas and would serve 16 radios. The two receiving antennas are used for diversity (see Fig. 8.34*a*).

2. *K* = 4 cell pattern (60◦ sectors). We do not use *K* = 4 in an omnicell system because the cochannel reuse distance is not adequate. Therefore, in a *K* = 4 cell pattern, 60◦ sectors are used.54 There are 24 sectors. In this *K* = 4 cell-pattern system, two approaches are used.

a. Transmitting-receiving 60◦ sectors. Each sector has a transmitting antenna carrying its own set of frequency radios and hands off frequencies to other neighboring sectors or other cells. This is a full *K* = 4 cell-pattern system. If 333 channels are used, with 13 radios per sector, there will be one transmitting antenna and one receiving antenna in each sector. At the receiving end, two of six receiving antennas are selected for an angle diversity for each radio channel (see Fig. 8.34*b*).

b. Receiving 60◦ sectors. Only 60◦ -sector receiving antennas are used to locate mobile units and handoff to a proper neighboring cell with a high degree of accuracy. All the transmitting antennas are omnidirectional within each cell. At the receiving end, the angle diversity for each radio channel is also used in this case.

5.3.3 Abnormal Antenna Configuration. If the call traffic is gradually increasing, there is an economic advantage in using the existing cell systems rather than the new splitting cell system (splitting into smaller cells). In the former, each site is capable of adding more radios. In a $K = 7$ cell pattern with 120° sectors, two transmitting antennas at each sector are used (Fig. 8.34*c*). Each antenna serves 16 radios if a 16-channel combiner is used. One observation from Fig. 8.34*c* should be mentioned here. The two transmitting antennas in each sector are placed relatively closer to the receiving antennas than in the single transmitting antenna case. This may cause some degree of desensitization in the receivers. The technology cited in Ref. 53 can combine 32 channels in a combiner; therefore, only one transmitting antenna is needed in each sector. However, this one transmitting antenna must be capable of withstanding a high degree of transmitted power. If each channel transmits 100 W, the total power that the antenna terminal could withstand is 3.2 kW.

The 32-channel combiner has a power limitation which would be specified by different manufacturers. Two receiving antennas in each 120° sector remain the same for space diversity use.

5.4 SPACE DIVERSITY ANTENNAS:

5.4.1 Horizontally Oriented Space-Diversity Antennas

A two-branch space-diversity receiver mounted on a motor vehicle has the advantage of reducing fading and thus can operate at a lower reception level. The advantage of using a space-diversity receiver to reduce interference is discussed in Chap. 10. The discussion here concerns a space-diversity scheme in which two vehicle-mounted antennas separated horizontally by 0.5λ wavelength[69] (15 cm or 6 in) can achieve the advantage of diversity. We must consider the following factor. The two antennas can be mounted either in line with or perpendicular to the motion of the vehicle. Theoretical analyses and measured data indicate that the inline arrangement of the two antennas produces fewer level crossings, that is, less fading, than the perpendicular arrangement does. The level crossing rates of two signals received from different horizontally oriented space-diversity antennas are shown in Fig. 8.50.

5.4.2 Vertically Oriented Space-Diversity Antennas[70]

The vertical separation between two space-diversity antennas can be determined from the correlation between their received signals. The positions of two antennas X_1 and X_2 are shown in Fig. 8.51. The theoretical derivation of correlation is[71]

$$\rho\left(\frac{d}{\lambda}, \theta\right) = \frac{\sin[(\pi d/\lambda)\sin\theta]}{(\pi d/\lambda)\sin\theta}$$

Equation (5.6) is plotted in Fig 5.6 A set of measured data was obtained by using two antennas vertically separated by 1.5λ wavelengths. The mean values of three groups of measured data are also shown in Fig. 8.52. In one group, in New York City, low correlation coefficients were observed. In two other groups, both in New Jersey, the average correlation coefficient for perpendicular streets was 0.35 and for radial streets, 0.225. The following table summarizes the correlation coefficients in different areas and different street
orientations.

	Correlation Coefficient	
Area	Average	Standard Deviation
New York City	0.1	0.06
Suburban New Jersey		
Radial streets	0.226	0.127
Perpendicular streets	0.35	0.182

From Fig. 5.5 we can also see that the signal arrives at an elevation angle of 29◦ in the suburban radial streets and 33◦ in the suburban perpendicular streets. In New York City the angle of arrival approaches 40◦ .

5.5 Umbrella-Pattern Antennas

In certain situations, umbrella-pattern antennas should be used for the cell-site antennas.

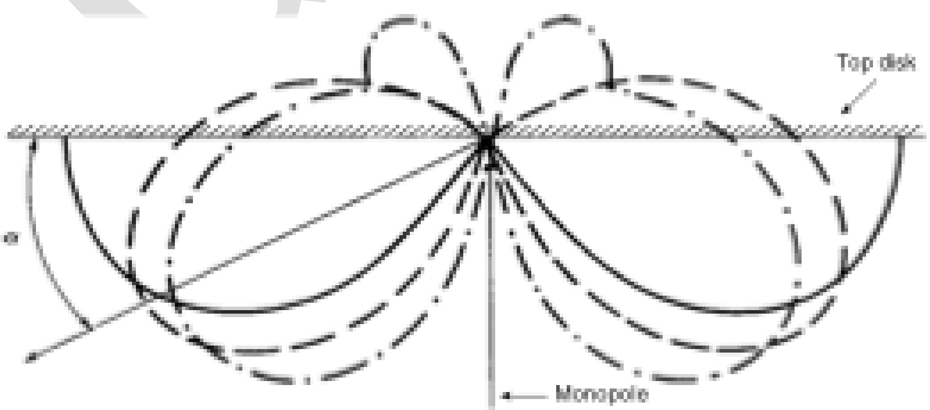


FIGURE5.6 Vertical-planepatternsofquarter-wavelengthstubantennaoninfinite groundplane(solid)andonfinitegroundplanesseveralwavelengthsindiameter(dashed line)andaboutonewavelengthindiameter(dottedline).(*AfterKraus,Ref.14.*)

5.5.1 NormalUmbrella-PatternAntenna.**57** Forcontrollingtheenergyinaconfined area, theumbrella-patternantennacanbedevelopedbyusingamonopolewithatopdisk (top-loading)asshowninFig.5.6.Thesizeofthediskdeterminesthetiltingangleofthe pattern.Thesmallerthedisk,thelargerthetiltingangleoftheumbrellapattern.

5.5.2 BroadbandUmbrella-PatternAntenna.**58** Theparameters of a*disconean-tenna*(abioconicalantennainwhichoneoftheconesisextendedto180◦toformadisk) areshowninFig. 5.7*a*. Thediameterofthedisk, thelengthofthecone, andtheopening ofthecone canbeadjustedtocreateanumbrella-patternantennaasdescribedinRef.58.

5.5.3 High-GainBroadbandUmbrella-PatternAntenna. Ahigh-gainantennacan beconstructedbyverticallystackinganumberofumbrella-patternantennasasshownin Fig.5.7*b*.

$$E_0 = \frac{\sin[(Nd/2\lambda)\cos\phi]}{\sin[(d/2\lambda)\cos\phi]} \cdot \text{(individual umbrella pattern)}$$

where ϕ = direction of wave travel
N = number of elements
d = spacing between two adjacent elements

(a) (b)

FIGURE5.7 Disconeantennas.(***a***)Singleantenna. (***b***)Anarrayofantennas.

5.7 Minimum Separation of Cell-Site Receiving Antennas

Separation between two transmitting antennas should be minimized to avoid the intermodulation discussed in Chap. 10. The minimum separation between a transmitting antenna and a receiving antenna necessary to avoid receiver desensitization is also described in Chap. 10. Here we are describing a minimum separation between two receiving antennas to reduce the antenna pattern ripple effects.

The two receiving antennas are used for a space-diversity receiver. Because of the near-field disturbance due to the close spacing, ripples will form in the antenna patterns (Fig. 8.40). The difference in power reception between two antennas at different angles of arrival is shown in Fig. 8.40. If the antennas are located closer; the difference in power between two antennas at a given pointing angle increases. Although the power difference is confined to a small sector, it affects a large section of the street as shown in Fig. 8.40. If the power difference is excessive, use of a space diversity will have no effect reducing fading. At 850 MHz, the separation of eight wavelengths between two receiving antennas creates a power difference of ±2 dB, which is tolerable for the advantageous use of a diversity scheme.61

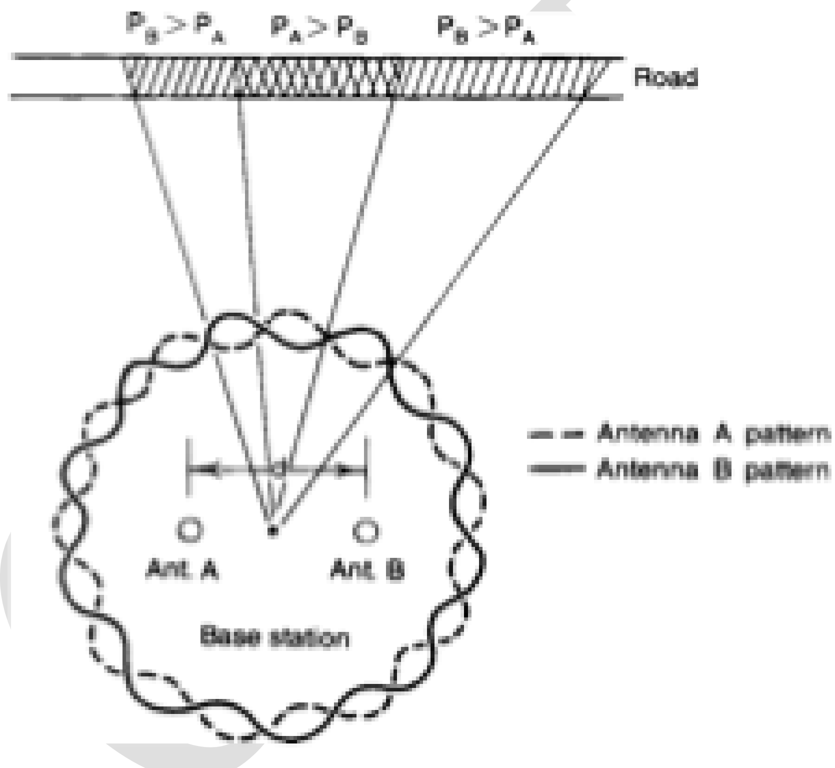


FIGURE 5.8 Antenna pattern ripple effect.

5.9 Mobile High-Gain Antennas

A high-gain antenna used on a mobile unit has been studied.68 This type of high-gain antenna should be distinguished from the directional antenna. In the directional antenna, the antenna beam pattern is suppressed horizontally; in the high-gain antenna, the pattern is suppressed vertically. To apply either a directional antenna or a high-gain antenna for reception in a radio environment, we must know the origin of the signal. If we point the directional antenna opposite to the transmitter site, we would in theory receive nothing. In a mobile radio environment, the scattered signals arrive at the mobile unit from every direction with equal probability. That is why an omnidirectional antenna must be used. The scattered signals also arrive from different elevation angles. Lee and Brandt[68] used two types of antenna, one $\lambda/4$ whip antenna with an elevation coverage of 39° and one 4-dB-gain antenna (4-dB gain with respect to the gain of a dipole) with an elevation coverage of 16°, and measured the angle of signal arrival in the suburban Keyport-Matawan area of New Jersey. There are two types of test: a line-of-sight condition and an out-of-sight condition. In Lee and Brandt's study, the transmitter was located at an elevation of approximately 100 m (300 ft) above sea level. The measured areas were about 12 m (40 ft) above sea level and the path length about 3 mi. The received signal from the 4-dB-gain antenna was 4 dB stronger than that from the whip antenna under line-of-sight conditions. This is what we would expect. However, the received signal from the 4-dB-gain antenna was only about 2 dB stronger than that from the whip antenna under out-of-sight conditions. This is surprising.

The reason for the latter observation is that the scattered signals arriving under out-of- sight conditions are spread over a wide elevation angle. A large portion of the signals outside the elevation angle of 16° cannot be received by the high-gain antenna. We may calculate the portion being received by the high-gain antenna from the measured beamwidth. For instance, suppose that a 4:1 gain (6 dBi) is expected from the high-gain antenna, but only 2.5:1 is received. Therefore, 63 percent of the signal$*$ is received by the 4-dB-gain antenna (i.e., 6 dBi) and 37 percent is felt in the region between 16 and 39°. Consider the data in the following table.

	Gain, dBi	Linear ratio	$\theta_0/2$, degrees
Whip antenna (2 dB above isotropic)	2	1.58:1	39
High-gain antenna	6	4:1	16
Low-gain antenna	4	2.5:1	24

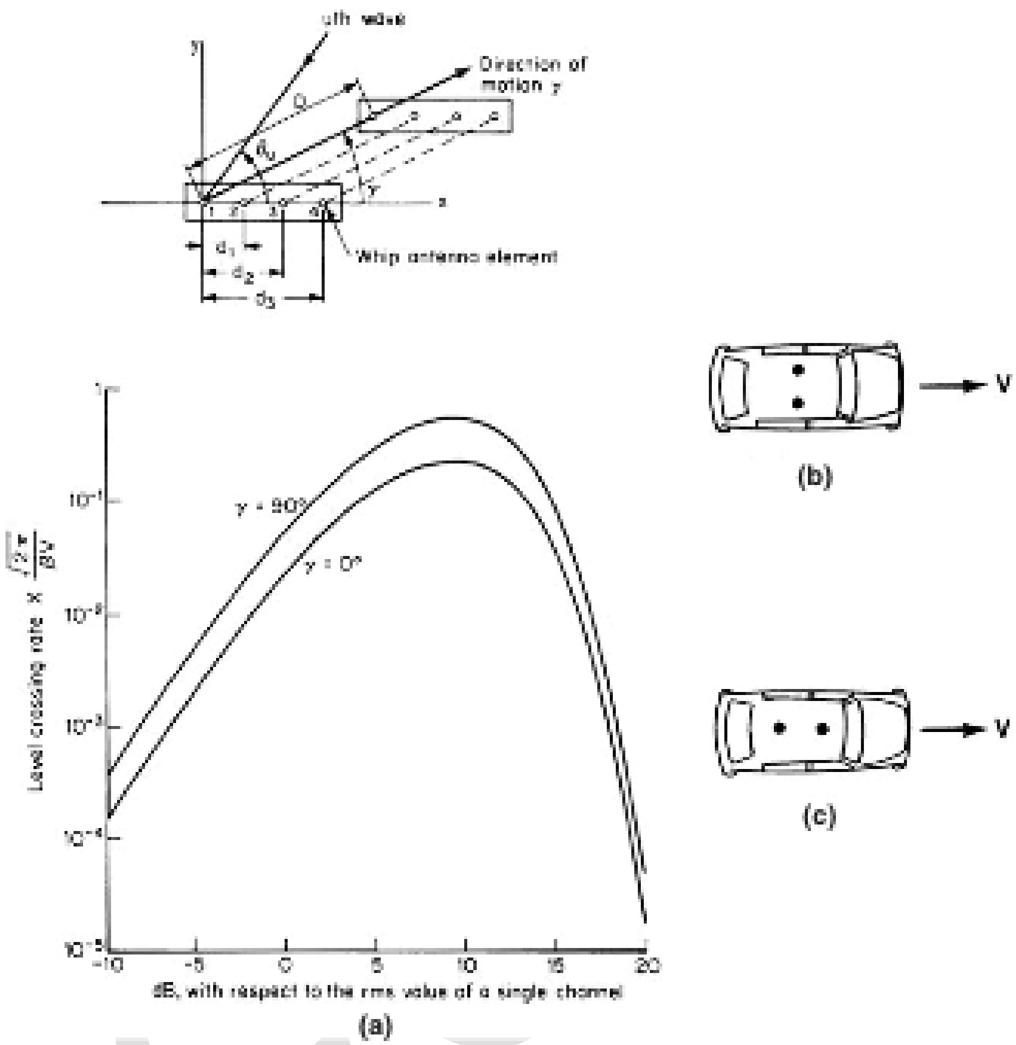


FIGURE 5.8 Horizontally spaced antennas. (***a***) Maximum difference in lcr of a four-branch equal-gain
signal between α
= 0 and α = 90◦ with antenna spacing of 0.15λ (***b***) Not recommended. (***c***) Recommended.

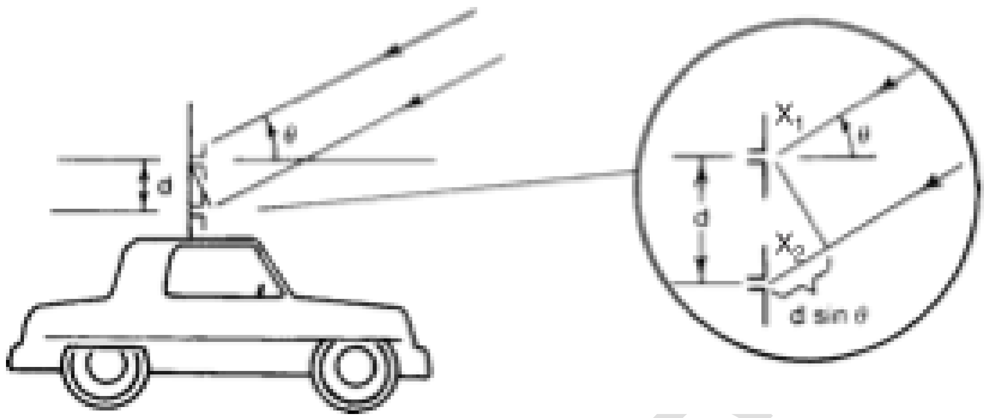


FIGURE 5.10 Vertical separation between two mobile antennas.
Therefore, a 2- to 3-dB-gain antenna (4 to 5 dBi) should be adequate for general use. An antenna gain higher than 2 to 3 dB does not serve the purpose of enhancing reception level. Moreover, measurements reveal that the elevation angle for scattered signals received in urban areas is greater than that in suburban areas.

Unit VII

Frequency Management and Channel Assignment

Frequency Management:

The function of frequency management is to divide the total number of available channels into subsets which can be assigned to each cell either in a fixed fashion or dynamically (i.e., in response to any channel among the available channels). The terms "frequency management" and "channel assignment" often create some confusion. Frequency management refers to designating setup channels and voice channels (done by the FCC), numbering the channels (done by the FCC), and grouping the voice channels into subsets (done by each system according to its preference). Channel assignment refers to the allocation of specific channels to cell sites and mobile units. A fixed channel set consisting of one more subsets is assigned to a cell site on a long-term basis. During a call, a particular channel is assigned to a mobile unit on a short- term basis. For a short-term assignment, one channel assignment per call is handled by the mobile telephone switching office (MTSO). Ideally channel assignment should be based on causing the least interference in the system. However, most cellular systems cannot perform this way.

Numbering the channels:

The total number of channels at present (January 1988) is 832. But most mobile units an systems are still operating on 666 channels. Therefore we describe the 666 channel numbering first. A channel consists of two frequency channel bandwidths, one in the low band and one in the high band. Two frequencies in channel 1 are 825.030 MHz (mobile transmit) 870.030 MHz (cell-site transmit). The two frequencies in channel 666 are 844.98 MHz (mobile transmit) and 898 MHz (cell-site transmit). The 666 channels are divided into two groups: block A system and block B system. Each market (i.e., each city) has two systems for a duopoly market policy. Each block has 333 channels, as shown in Fig. 1.1.

The 42 set-up channels are assigned as follows

Channels 313-333 block A

Channels 334-354 block B

The voice channels are assigned as follows.

Channels 1-312 (312 voice channels) block A

Channels 355-666 (312 voice channels) block B

1A	2A	3A	4A	5A	6A	7A	1B	2B	3B	4B	5B	6B	7B	1C	2C	3C	4C	5C	6C	7C
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147
148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189
190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231
232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273
274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294
295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	—	—	—
313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333
334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354
355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375
376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417
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439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459
460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501
502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522
523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543
544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564
565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585
586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606
607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627
628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648
649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	—	—	—

Block A system (rows 1–333, above the line); Block B system (rows 334–666, below the line); Control channel sets (rows 313–333 and 334–354)

Fig. 1.1. Frequency management chart

These 42 set-up channels are assigned in the middle of all the assigned channels to facilitate scanning of those channels by frequency synthesizers. In the new additional spectrum allocation of 10 MHz (sec Fig. 1.2.), an additional 166 channels are assigned. Since a 1 MHz is assigned below 825 MHz (or 870 MHz) in the future, additional channels will be numbered up to 849 MHz (or 894 MHz) and will then circle back. The last channel number is 1023. There are no Channels between channels 799 and 991.

M DEM T*

fiwt 935 BIS a-si mi Big Sii MHI

A	ft	B	A	8	ft

OMIT** 991 1 333 Ö« Ìli 799

10Ï3

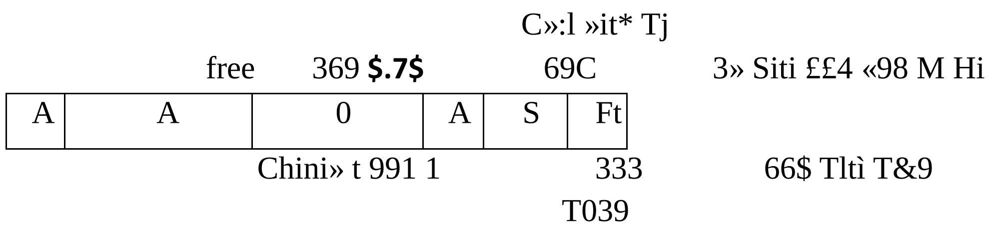


Fig.6.2. New additional spectrum allocation

Grouping into subsets:

The number of voice channels for each system is 312. We can group these into any number of subsets. Since there are 21 set-up channels for each system, it is logical to group the 312 channels into 21 subsets. Each subset then consists of 16 channels. In each set, the closest adjacent channel is 21 channels away, as shown in Fig. 1.1. The 16 channels in each subset can be mounted on a frame and connected to a channel combiner. Wide separation between adjacent channels is required for meeting the requirement of minimum isolation. Each 16-channel subset is idealized for each 16-channel combiner. In a seven- cell frequency-reuse cell system each cell contains three subsets, iA+iB+iC, where i is an integer from 1 to 7. The total number of voice channels in a cell is about 45. The minimum separation between three subsets is 7 channels. If six subsets are equipped in an omnicell site, the minimum separation between two adjacent channels can be only three (21/6> 3) physical channel bandwidths.

For example,
1A+1B+1C+4A+4
B +4C

or 1A+1B+1C+5A+5B+5C

Frequency -Spectrum Utilization:

Since the radio-frequency spectrum is finite in mobile radio systems, the most significant challenge is to use the radio-frequency spectrum as efficiently as possible. Geographic location is an important factor in the application of the frequency-reuse concept in mobile cellular technology to increase spectrum efficiency. Frequency management involving the assignment of proper channels in different cells can increase spectrum efficiency. Thus, within a cell the channel assignment for each call is studied.

The techniques for increasing frequency spectrum can be classified as

1. Increasing the number of radio channel using narrow banding, spread spectrum, or time division.
2. Improving spatial frequency-spectrum reuse.
3. Frequency management and channel assignment.
4. Improving spectrum efficiency in time.

5. Reducing the load of invalid calls
   a. Off-air call setup—reducing the load of setup channels
   b. Voice storage service for No-Answer calls
   c. Call forwarding
   d. Reducing the customers' Keep-Dialing cases
   e. Call waiting for Busy-Call situations
   f. Queuing

Grouping of Set-up channels.

Set-up channels also called control channels are the channels designated to setup calls. We should not be confused by fact that a call always needs a set-up channel. A system can be operated without set-up channels. If we are choosing such a system all the 333 channels in each cellular system (block A or block B) can be voice channels; however each mobile unit must then scan 333 channels continuously and detect the signaling for its call. A customer who wants to initiate a call must scan all the channels and find an idle (unoccupied) one to use. In a cellular system, we are implementing frequency-reuse concepts. In this case the set-up channels are acting as control channels. The 21 set-up channels are taken out from the total number of channels. The number 21 is derived from a seven-cell frequency-reuse pattern with three 120° sectors per cell, or a total of 21 sectors, which require 21 set-up channels. However, now only a few of the 21 setup channels are being used in each system. Theoretically, when cell size decreases the use of set-up channels should increase. Set-up channels can be classified by usage into two types: access channels and paging channels. An access channel is used for the mobile-originating calls and paging channels for the land originating calls. For this reason, a set-up channel is sometimes called an 'access channel' and sometimes called a 'paging channel.' Every two- way channel contains two 30-kHz bandwidth.. Normally one set-up channel is also specified by two operations as a forward set-up channel (using the upper band) and a reverse set-up channel (using the lower band). In the most common types of cellular systems, one set-up channel is used for both access and paging. The forward setup channel functions as the paging channel for responding to the mobile-originating calls. The reverse set-up channel functions as the access channel for the responder to the paging call. The forward set-up channel is transmitted at the cell site, and the reverse set-up channel is transmitted at the mobile unit. All set-up channels carry data information only.

Access channels and operational techniques

. Access channels:

In mobile-originating calls, the mobile unit scans its 21 set-up channels and chooses the strongest one. Because each set-up channel is associated with one cell, the strongest set-up channel indicates which cell is to serve the mobile-originating calls. Th. mobile unit detects the system information transmitted from the cell site. Also, the mobile unit monitors the Busy/Idle status bits over the desired forward setup channel. When the idle bits are received, the mobile unit can use the corresponding reverse set-up channel to initiate a call.

Frequently only one system operates in a given city; for instance, block B system might be operating and the mobile unit could be set to "preferable A system." When the mobile unit first scans the 21 set-up channels in block A, two conditions can occur.

1. If no set-up channels of block A are operational, the mobile unit automatically switches to block B.

2. If a strong set-up signal strength is received but no message can be detected, then the scanner chooses the second strongest set-up channel. If the message still cannot be detected, the mobile unit switches to block B and scans to block B set-up channels.

The operational functions are described as follows:

1. **Power of a forward set-up channel [or forward control channel (FOCC)]:** The power of the set-up channel can be varied in order to control the number of incoming calls served by the cell. The number of mobile-originating calls is limited by the number of voice channels in each cell site, when the traffic is heavy, most voice channels are occupied and the power of the set-up channel should be reduced in order to reduce the coverage of the cell for the incoming calls originating from the mobile unit. This will force the mobile units to originate calls from other cell sites, assuming that all cells are adequately overlapped.

2. **The set-up channel received level:** The setup channel threshold level is determined in order to control the reception at the reverse control channel (RECC). If the received power level is greater than the given set-up threshold level, the call request will be taken.

3. **Change power at the mobile unit:** When the mobile unit monitors the strongest signal strength from all Set-up channels and selects that channel to receive the messages, there are three types of message.

a. **Mobile station control message.** This message is used for paging and consists of one, two, or four words -DCC, MIN, SCC and VMAX.

b. **System parameter overhead message.** This message contains two words, including DCC, SID, CMAX, or CPA.

c. **Control-filler message.** This message may be sent with a system parameter overhead message, CMAC—a control mobile attenuation code (seven levels).

4. **Direct call retry.** When a cell site has no available voice channels, it can send a direct call- retry message through the set-up channel. The mobile unit will initiate, the call from a neighboring cell which is on the list of neighboring cells in the direct call-retry message.

5. Explain about paging channels.

Paging channels:

Each cell site has been allocated its own setup channel (control channel). The assigned forward set-up channel (FOCC) of each cell site is used to page the mobile unit with the same mobile station control message.

Because the same message is transmitted by the different set-up channels, no simulcast interference occurs in the system. The algorithm for paging & mobile unit can be performed in different ways. The simplest way is to page from all the cell sites. This can occupy a large amount of the traffic load. The other way is to page in an area corresponding to the mobile unit phone number. If there is no answer, the system tries to page in other areas. The drawback is that response time is sometimes too long.
When the mobile unit responds to the page on the reverse set-up channel, the cell site which receives the response checks the signal reception level and makes a decision regarding the voice channel assignment based on least interference in the selected sector or underlay-overlay region.

Self location scheme at the mobile unit and the autonomous registration.

Self -location scheme at the mobile unit:

In the cellular system, 80 percent of calls originate from the mobile unit but only 20 percent originate, from the land line. Thus, it is necessary to keep the reverse set-up channels as open as possible. For this reason, the self-location scheme at the mobile unit is adapted. The mobile unit selects a set-up channel of one cell site and makes a mobile-originating call. It is called a self- location scheme.

However, the self-location scheme at the mobile unit prevents the mobile unit from sending the necessary information regarding its location to the cell site. Therefore, the MTSO does not know where the mobile is. When a land-line call is originated, the MTSO must page all the cell sates In order to search for the mobile unit. Fortunately, land-line calls constitute only 20 percent of land-line originating calls, so the cellular system has no problem in handling them. Besides, more than 50 percent of land-line originating calls are no response.

Autonomous registration:

If a mobile station is equipped for autonomous registration, then the mobile station stores the value of the last registration number (REGID) received on a forward control channel. Also, a REGINCR (the increment in time between registrations) is received by the mobile station. The next registration ID should be

$$NXTREG = REGID + REGINCR$$

This tells the mobile unit how long the registration should be repeatedly sent to the cell site, so that the MTSO can track the location of the mobile. This feature is not used in cellular systems at present. However when the volume of land-line calls begins to increase or the number of cell sites increases, this feature would facilitate paging of the mobile units with less occupancy time on all set-up channels.

Fixed channel assignment schemes

Adjacent-Channel Assignment:

Adjacent-channel assignment includes neighboring-channel assignment and next-channel assignment. The near-end-far-end (ratio) interference, can occur among the neighboring channels (four channels on each side of the desired channel). Therefore, within a cell we have to be sure to assign neighboring channels in an omnidirectional-cell system and in a directional- antenna-cell system properly. In an omnidirectional-cell system, if one channel is assigned to the middle cell of seven cells, next channels cannot be assigned in the same cell. Also, no next channel (preferably including neighboring channels) should be assigned in the six neighboring sites in the same cell system area (Fig. 7.1a). In a directional-antenna-cell system, if one channel is assigned to a face, next channels cannot be assigned to the same face or to the other two faces in the same cell. Also, next channels cannot be assigned to the other two faces at the same cell site (Fig. 7.1b). Sometimes the next channels are assigned in the next sector of the same cell in order to increase capacity. Then performance can still be in the tolerance range if the design is proper.

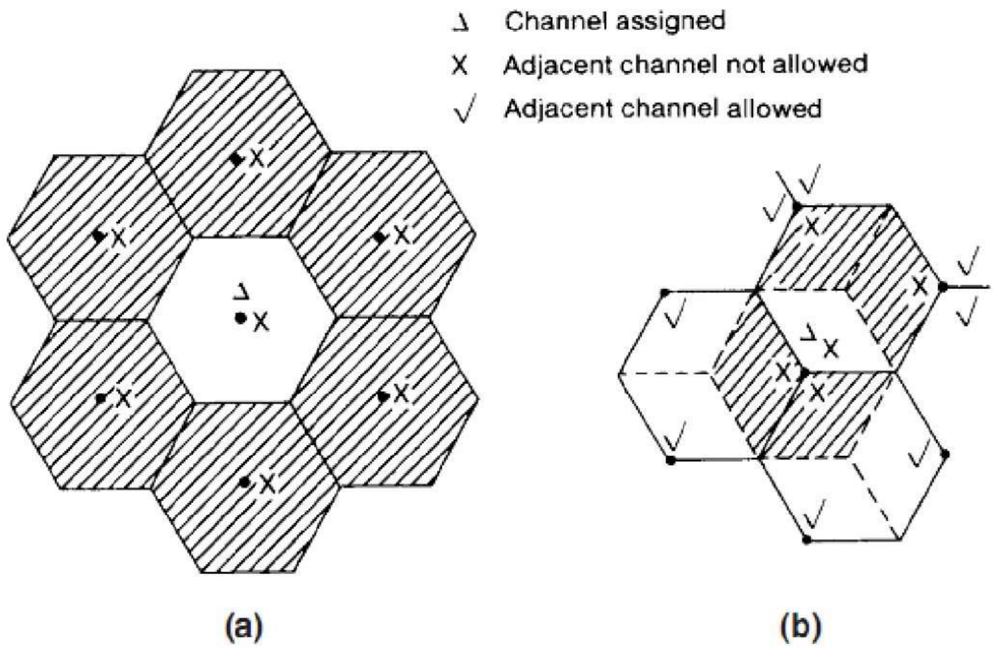


Fig.6.1 Adjacent channel assignment (a) Omni direction antenna cells; (b) Directional antenna cells

Channel Sharing:

Channel sharing is a short-term traffic-relief scheme. A scheme used for a seven-cell three-face system is shown in Fig. 7.2. There are 21 channel sets, with each set consisting of about 16 channels. Figure7.2 shows the channel set numbers. When a cell needs more channels, the channels of another face at the same cell site can be shared to handle the short-term overload. To obey the adjacent-channel assignment algorithm, the sharing is always cyclic. Sharing always increases the trunking efficiency of channels. Since we cannot allow adjacent channels to share with the nominal channels in the same cell, channel sets 4 and 5 cannot both be shared with channel sets 12 and 18, a indicated by the grid mark. Many grid marks are indicated in Fig.7.2 for the same reason. However, the upper subset of set 4 can be shared with the lower subset of set 5 with no interference. In channel-sharing systems, the channel combiner should be flexible in order to combine up to 32 channels in one face in real time. An alternative method is to install a standby antenna.

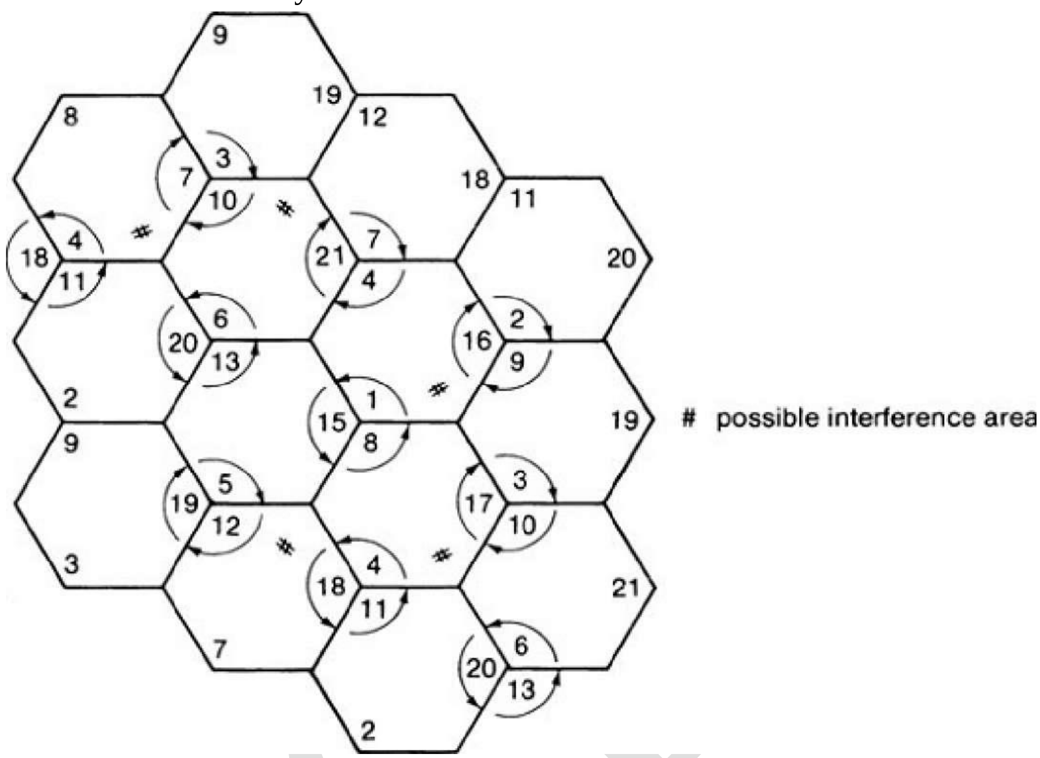


Fig.6.2. Channel sharing algorithm

Channel Borrowing:

Channel borrowing is usually handled on a long-term basis. The extent of borrowing more available channels from other cells depends on the traffic density in the area. Channel borrowing can be implemented from one cell-site face to another face at the same cell site. In addition, the central cell site can borrow channels from neighboring cells. The channel-borrowing scheme is used primarily for slowly-growing systems. It is often helpful in delaying cell splitting in peak traffic areas. Since cell splitting is costly, it should be implemented only as a last resort.

8. What are the advantages of sectorized cells?

Advantage of Sectorization:

The total number of available channels can be divided into sets (subgroups) depending on the sectorization of the cell configuration: the 120°-sector system, the 60°-sector system, and the 45°-sector system. A seven-cell system usually uses three 120°sectors per cell, with the total number of channel sets being 21. In certain locations and special situations, the sector angle can be reduced (narrowed) in order to assign more channels in one sector without increasing neighboring-channel interference. Sectorization serves the same purpose as the channel- borrowing scheme in delaying cell splitting. In addition, channel coordination to avoid cochannel interference is much easier in sectorization than in cell splitting. Given the same number of channels, trunking efficiency decreases in sectorization.

omni cells and sectorized cells.

If a K = 7 frequency-reuse pattern is used, the frequency sets assigned in each cell can be followed by the frequency-management chart. However, terrain is seldom flat; therefore, K = 12 is sometimes needed for reducing cochannel interference. For K = 12, the channel-reuse distance is D = 6R, or the cochannel reduction factor q = 6.

Sectorized Cells: There are three basic types.

1. The 120°-sector cell is used for both transmitting and receiving sectorization. Each sector has an assigned a number of frequencies. Changing sectors during a call requires handoffs.
2. The 60°-sector cell is used for both transmitting and receiving sectorization. Changing sectors during a call requires handoffs. More handoffs are expected for a 60° sector than a 120° sector in areas close to cell sites (close-in areas).
3. The 120° or 60°-sector cell is used for receiving sectorization only. In this case, the transmitting antenna is omnidirectional. The number of channels in this cell is not sub- divided for each sector. Therefore, no handoffs are required when changing sectors. This receiving- sectorization-only configuration does not decrease interference or increase the D/R ratio; it only allows for a more accurate decision regarding handing off the calls to neighboring cells.

Tthe Underlay-Overlay Arrangement.

In actual cellular systems cell grids are seldom uniform because of varying traffic conditions in different areas and cell-site locations.

Overlaid Cells: To permit the two groups to reuse the channels in two different cell-reuse patterns of the same size, an "underlaid" small cell is sometimes established at the same cell site as the large cell (see Fig. 10a). The "doughnut" (large) and "hole" (small) cells are treated as two different cells. They are usually considered as "neighboring cells."

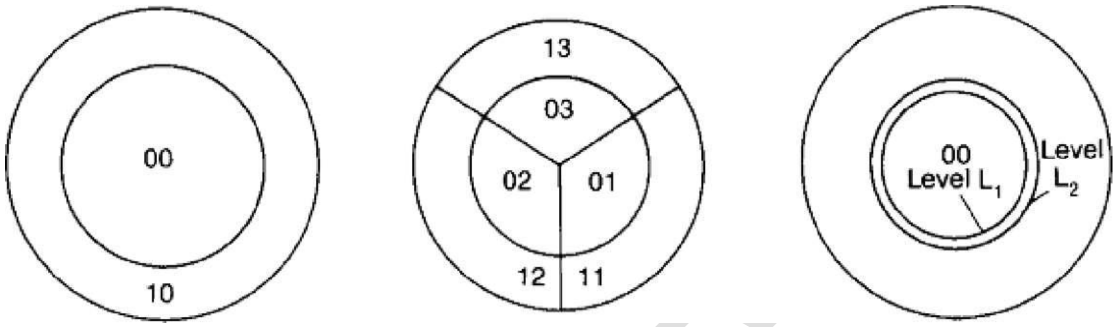


Fig.10. Underlaid-overlaid cell arrangements. (a) Underlay-overlay in omnicell; (b) Underlay-overlay in sectorized cell; (c) Two level handoff scheme

The use of either an omnidirectional antenna at one site to create two sub ring areas or three directional antennas to create six subareas is illustrated in Fig. 10b. As seen in Fig.10, a set of frequencies used in an overlay area will differ from a set of frequencies used in an underlay area in order to avoid adjacent-channel and cochannel interference.

The channels assigned to one combiner—say, 16 channels—can be used for overlay, and another combiner can be used for underlay.

Implementation:

The antenna of a set-up channel is usually omnidirectional. When an incoming call is received by the set-up channel and its signal strength is higher than a level L, the underlaid cell is assigned; otherwise, the overlaid cell is assigned. The handoffs are implemented between the underlaid and overlaid cells. In order to avoid the unnecessary handoffs, we may choose two levels L1 and L2 and L1 > L2 as shown in Fig. 10(c). When a mobile signal is higher than a level L1 the call is handed off to the underlaid cell. When a signal is lower than a level L2 the call is handed off to the overlaid cell. The channels assigned in the underlaid cell have more protection against cochannel interference.

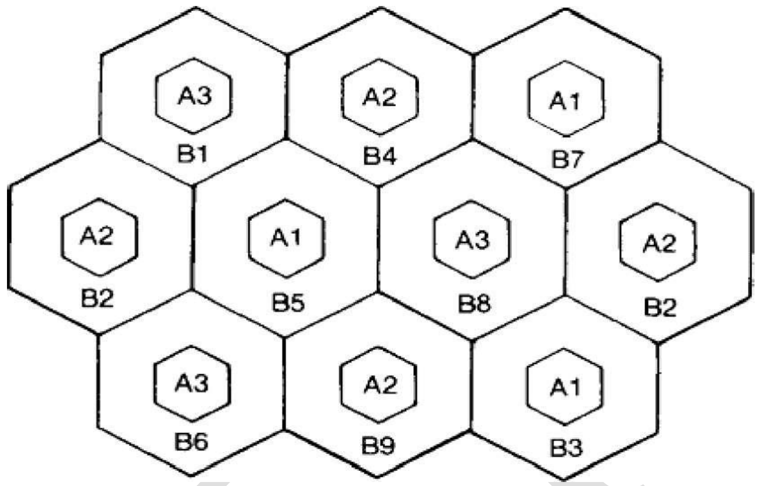
11. Present the reuse partition scheme in overlaid cell system, mention the advantages associated with it.

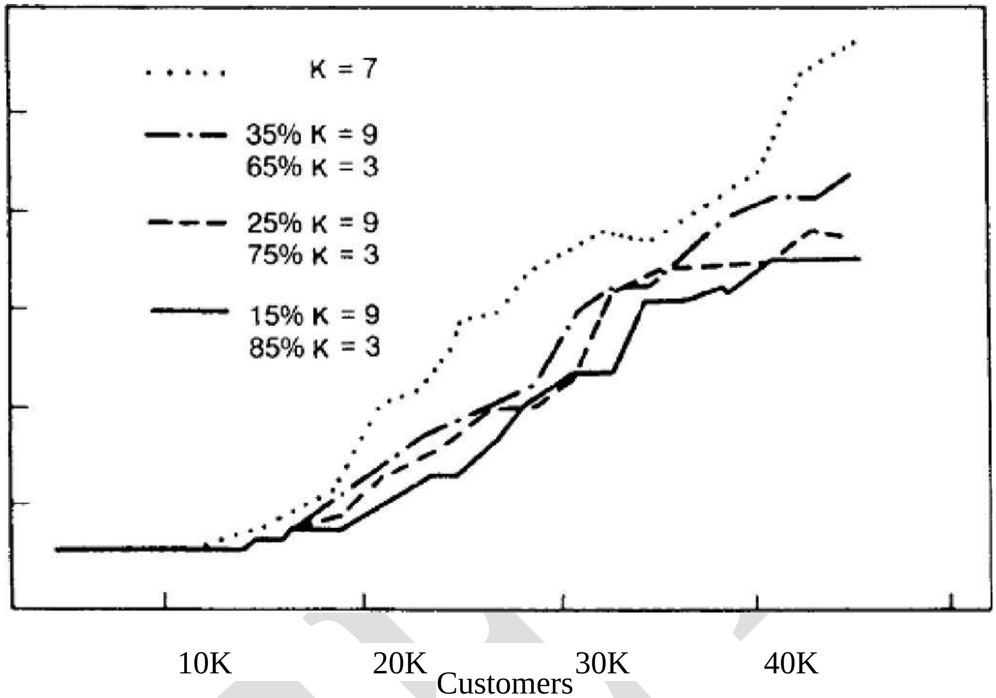
<u>Reuse Partition</u>:

Through implementation of the overlaid-cell concept, one possible operation is to apply a multiple-K system operation, where K is the number of frequency-reuse cells. The conventional system uses K = 7. But if one K is used for the underlaid cells, then this multiple-K system can have an additional 20 percent more spectrum efficiency than the single K system with an equivalent voice quality. In Fig. 6.5 (a), the K = 9 pattern is

(a)

assigned to overlaid cells and the K = 3 pattern is assigned to underlaid cells. Based on this arrangement the number of cell sites can be reduced, while maintaining the same traffic capacity. The decrease in the number of cell sites which results from implementation of the multiple K systems is shown in Fig. 6.5(b).





(b)

Fig.6.5 Reuse partition scheme (a) Ka=3; Kb=9; (b) Reuse partitioning

Reuse partition performance

The advantages of using this partition based on the range of K are

1. The K range is 3 to 9; the operational call quality can be adjusted and more reuse patterns are available if needed.

2. Each channel set of old K = 9 systems is the subset of new K = 3 systems.
Therefore the amount of radio retuning in each cell in this arrangement is minimal.

3. When cell splitting is implemented, all present channel assignments can be retained.

Non-fixed channel assignment- corresponding algorithms.

Non Fixed Channel Assignment Algorithms:

1. **Fixed Channel Algorithm:** The fixed channel assignment (FCA) algorithm is the most common algorithm adopted in many cellular systems. In this algorithm, each cell assigns its own radio channels to the vehicles within its cell.

2. **Dynamic Channel Assignment:** In dynamic channel assignment (DCA), no fixed channels are assigned to each cell. Therefore, any channel in a composite of N radio channels can be assigned to the mobile unit. This means that a channel is assigned directly to a mobile unit. On the basis of overall system performance, DCA can also be used during a call.

3. **Hybrid Channel Assignment:** Hybrid channel assignment (HCA) is a combination of FCA and DCA. A portion of the total frequency channels will use FCA and the rest will use DCA.

4. **Borrowing Channel Assignment:** Borrowing channel assignment (BCA) uses FCA as a normal assignment condition. When all the fixed channels are occupied, then the cell borrows channels from the neighboring cells.

5. **Forcible-Borrowing Channel Assignment:** In forcible-borrowing channel assignment (FBCA), if a channel is in operation and the situation warrants it, channels must be borrowed from the neighboring cells and at the same time, another voice channel will be assigned to continue the call in the neighboring cell. There are many different ways of implementing FBCA. In a general sense, FBCA can also be applied while accounting for the forcible borrowing of the channels within a fixed channel set to reduce the chance of cochannel assignment in a reuse cell pattern. The FBCA algorithms based on assigning a channel dynamically but obeying the rule of reuse distance. The distance between the two cells is reuse distance, which is the minimum distance at which no cochannel interference would occur. Very infrequently, no channel can be borrowed in the neighboring cells. Even those channels currently in operation can be forcibly borrowed and will be replaced by a new channel in the neighboring cell or the neighboring cell of the neighboring cell. If all the channels in the neighboring cells cannot be borrowed because of interference problems, the FBCA stops.

The average blocking in spatially uniform and non uniform traffic distribution for FCA, BCA and FBCA.

On the basis of the FBCA, FCA, and BCA algorithms, a seven-cell reuse pattern with an average blocking of 3 percent is assumed and the total traffic service in an area in 250 Erlangs. The traffic distributions are

(1) Uniform traffic distribution—11 channels per cell;

(2) A non uniform traffic distribution—the number of channels in each cell is dependent on the vehicle distribution (Fig.13.1).

The simulation model is described as follows:

1. Randomly select the cell (among 41 cells).
2. Determine the state of the vehicle in the cell (idle, off-hook, on-hook, and handoff)

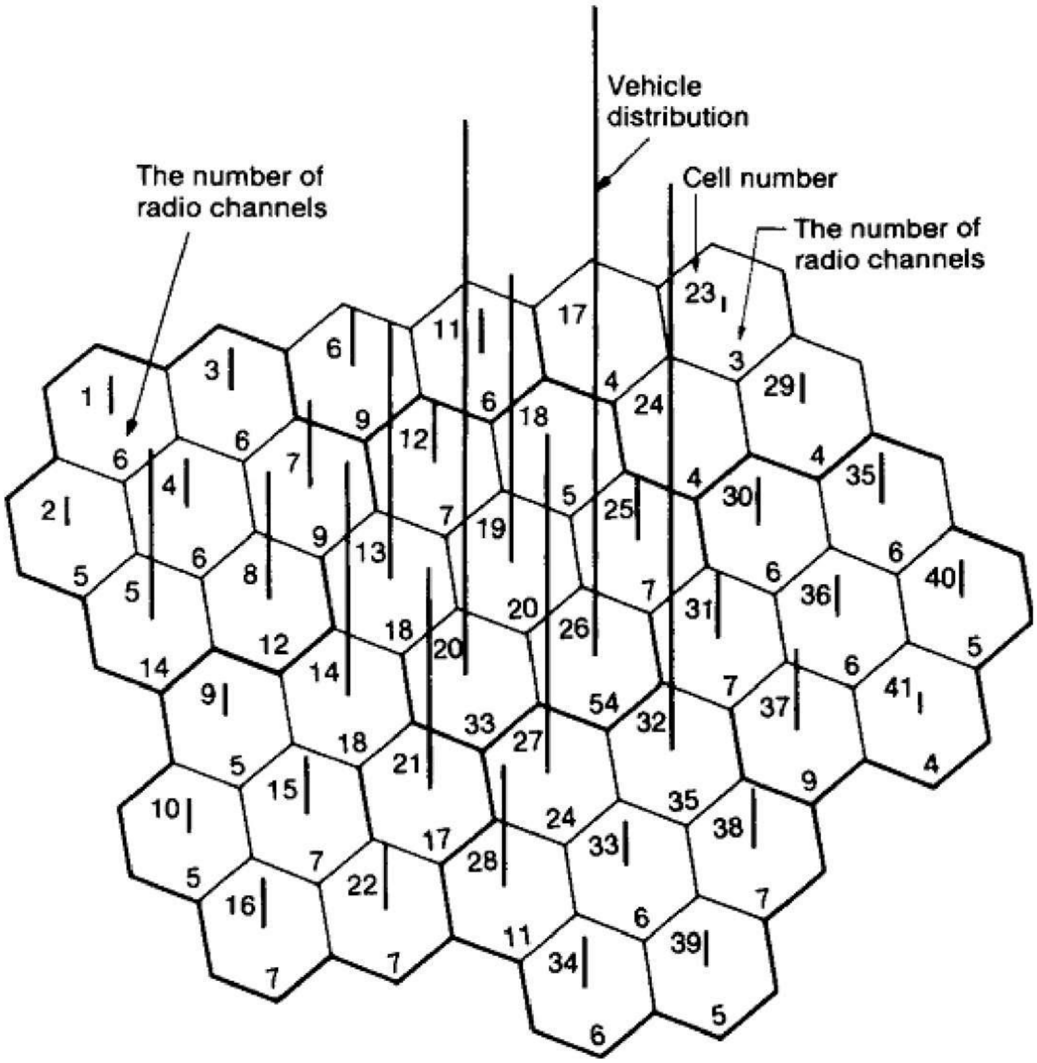
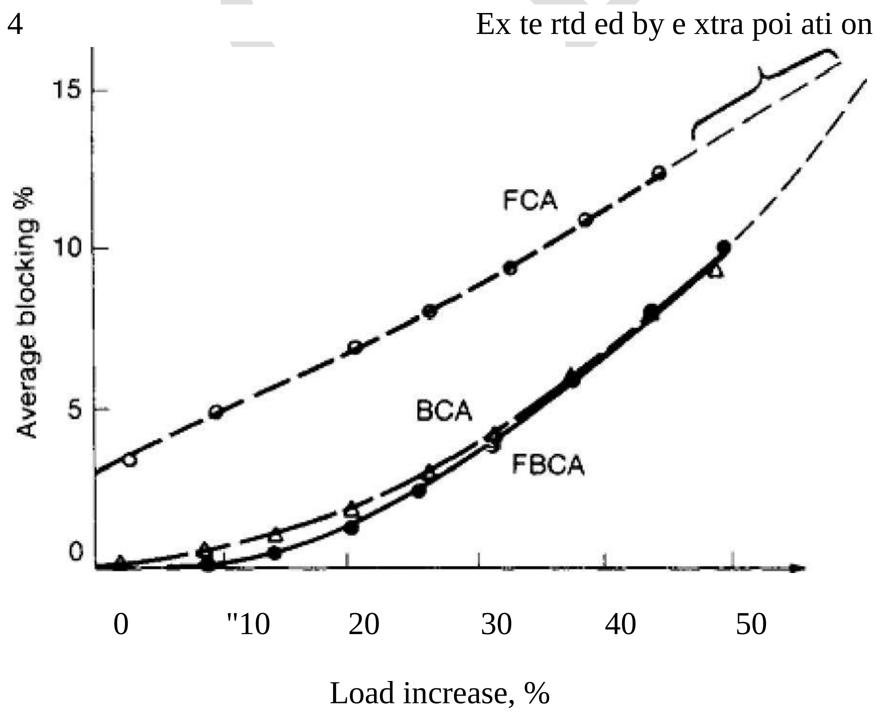


Fig. 6.6 Cellular system Vehicle and radio-channel distribution in the busy rush hour

3. In off-hook or handoff state, search for an idle channel. The average number of handoffs is assumed to be 0.2 times per call. However, FBCA will increase the number of handoffs.

Average Blocking: Two average blocking cases illustrating this simulation are shown in Fig. 13.2. In a uniform traffic condition (Fig. 13.2a), the 3 percent blocking of both BCA and FBCA will result in a load increase of 28 percent, compared to 3 percent blocking of FCA. There is no difference between BCA and FBCA when a uniform traffic condition exists.

In a non uniform traffic distribution (Fig. 13.2b), the load increase in BCA drops to 23 percent and that of FBCA increases to 33 percent, as at an average blocking of 3 percent. The load increase can be utilized in another way by reducing the number of channels. The percent increase in load is the same as the percent reduction in the number of channels.



(a)

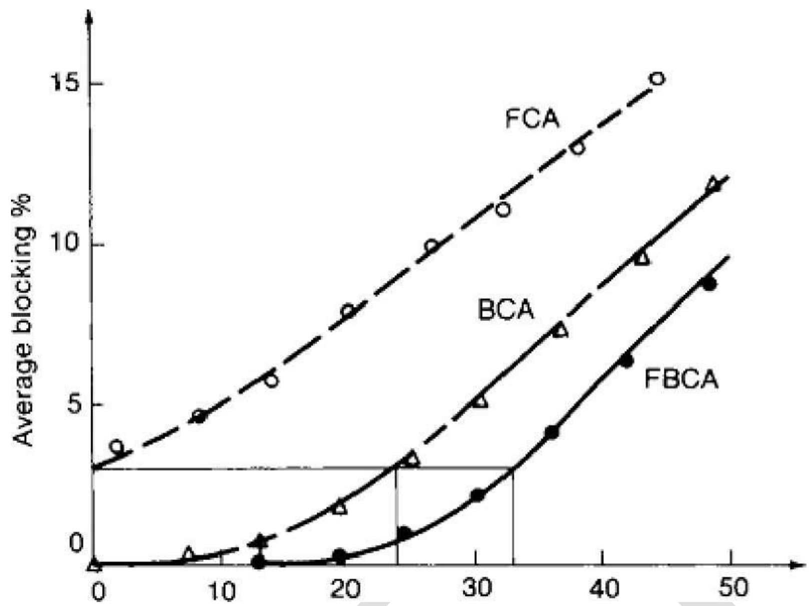


Fig.6.8. Comparison of average blockings from three different schemes (a) Average blocking in spatially uniform traffic distribution; (b) average blocking in spatially on uniform traffic distribution.

Handoff Blocking: Blocking calls from all handoff calls occurring in all cells is shown in Fig. 13.3. Handoff blocking is not considered as the regular cell blocking which can only occur at the call setup stage. In both BCA and FBCA, load is increased almost equally to 30 percent, as compared to FCA at 3 percent handoff blocking in uniform traffic (Fig. 13.3a). For a non uniform traffic distribution, the load increase of both BCA and FBCA at 4 percent blocking is about 50 percent (Fig. 13.3b), which is a big improvement, considering the reduction in interference and blocking. Otherwise, there would be multiple effects from interference in several neighboring cells.

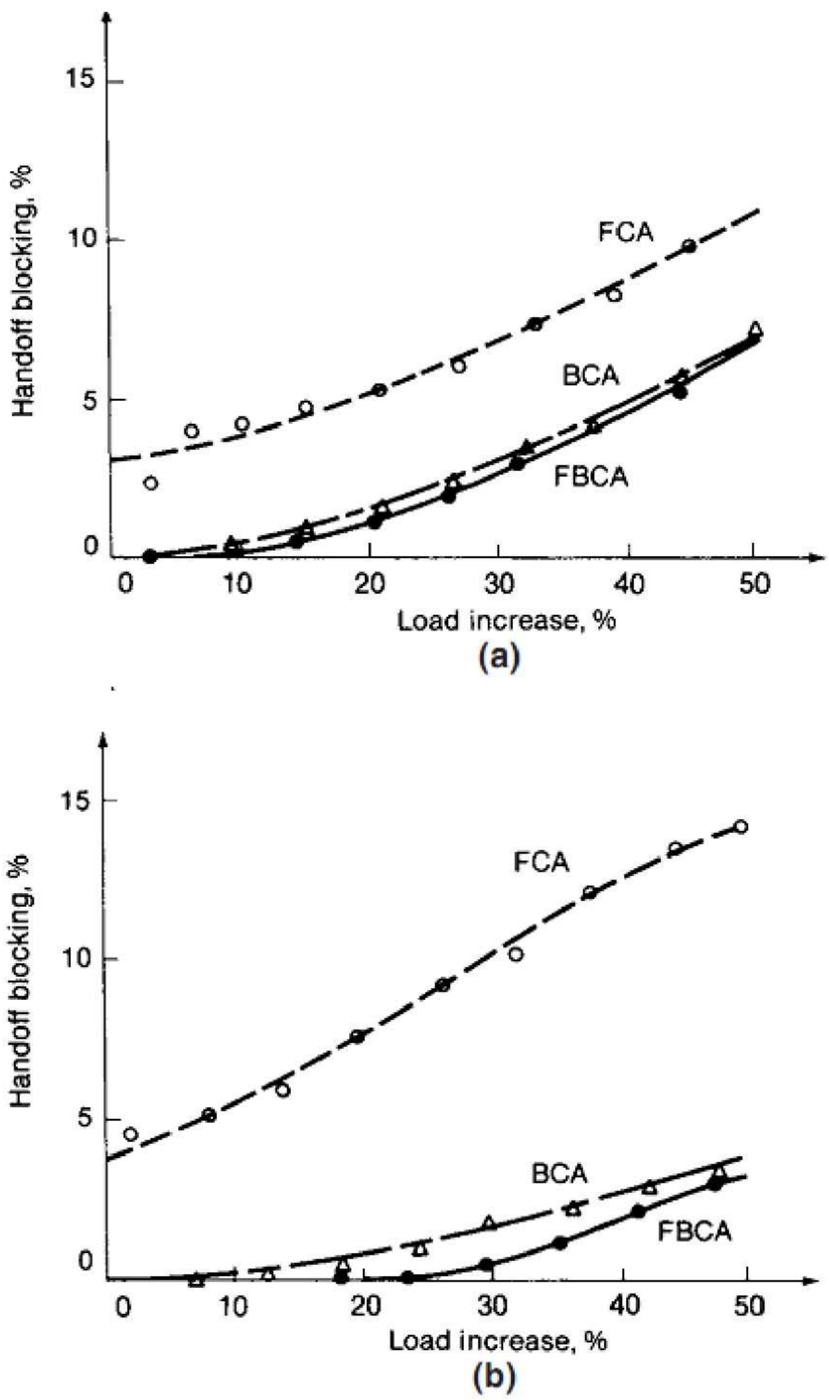


Fig.6.9. Comparison of handoff blocking from three different schemes (a) Handoff blocking in spatially uniform traffic distribution; (b) handoff blocking in spatially non uniform traffic distribution.

UNIT VIII

HANDOFFS AND DROPPED CALLS

Handoff : It is the process of automatically changing frequencies as the mobile unit moves into a different zone so that conversation can be continued in a new frequency zone without redialing.

Handoff is needed in two situations where the cell site receives weak signals from the mobile unit:

1) at the cell boundary, say, -100 dBm, which is the level for requesting a handoff in a noise-limited environment; and

(2) when the mobile unit is reaching the signal-strength holes (gaps) within the cell site as shown in Fig. 1.

7.2 Types of Handoff:

In digital systems there are different types of handoff, but in an analog system, there is only one type of handoff, which is the hard handoff.

A. Natures of handoff:

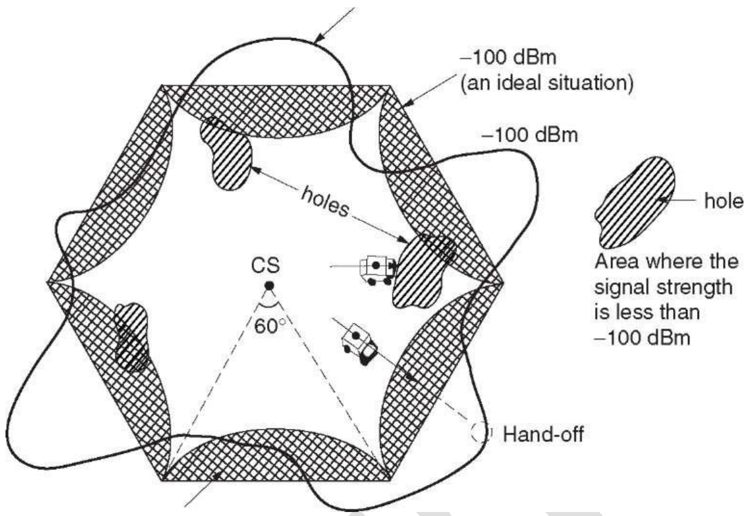
1.Hard handoff: This is a break-before-make process and handoff between two frequencies. All FDMA, TDMA, and OFDMA digital systems, and analog systems, can perform hard handoffs.

2.Soft handoff: This is a make-before-break process. Because CDMA has to perform the handoff between two code channels, not two frequencies, it is difficult to perform the hard handoffs. Because of the soft handoffs, the process needs to secure two code channels during the handoff process. Therefore, the capacity is reduced in the soft handoff region, but the drop call is reduced also due to the diverse nature of switching two code channels.

3. Softer handoff: Handoff occurring between sectors only at the serving cell. It is a make-before-break type using combined diversity of two code channels.

-100 dBm

(in a real situation)



handoff region

figure 7.1 Occurrence of handoff.

B. Purposes of handoff:

1. Intracell handoff: can be a sector-to-sector handoff.
2. Intercell handoff: a handoff from an old cell to a new cell.
3. Inter BSC/MSC handoff: using compressed mode, referred to as the slotted mode.

In this mode, the transmission and reception are halted for a short time, of the order a few milliseconds, in order to perform measurements on the other frequencies from other systems.

4. Intersystem handoff: handoff between two same type systems.
5. Intercarrier handoffs: handoff occurs between two carriers.
6. Intermode handoff: the handoff occurs from one of the modes TDMA, CDMA,

GSM, and GPRS to another mode.

C. Algorithms of handoff:

MCHO (Mobile Control Handoff): It is the responsibility of MS to choose the best BS.

1. NCHO (Network Control Handoff): It is the responsibility of network to choose the best BS.
2. NCHO/MAHO (Network Control Handoff/Mobile Assists Handoff): It is the responsibility of network to choose the best BS, but with the information supplied by the mobile's assist.

7.1.3 Two Decision-Making Parameters of Handoff:

There are two decision-making parameters of handoff:

(1) that based on signal strength and

(2) that based on carrier-to-interference ratio. The handoff criteria are different for these two types.

In type 1, the signal-strength threshold level for handoff is -100 dBm in noise-limited systems and -95 dBm in interference-limited systems.

In type 2, the value of C/I at the cell boundary for handoff should be at a level, 18 dB for AMPS in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

Type 1 is easy to implement. The location receiver at each cell site measures all the signal strengths of all receivers at the cell site. However, the received signal strength (RSS) itself includes interference.

$$RSS = C + I \qquad (7.1\text{-}1)$$

Where, C is the carrier signal power and I is the interference. Suppose that we set up a threshold level for RSS; then, because of the I, which is sometimes very strong, the RSS level is higher and far above the handoff threshold level. In this situation handoff should theoretically take place but does not. Another situation is when I is very low but RSS is also low. In this situation, the voice quality usually is good even though the RSS level is low, but since RSS is low, unnecessary handoff takes place. Therefore, it is an easy but not very accurate method of determining handoffs. Some analog systems use SAT information together with the received signal level to determine handoffs (Sec. 15.1.2). Some CDMA systems use pilot channel information.

Type 2: Handoffs can be controlled by using the carrier-to-interference ratio C/I.

C + I C

----- (11.1-2)

II

In Eq. (11.1-2), we can set a level based on C/I, so C drops as a function of distance but I is dependent on the location. If the handoff is dependent on C/I, and if the C/I drops, it does so in response to increase in (1) propagation distance or (2) interference. In both cases, handoff should take place. In today's cellular systems, it is hard to measure C/I during a call because of analog modulation. Sometimes we measure the level I before the call is connected, and the level $C + I$ during the call. Thus $(C + I)/I$ can be obtained.

7.1.4 Determining the Probability of Requirement for Hard Handoffs[6]

To find the probability of requiring a hard handoff, we can carry out the following simulation. Suppose that a mobile unit randomly initiates a call in a 16-km (10-mi) cell. The vehicle speed is also randomly chosen between 8 and 96 km/h (5 to 60 mi/h). The direction is randomly chosen to be between 0 and 360°; then the chance of reaching the boundary is dependent on the call holding time.

Figure 7.2 depicts the probability curve for requiring handoff. Table 11.1 summarizes the results. If the call holding time is 1.76 min, the only chance of reaching the boundary is 11 percent, or the chance that a handoff will occur for the call is 11 percent. If the call holding time is 3 min, the chance of reaching the boundary is 18 percent. Now we may debate whether a handoff is needed or not. In rural areas, handoffs may not be necessary. However, commercial mobile units must meet certain requirements, and handoffs may be necessary at different times. Military mobile systems may opt not to use the handoff feature and may apply the savings in cost to implement other security measures.

7.1.5 Number of Hard Handoffs Per Call

The smaller the cell size, the greater the number and the value of implementing handoffs. The number of handoffs per call is relative to cell size. From the simulation, we may find

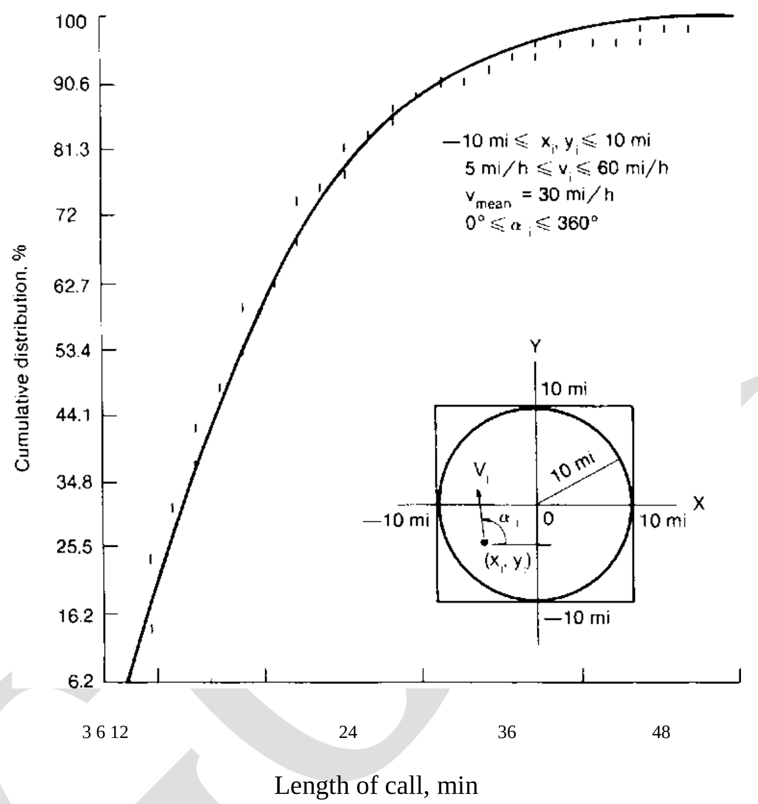


FIGURE 7.2 The probability of requiring handoff.

0.2 handoff per call in a 16- to 24-km cell 1-2 handoffs per call in a 3.2- to 8-km cell 3-4 handoffs per call in a 1.6- to 3.2-km cell

7.2 INITIATION OF A HARD HANDOFF:

At the cell site, signal strength is always monitored from a reverse voice channel. When the signal strength reaches the level of a handoff (higher than the threshold level for the minimum required voice quality), then the cell site sends a request to the mobile switching (MSO)* for a handoff on the call. An intelligent decision can also be made at the cell site as to whether the handoff should have taken place earlier or later. If an unnecessary handoff is requested, then the decision was made too early. If a failure handoff occurs, then a decision was made too late.

The following approaches are used to make handoffs successful and to eliminate all unnecessary handoffs. Suppose that -100 dBm is a threshold level at the cell boundary at which a handoff would be taken. Given this scenario, we must set up a level higher than -100 dBm—say, -100 dBm + A dB—and when the received signal reaches this level, a handoff request is initiated. If the value of A is fixed and large, then the time it takes to lower -100 dBm + A to -100 dBm is longer. During this time, many situations, such as the mobile unit turning back toward the cell site or stopping, can occur as a result of the direction and the speed of the moving vehicles. Then the signals will never drop below -100 dBm. Thus, many unnecessary handoffs may occur simply because we have taken the cell site and many calls can be lost while they are handed off. Therefore, A should be varied according to the path-loss slope of the received signal strength (Sec. 8.2) and the level-crossing rate (LCR) of the signal strength (Sec. 2.3.3) as shown in Fig. 7.3.

Let the value of A be 10 dB in the example given in the preceding paragraph. This would mean a level of -90 dBm as the threshold level for requesting a handoff. Then we can calculate the velocity v of the mobile unit based on the predicted LCR[7] at a — 10-dB level with respect to the root-mean-square (rms) level, which is at —90 dBm. Here, two pieces of information, the velocity of vehicle v and the pathloss slope γ, can be used to determine the value of A dynamically so that the number of unnecessary handoffs can be reduced and the required handoffs can be completed successfully. There are two circumstances where handoffs are necessary but cannot be made:

(1) when the mobile unit is located at a signal-strength hole within a cell but not at the boundary (see Fig. 7.3) and

(2) when the mobile unit approaches a cell boundary but no channels in the new cell are available.

In case 1, the call must be kept in the old frequency channel until it is dropped as the result of an unacceptable signal level.

In case 2, the new cell must reassign one of its frequency channels within a reasonably short period or the call will be dropped.

The MSO usually controls the frequency assignment in each cell and can rearrange channel assignments or split cells when they are necessary.

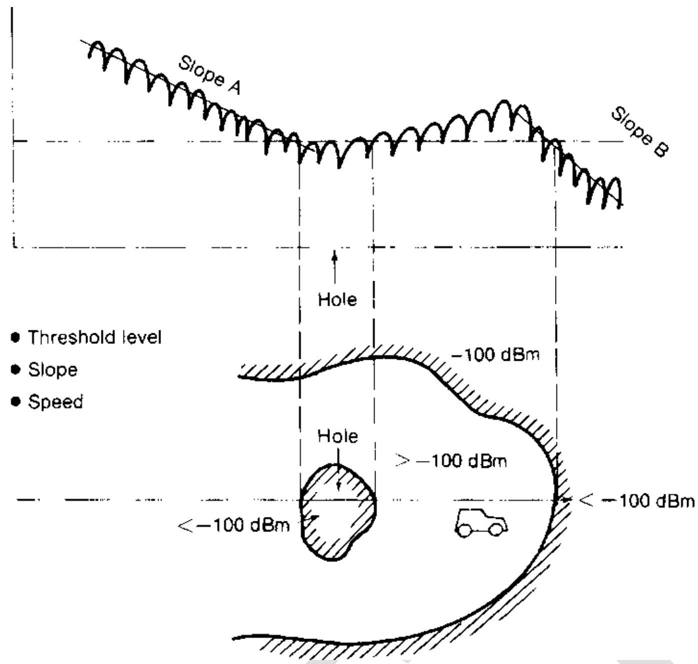


figure 7.3 Parameters for handling a handoff.

* MSO is a general term which stands for either MTSO in AMPS, or BSC sometimes MSC in digital systems.

7.3 DELAYING A HANDOFF:

7.3.1 Two-Handoff-Level Algorithm

In many cases, a two-handoff-level algorithm is used. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available cell could take the call.

A plot of signal strength with two request handoff levels and a threshold level is shown in Fig. 7.4. The plot of average signal strength is recorded on the channel received

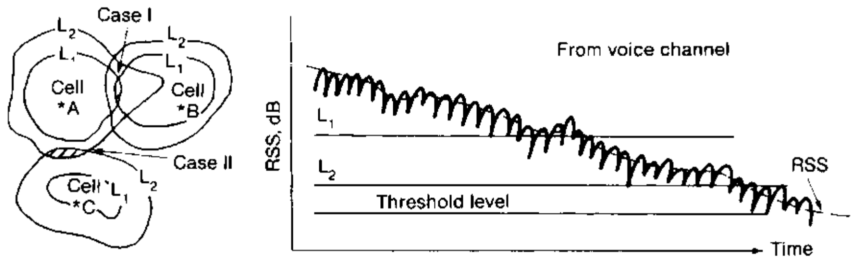


figure 7.4 A two-level handoff scheme.

signal-strength indicator (RSSI), which is installed at each channel receiver at the cell site. When the signal strength drops below the first handoff level, a handoff request is initiated. If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighboring cell is busy, the handoff will be requested periodically every 5 s. At the first handoff level, the handoff takes place if the new signal is stronger (see case I in Fig. 7.4). However, when the second handoff level is reached, the call will be handed off with no condition .

The MSO always handles the handoff call first and the originating calls second. If no neighboring calls are available after the second handoff level is reached, the call continues until the signal strength drops below the threshold level; then the call is dropped. In AMPS systems if the supervisory audio tone (SAT) is not sent back to the cell site by the mobile unit within 5 s, the cell site turns off the transmitter.

7.3.2 Advantage of Delayed Handoffs

Consider the following example. The mobile units are moving randomly and the terrain contour is uneven. The received signal strength at the mobile unit fluctuates up and down. If the mobile unit is in a hole for less than 5 s (a driven distance of 140 m for 5 s, assuming a vehicle speed of 100 km/h), the delay (in handoff) can even circumvent the need for a handoff.

If the neighboring cells are busy, delayed handoff may take place. In principle, when call traffic is heavy, the switching processor is loaded, and thus a lower number of handoffs would help the processor handle call processing more adequately. Of course, it is very likely that after the second handoff level is reached, the call may be dropped with great probability.

The other advantage of having a two-handoff-level algorithm is that it makes the handoff occur at the proper location and eliminates possible interference in the system. Figure 11.4, case I, shows the area where the first-level handoff occurs between cell A and cell B. If we only use the second-level handoff boundary of cell A, the area of handoff is too close to cell B. Figure 7.4, case II, also shows where the second-level handoff occurs between cell A and cell C. This is because the first-level handoff cannot be implemented.

7.4 FORCED HANDOFFS:

A **forced handoff** is defined as a handoff that would normally occur but is prevented from happening, or a handoff that should not occur but is forced to happen.

7.4.1 Controlling a Handoff

The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer or assign a high handoff threshold level to request a handoff earlier. The MSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site.

7.4.2 Creating a Handoff

In this case, the cell site does not request a handoff but the MSO finds that some cells are too congested while others are not. Then, the MSO can request call sites to create early handoffs for those congested cells. In other words, a cell site has to follow the MSO's order and increase the handoff threshold to push the mobile units at the new boundary and to hand off earlier.

7.5 MOBILE ASSISTED HANDOFF (MAHO) AND SOFT HANDOFF:

In a normal handoff procedure, the request for a handoff is based on the signal strength (or the SAT range of AMPS) of a mobile signal received at the cell site from the reverse link. In the digital cellular system, the mobile receiver is capable of monitoring the signal strength of the setup channels of the neighboring cells while serving a call. For instance, in a TDMA system, one time slot is used for serving a call, the rest of the time slots can be used to monitor the signal strengths of setup channels. When the signal strength of its voice channel is weak, the mobile unit can request a handoff and indicate to the switching office which neighboring cell can be a candidate for handoff. Now the switching office has two pieces of information: the signal strengths of both forward and reverse setup channels of a neighboring cell or two different neighboring cells. The switching office (MSO) therefore, has more intelligent information to choose the proper neighboring cell to handoff to.

The soft handoff is applied to one kind of digital cellular system named CDMA. In CDMA systems, all cells can use the same radio carrier. Therefore, the frequency reuse factor K approaches one. Because the operating radio carriers of all cells are the same, no need to change from one frequency to another frequency but change from one code to another code. Thus, there is no hard handoff. We call this kind of handoff a soft handoff. If sometimes there are more than one CDMA radio carrier operating in a cell, and if the soft handoff from one cell to another is not possible for some reason, the intracell hard handoff may take place first, then go to the inter-cell soft handoff.

7.6 CELL-SITE HANDOFF ONLY:

This scheme can be used in a non cellular system. The mobile unit has been assigned a frequency and talks to its home cell site while it travels. When the mobile unit leaves its home cell and enters a new cell, its frequency does not change; rather, the new cell must tune into the frequency of the mobile unit (see Fig. 7.9). In this case only the cell sites need the frequency information of the mobile unit. Then the aspects of mobile unit control can be greatly simplified, and there will be no need to provide handoff capability at the mobile unit. The cost will also be lower.

This scheme can be recommended only in areas of very low traffic. When the traffic is dense, frequency coordination is necessary for the cellular system. Then if a mobile unit does not change frequency on travel from cell to cell, other mobile units then must change frequency to avoid interference.

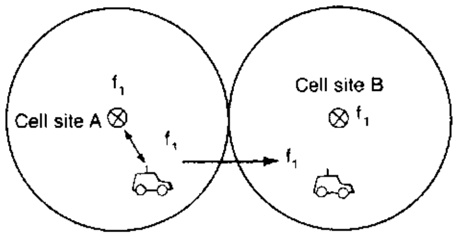


FIGURE 11.9 Cell-site handoff-only scheme.

Therefore, if a system handles only low volumes of traffic, that is, if the channels assigned to one cell will not reuse frequency in other cells, then it is possible to implement the cell-site handoff feature as it is applied in military systems.

7.7 INTERSYSTEM HANDOFF:

Occasionally, a call may be initiated in one cellular system (controlled by one MSO)* and enter another system (controlled by another MSO) before terminating. In some instances, **intersystem handoff** can take place; this means that a call handoff can be transferred from one system to a second system so that the call be continued while the mobile unit enters the second system.

The software in the MSO must be modified to apply this situation. Consider the simple diagram shown in Fig. 7.10. The car travels on a highway and the driver originates a call in system A. Then the car leaves cell site A of system A and enters cell site B of system B. Cell sites A and B are controlled by two different MSOs. When the mobile unit signal becomes weak in cell site A, MSO A searches for a candidate cell site in its system and cannot find one. Then MSO A sends the handoff request to MSO B through a dedicated line between MSO A and MSO B, and MSO B makes a complete handoff during the call conversation. This is just a one-point connection case. There are many ways of implementing intersystem handoffs, depending on the actual circumstances. For instance, if two MSOs are manufactured by different companies, then compatibility must be determined before implementation of intersystem handoff can be considered.

7.8 INTRODUCTION TO DROPPED CALL RATE

7.8.1 The Definition of Dropped Call Rate

The definition of a dropped call is after the call is established but before it is properly terminated. The definition of "the call is established" means that the call is setup completely by the setup channel. If there is a possibility of a call drop due to no available voice channels, this is counted as a blocked call not a dropped call.

If there is a possibility that a call will drop due to the poor signal of the assigned voice channel, this is considered a dropped call. This case can happen when the mobile or portable units are at a standstill and the radio carrier is changed from a strong setup channel to a weak voice channel due to the selective frequency fading phenomenon.

The perception of dropped call rate by the subscribers can be higher due to:

1. The subscriber unit not functioning properly (needs repair).
2. The user operating the portable unit in a vehicle (misused).
3. The user not knowing how to get the best reception from a portable unit (needs education).

7.8.2 Consideration of Dropped Calls

In principle, dropped call rate can be set very low if we do not need to maintain the voice quality. The dropped call rate and the specified voice quality level are inversely proportional. In designing a commercial system, the specified voice quality level is given relating to how much C/1 (or C/N) the speech coder can tolerate. By maintaining a certain voice quality level, the dropped call rate can be calculated by taking the following factors into consideration:

1. Provide signal coverage based on the percentage (say 90 percent) that all the received signal will be above a given signal level.
2. Maintain the specified co-channel and adjacent channel interference levels in each cell during a busy hour (i.e., the worst interference case).

$$P_n = 1 - X^n \qquad (11.11\text{-}2)$$

P_n is the probability of a dropped call when the call has gone through n handoffs and

$$X = (1 - S)(1 - |)(1 - 0t)(1 - p)^2 \qquad (11.11\text{-}3)$$

S = Probability that the signal is below the specified receive threshold (in a noise- limited system).

i = Probability that the signal is below the specified cochannel interference level (in an interference-limited system).

t = Probability that no traffic channel is available upon handoff attempt when moving into a new cell.

0 = Probability that the call will return to the original cell.

p = Probability of blocking circuits between BSC and MSC during handoff.

a_n = The weighted value for those calls having n handoffs, and $\wedge^{N}{}_{= 0}\, a_n = 1$

N = N is the highest number of handoffs for those calls.

Equation (11.11-3) needs to be explained clearly as follows:

1. z_1 and z_2 are two events, z_1 is the case of no traffic channel in the cell, z_2 is the case of no-safe return to original cell. Assuming that z_1 and z_2 are independent events, then

$$P talzO \bullet P(z0 = P(z2) \bullet P(z1) = 0 \bullet t$$

2. (1 - p) is the probability of a call successfully connecting from the old BSC to the MSC. Also, (1 - p) is the probability of a call successfully connecting from the MSC to the new BSC. Then the total probability of having a successful call connection is

BSC (old) ^ MSC (1 - p)\ )2
MSC ^ BSC (new) (1 - p)/ ^ (1 p)

3. The call dropped rate P expressed in Eq. (11.11-1) can be specified in two cases:

1. In a noise limited system (startup system): there is no frequency reuse, the call dropped rate P_A is based on the signal coverage. It can also be calculated under busy hour conditions.
In a noise-limited environment (for worst case)

5 = 5 / = /

T = T1

0 = 01 \ the conditions for the noise limited case ß = /

2. In an interference-limited system (mature system): frequency reuse is applied, and the dropped rate P_B is based on the interference level. It can be calculated under busy hour conditions.
In an interference-limited environment (for worst case)

8 = 82

ß = ßi T = T2

0 = 02 \ the conditions for the interference limited case ß = ß2

Equation (11.11-1) has to make a distinguished difference between P_A and P_B. The cases of P_A and P_B do not occur at the same time. When capacity is based on frequency reuse, the interference level is high, the size of the cells is small, and coverage is not an issue. The call dropped rate totally depends on interference.

Additional topics notes

UNIT II: Assignment Topics

- Antenna tilting
- Co-channel interference reduction Factor
- Desired C/I in a Omni directional Antenna Systems

UNIT IV: Assignment Topics

- Antenna height gain
- General formula for mobile propagation over water & Flat open area, near and long distance propagation

UNIT VI: Assignment Topics

- frequency management
- channel sharing
- channel borrowing

UNIT VIII: Assignment Topics

- 3G,4G Systems
- SCM and SID
- Interleaving and coding

Reduction of Co- Channel interference by Notch in Tilted Antenna

In a mobile radio environment, the height of a cell site antenna is usually two order of magnitude less than the distance between the cell site and the mobile unit. The elevation angle as observing the cell-site antenna from the mobile unit then is very small. Therefore, the portion of an antenna gain pattern which affects a remote edge of a serving cell region is substantially the same as the portion affecting a nearby cochannel interfering cell.

Consequently, antennas in cellular systems have been typically oriented to direct their principal radiation along a plane which is essentially horizontal, i.e., parallel to a plane that is tangent to the average curvature of the earth at the base of the antenna site. Reliance has been placed upon propagation loss effect and the placement of cochannel antenna sites at a sufficient spacing to assure acceptable low levels of cochannel interference.

To arrange a sufficient geographical spacing between two cochannel cells in a cellular system, is costly. At present, the conventional cochannel-cell spacing of a cellular system is 4.6 times the cell radius. Under this situation, the cochannel interference sometimes are strongly existing.

The scheme of dividing a cell into three sectors and using directional antenna in each sector does reduce the cochannel interference. Sometimes it is still not enough. The following scheme introduced here is to further reduce the cochannel interference

We find that the average S/I ratio in a cell region served by a serving cell antenna site is improved by tilting the antenna gain pattern downward by a predetermined amount at every cell site in the cellular system.

Reduction of co-channel interference in a cellular mobile system is always a challenging

problem. A number of methods can be considered such as:

1. Increasing the separation between two co channel cell

2. Using directional antenna in the base station, or

3. Lowering the antenna height at the base station.

Method 1 is not advisable because as the number of frequency-reuse cell increases, the system efficiency, which is directly proportional to the number of channels per cell, decreases. Method 3 is not recommended because such an arrangement also weakens the reception level at the mobile unit. However, method 2 is good approach. Especially when the number of frequency-reuse cells is fixed. The use of directional antennas in each cell can serve two purposes:

1. For the further reduction of co channel interference if the interference can

be eliminated by a fixed separation if co channel cells and

2. Increasing the channel capacity when the traffic increases. Here we try to further reduce the co channel interference by intelligently setting up the directional antenna.

Cautions in tilting antennas

When a base station antenna is tilted down by 10°, the strength of the received signal in the horizontal direction is decreased by 4 dB. But the strength of the received signal 1° below the horizontal is decreased by 3.5 dB only 0.5 dB stronger than in the 0° case. This is very important observation. For e.g., the elevation angel at the boundary of a

2-miles serving cell with a 100ft antenna mast is about 0.5°.this means that the serving cell and the interfering cell are separated by only 0.5° at most then by tilting three antenna down by 10°, the interference by the interfering cell is reduced by an additional 0.25 dB. This is an insignificant improvement the total power received is 4 dB less than

in the no-tilt case. If the tilt is increased to 20°, the received power drops by 16 dB and the reduction in interference due to tilting the antenna is only 1 dB at the interference cell. Therefore the antenna vertical pattern and the antenna height play a major role in justifying antenna tilting. Sometimes, tilting the antenna upward may increase signal coverage if interference is not a problem.

Special features of Handling Traffic

The introduction of GPRS services into GSM networks creates new challenges to network planning engineers. One critical challenge comes from the requirement for providing a certain quality of service for GPRS traffic without significantly degrading the performance of existing GSM services. In a GSM/GPRS integrated network, it becomes necessary to reserve exclusive channels for GPRS in order to provide base-line QoS for GPRS users. On the other hand, the exclusive reservation obviously reduces the capacity of GSM traffic so that has significant impact on the performance of GSM traffic (especially GSM handover traffic). In this paper, we primarily evaluate the performance degradation of GSM handover traffic due to the introduction of GPRS in a GSM/GPRS network when various priority schemes for handover traffic over new call traffic are applied. A simplified case study of a GPRS/GSM network is simulated by using an event-driven simulator. The effect of an increasing GPRS penetration factor on the performance of existing GSM services is also studied. Our key results show that the performance of GSM handover traffic can be significantly degraded by the capacity reduction resulting from the introduction of GPRS but can be amended by using appropriate priority schemes.

Introduction

Many studies have predicted that within next few years there will be an extensive demand for mobile data services, specially wireless Internet [1]. In order to address the inefficiencies of current circuit-switched mobile networks, such as GSM, for carrying bursty data traffic (typical Internet applications show such traffic behavior), packet switching techniques have emerged in mobile networks.

GPRS is a new bearer service that greatly improves and simplifies wireless access to packet data networks, e.g., to the Internet. The basic GPRS concept is to utilize rest traffic channels unused by GSM traffic. In general, GSM traffic has higher priority than GPRS traffic when allocating channels, which means that an ongoing GPRS channel has to be terminated for a pending GSM traffic. On the other hand, in a GSM and GPRS integrated network high GSM traffic load may prevent GPRS traffic from achieving an acceptable quality guarantee if no channel is exclusively dedicated to GPRS. Therefore, given a number of channels for both GSM and GPRS, it is reasonable that a fraction of the channels are exclusively assigned to GPRS and the rest are shared between GSM and GPRS while GSM traffic has higher priority over GPRS traffic. The combination of shared and dedicated traffic channels is so called partial sharing (PS) technique. When the exclusive reservation of channels for GPRS takes place without allocating new spectrum, the GPRS PS implementation obviously reduces the capacity of existing GSM services. This reduction is especially critical in the case of GSM handover traffic because terminating a call in progress is clearly less desirable than blocking a new call attempt. Therefore, methods for improving the handover performance become necessary when the capacity reduction is considerable.

The performance of GPRS service has been extensively investigated in past years, but very few results have appeared regarding the effect of GPRS PS implementation on the existing GSM services. In the performance loss of GSM services due to the introduction of GPRS is studied as an additional experiment, and no solution is given for counteracting the reduction of GSM capacity. In the impact of GPRS on the quality of existing GSM services is analyzed and a method for calculating the outage probability of a GPRS/GSM network is proposed, but the capacity reduction of GSM services is just mentioned.

Different handover priority-based channel allocation schemes in order to counteract the reduction of capacity of GSM services at the same time that prioritize handover traffic over new call attempts. We investigate the effectiveness of these handover prioritization schemes on improving the performance of handover traffic in a GPRS/GSM network. Particularly, we present the effect of an increasing GPRS penetration factor on the performance of GSM traffic.

Handover handling schemes

When allocating a channel, a simple scheme employed by cellular technologies handles both types of calls (new calls and handovers) without preference. This means that the probabilities of new call blocking and handover failure are the same. This scheme is referred to as the non-prioritized scheme (NPS). However, from the user's point of view, the forced termination of an ongoing call is considered to be worse than blocking a new call attempt. Therefore, it becomes necessary to introduce methods for decreasing the probability of handover failure as well as new call blocking.

Various handover prioritization schemes have been studied in the past [5-8]. These schemes can be sorted into four classes:

- Reserving a number of channels exclusively for handovers
- Queuing handover requests
- Sub-rating an existing call to accommodate a handover
- Combination of the above classes

These schemes are separately described in the following subsections.

Note that these schemes take place on the basis of PS implementation. For example, given a fixed number of channels (N_{ch}) in a GSM/GPRS cell, a fraction of channels are exclusively reserved for GPRS (N_{gprs}). The N_{gprs} is referred to GPRS penetration factor. Then the rest channels (N_{shared}) can be used for both GSM and GPRS, where these priorization schemes apply.

1.1. Reserved channel scheme (RCS)

This scheme reserves a number of channels exclusively for handovers requests from N_{shared}. Then, the N_{shared} channels are divided into two different groups: a *common channel group* (N_{com}) and a *reserved channel group* (N_{ho}): the N_{com} channels can be used by new calls as well as handovers, whereas the N_{ho} channels can only be used by handovers. There are two types of reservation:

- *Pre-reservation (RCS-pre)*

On the arrival of a handover request, a channel in N_{ho} is allocated for the handover. If N_{ho} is fully occupied by handover traffic, the handover request contends with new call attempts for a channel in the N_{com} pool. This ensures that certain minimal handover traffic will be admitted even under heavy load.

- *Post-reservation (RCS-post)*

On the arrival of a new handover request, it contends with new call attempts for admission into the N_{com} pool. If N_{com} is full, it will be allocated in the N_{ho} pool. This post-reserved pool ensures that even under heavy loads extra priority is given to handovers.

Reserving channels for handovers means fewer channels can be granted to new calls, so the blocking probability of new calls may significantly increase. This disadvantage can be overcome by using a queueing scheme in the following subsection.

1.2. *Queueing priority scheme (QPS)*

On the arrival of a new handover request, if there is no free channel in the target cell for the request, the handover request is queued and the mobile station (MS) continues to use the old channel in the current cell until a free channel becomes available in the target cell. The queueing can be performed at Base Transceiver Station (BTS)/Base Station Controller (BSC) or Mobile Switch Center (MSC) in GSM system. One new call in the target cell is served only when a channel is available and no handover request exists in the queue. If any channel is released while handover requests are queued, the released channel is assigned to a handover in the queue. The “next” handover to be served is selected based on queueing policies, which also influence the performance of the scheme:

- *FIFO priority queueing(F-QPS)*

With the FIFO queueing discipline, if a handover request finds all channels occupied in the target cell, the request is queued according to a FIFO discipline, i.e., the last handover request joins the end of the queue and the first to be served is the first in the queue (the earliest one to arrive in the queue).

- *Measurement-based priority queueing (M-QPS)*

During the time interval the MS spends in the handover area, its communication with the current BTS degrades at a rate depending on various factors, such as its velocity and direction. This degradation rate is easily monitored by the means of radio channel measurements, usually taken by the MS and submitted to the network (Moblie Assisted Handoff - MAHO procedures of the GSM system). Then, the handover area can be viewed as a region marked by different ranges of values of the power ratio. Then, the highest priority belongs to the MS whose power level is the closest to a receiver threshold. On the other hand, the MS that has just issued a handover request has the least priority. The power levels are monitored continuously, and the priority of an MS dynamically changes depending on its power level. Obviously, the last comer joins the end of the queue, but the queue is dynamically reordered as new measurement results are submitted. When a channel is released, it is granted to the MS with the highest priority.

1.3. *Sub-rating scheme (SRS)*

This scheme creates a new channel by sub-rating an existing call for a handover request when all channels are occupied in the target BTS. Sub-rating means that an occupied full-rate channel is temporarily divided into two channels at half the original rate: one to serve the existing call and the other to serve the handover request. A protocol required to sub-rate a traffic channel is described in [8].

1.4. *Hybrid schemes (HS)*

It is possible to combine the above handover prioritization schemes. For instance, N_{ho} channels can be exclusively reserved for handovers while allowing queueing of handover requests. This results in shortening the queuing length of handover requests. Another possibility is to use the RCS-pre and the RCS-post schemes at the same time. A random number between 0 and 1 is generated in the BTS/BSC/MSC: if this number lies between 0 and 0.5, the RCS-pre is performed for handover calls; otherwise, the RCS-post is performed.

2. Model description of the studied system

The performance of a cellular network can be investigated by using either simulation or analytical study (or their combination). Simulation models are preferred when studying the behavior of a specific cellular system covering a given area.

we carry out the performance study on the basis of computer simulation. An event-driven simulator has been implemented using a simulation library developed in C++

2.1. System parameters

The simulation focuses on one cell in an overlaid GPRS/GSM cellular network. Its behavior is isolated from those of other cells. The simulation concentrates on the uplink procedure where resource contention and resource reservation take place.

The penetration factor of GPRS service is expected to be higher in urban/suburban areas, so the type of cell should be common in these areas. Therefore, we choose to study a ***microcell***, that is, a cell with a relatively small size. In a microcell scenario the number of handovers per active call is higher than that in a macro cell. Common microcell radius is between 200m and 1km [10]. R_{micro}= 800m is assumed for the simulation. Furthermore, it is considered that users in cell border are always in line-of-sight (LOS) in order to avoid street-corner effect.

For simplicity, we employ a fixed frequency assignment strategy. Moreover, we consider that channels are allocated in a fixed manner, that is, no dynamic changing based on traffic load is implemented. In practice, a dynamic channel allocation can be implemented which allows flexible adaptation to different traffic conditions.

The number of TRXs in the cell is set to 4. Then, there are 32 physical channels (i.e., $N_t = 32$) available in the cell (every carrier is divided into 8 timeslots). We assume that 3 channels are reserved for network signaling (i.e., $N_{sig} = 3$). Thus, only 29 traffic channels are available for carrying user's information (i.e., $N_{ch} = 29$).

The GPRS PS implementation exclusively dedicates N_{gprs} channels to GPRS, and the remaining channels $N_{shared} = N_{ch} – N_{gprs}$ are shared by GSM and GPRS services. In the N_{shared} channel pool, GSM traffic has higher priority with pre-emption over GPRS traffic so that the capacity of GSM traffic is the N_{shared} channels.

2.2. Traffic and mobility models

The arrival of GSM calls to the cell is the superposition of two processes corresponding to newly initiated calls within the cell (*new calls*) and calls handed over from the neighboring cells (*handovers*). It is assumed that new calls and handover requests are both generated according to a Poisson process with an arrival rate λ_n and λ_h respectively. Calls that are initiated in the cell can be divided into those that complete inside the cell and those that are handed over to other cells. In the same way, handovers can also be divided into calls that terminate in the cell and those that continue to other cells. Therefore, a channel could be occupied by the arrival of a new call or a handover, and it could be released either by completion of the call or a handover to another cell. The time spent by a user on a particular channel in a given cell is defined as the *channel holding (or occupancy) time*.

Although the channel holding time is taken equivalent to the call duration time in a fixed telephone network, it is often a fraction of the total call duration in a cellular mobile network. In general, the channel holding time is a random variable that is a function of system parameters such as cell size, user location, user mobility and call duration time [11]. In [11] it is found that the distribution function of the channel holding time in a single cell follows a negative exponential distribution. We use this result in our simulations.

We assume a normal distributed speed with mean 30km/h and standard deviation equal to 20km/h and truncated at [0,100]km/h (medium mobility users) [11]. For a cell radius of R_{micro}= 800m, by assuming the mean call duration time as 120 seconds and the average velocity as 30km/h, the mean channel holding time is 60 seconds [12]. Furthermore, we consider 35% of the total offered traffic resulted from handover requests.

2.3. Model for the QPS scheme

The simulation models for the NPS and the RCS schemes are obvious. For the QPS, a maximum possible queueing time is used. This maximum queueing time is given by the time interval the MS spends in the handover area. Moreover, only a finite queue length is allowed in order to avoid very large queue sizes. It is assumed that once a handover request is issued the power that the MS receives from the current BTS will monotonically degrade [6]. The rate of degradation, and hence the maximum tolerable degradation interval, depend on the velocity of the MS. Since a truncated normal distribution for the velocity has been considered, normally distributed degradation intervals are considered in this paper, instead of exponentially distributed degradation intervals in other works [5][7].

In micro cell environment, the overlapped area between microcells can be very different depending on several factors. We consider a minimum value for the overlapped area equal to 50m (one-sixteenth of the R_{micro}), which implies the worst case situation (smallest overlapped area). Therefore, the maximum tolerable degradation interval (T_{di}) associated with each MS entering the handover area for a R_{micro} =

800m is drawn from a normal distribution with a mean of 6 seconds and a standard deviation of 4 seconds.

2.4. Performance parameters

The following performance parameters will be used for evaluating the performance of GSM traffic:

- *Probability of new call blocking* P_{nb} is the probability that a new call attempt cannot be served due to the lack of free channels.
- *Probability of handover failure* P_{hf} is the probability that an incoming handover request cannot be satisfied because of the lack of free channels, and thus results in a termination of the call.
- *Network throughput*, which is evaluated by means of the *total carried traffic* A_{carr}. The carried traffic is the amount of traffic admitted to the cellular network as opposed to the offered traffic. It indicates the average number of busy channels (ongoing calls) at any one time in the cell.
- C*hannel utilization* U_{ch}, which is a normalization of the A_{carr}, is the percentage of the overall simulation time that a specific channel is being used. This parameter is usually given as the average channel utilization of several channels.

These performance parameters will be examined as a function of the total GSM offered traffic load. Values for a maximum blocking probability of 2% will be marked in the curves with a dash-dot line; this means that the cell has been engineered at 2% blocking probability for the mean traffic load in rush hours, which gives the values for the worst case situation. As a result, the actual capacity reduction experienced by GSM services would be less than that obtained in all studied cases because real offered traffic will be usually smaller than that in rush hours. By evaluating all these performance parameters, the performance of the network with a specific handover priority-based channel allocation scheme can be achieved.

Standard bodies Spectrum for 3G

1. Spectrum Regulation
2. Spectral Allocation in US controlled by FCC
3. (commercial) or OSM (defense)
4. FCC auctions spectral blocks for set applications.
5. Some spectrum set aside for universal use

6. Worldwide spectrum controlled by ITU-R
7. Standards
8. Interacting systems require standardization
9. Companies want their systems adopted as standard
10. Alternatively try for de-facto standards
11. Standards determined by TIA in US
12. IEEE standards often adopted
13. Process fraught with inefficiencies and conflicts
14. Worldwide standards determined by ITU-T

Trends of Wireless mobile

TDMA based 2/2.5G digital systems like GSM/EDGE and CDMA (spread spectrum) based digital systems like IS95 for wireless cellular communication have created an increasing market within Europe, the US and SEA since 1992 and have gained nearly world-wide acceptance. The total number of cellular subscribers has already reached the range of 1 billion and may grow to 2 billion by end of this decade. The 3G WCDMA based UMTS system started service in Japan in 2001 and in Europe in 2003. Advanced Smart Cellular Phones are, already today, extended with Cordless, Navigation, Broadcasting and other services, e.g. DECT, WDCT, BT, Zigbee, RKE, GPS/Galileo, FM radio, DAB, TV, DVB, WLAN, RF TAGs. These multi-system phones will enable in the future nearly unlimited wireless connectivity and services.

Recent activity in 4G (fourth generation) mobile communication systems has steeped the race in its implementation at the earliest. 4G wireless being an upcoming standard witnesses burgeoning interest amongst researchers and vendor. It is being designed to allow seamless integration and communication between wireless devices across diverse wireless standards as well as broadband networks wirelessly. Access to different radio technologies is facilitated due to IP-based-4G mobile communication system connecting the user. This paper attempts to make an assessment in development, transition, and roadmap for fourth generation mobile communication system with a perspective of wireless convergence domain and future research issues.

In the current information era, mobile communications has enabled us to use laptop personal computers linked to the internet without a ‘wired’ LAN. Simply put, if the internet gave us the ability to access any web address on a desktop, mobiles have given us the access at any time and from anywhere. This capability, derived from modern telecommunication technology, is crucial in conducting international business operations. Nevertheless, due to various mobile protocols and networks available in different parts of the world nowadays, for example, analogue, GSM, TDMA or CDMA, it becomes challenging for the airtime providers to expand their services across technological incompatibility. The developing Third-Generation (3G) standard is attempting to unify all new-generation mobile devices in a single platform. With the new standard, the mobile gadgets may replace desktop PCs, laptop PCs, credit cards or even wallets in the near future.

Table 1 Key technology milestones in mobile communication industry

Year	Technology milestone
1901	Guglielmo Marconi’s first wireless telegraphy sent signals across the Atlantic ocean
1910	The first car-telephone by Ericsson
1946	The first commercial American radio-telephone service by AT&T and Southwestern Bell
1969	The first commercial cellular radio system by Bell System
1973	The first handheld cell phone by Motorola
1978	First generation of analogue cellular systems by Bahrain Telephone Company
1982	The rise of GSM in western Europe
1990	North American set IS-54B standard up for digital cellular systems using TDMA technique.

Mobile satellite

To complement the cellular phone and wireless computing networks, mobile satellites offer a combination of all-digital transparent voice, data, fax and paging services to and from handheld telephone devices. The systems share an air interface standard named Geostationary Mobile Satellite Standard (GMMS) that is similar to GSM. This means that the Satphone customers will be able to use mobile phones that are compatible with satellite systems in any country where GMSS is offered; in effect, creating roaming capabilities that normal land-based mobile phone users need to pay extra for when the handsets are used in areas outside the network coverage.

Nowadays, there are more than 1000 satellites orbiting the globe. . They can be positioned in orbits with different heights and shapes (circular or elliptical). Based on the orbital radius, all satellites fall into one of the following three categories: Low Earth Orbit (LEO), Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO) .

Assignment questions

UNIT 2:

1. Explain the components of basic cellular systems.
2. Write short notes on the method of avoiding co-channel interference.
3. What are the elements of cellular mobile systems?
4. What is the use of directional antennas?

UNIT 4:

1. Compare a hilly terrain and a flat terrain with two important points.
2. Explain constant standard deviation along a path loss curve in detail.
3. Derive the diff general formula used for signal propagation over water and flat open area.
4. Explain the phase difference between direct and reflected path in detail.

UNIT 6:

1. Explain channel sharing and channel borrowing concepts in detail.
2. Explain non fixed channel assignment in detail.
3. What is known as dynamic channel assignment, average blocking and handoff blocking? Explain.
4. Explain cell sectorization technique.

Tutorial sheets

Tutorial Class Topics and related Information

Tutorial Class

- Limitations of Conventional cellular mobile systems
- Handoff procedure
- Service quality:
- Digital cellular systems

Question Bank

1. Draw the general view of telecommunication and explain the function of the each unit?

Antenna:

Antenna pattern, antenna gain, antenna tilting, and antenna height 6 all affect the cellular system design. The antenna pattern can be omnidirectional, directional, or any shape in both the vertical and the horizon planes. Antenna gain compensates for the transmitted power. Different antenna patterns and antenna gains at the cell site and at the mobile units would affect the system performance and so must be considered in the system design. The antenna patterns seen in cellular systems are different from the patterns seen in free space. If a mobile unit travels around a cell site in areas with many buildings, the omnidirectional antenna will not duplicate the omnipattern. In addition, if the front-to-back ratio of a directional antenna is found to be 20 dB in free space, it will be only 10 dB at the cell site. Antenna tilting can reduce the

Answer: The general view of the cellular system is shown in Fig.1.

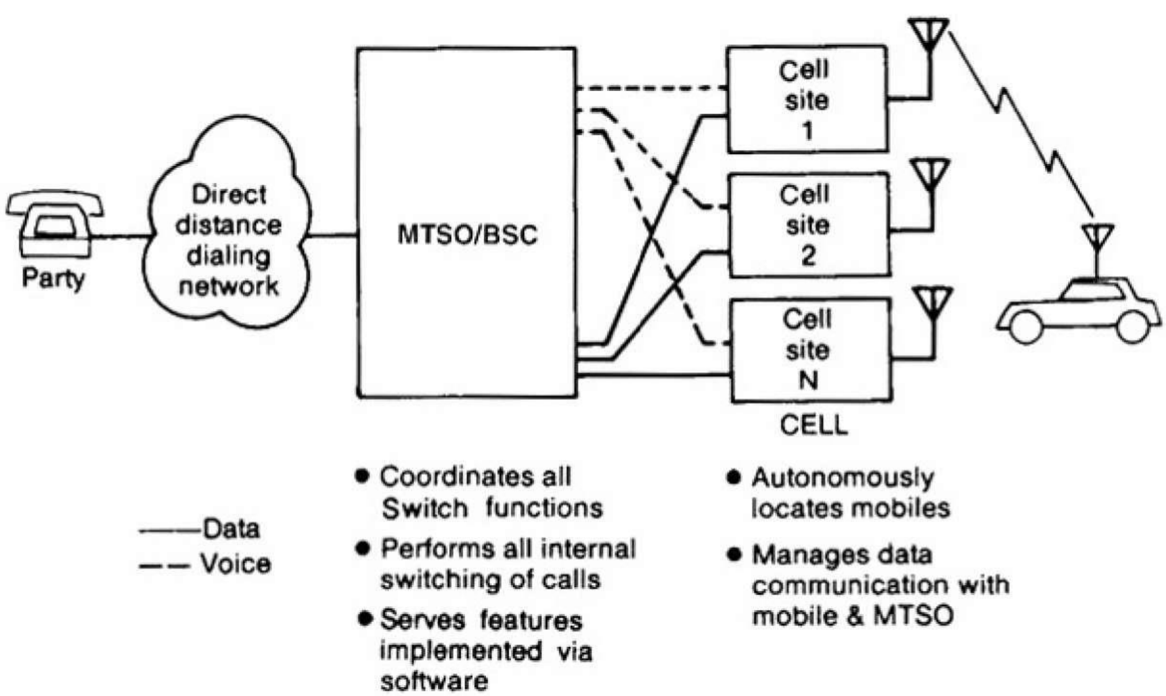


Fig. 1 A general view of cellular telecommunications system

interference to the neighboring cells and enhance the weak spots in the cell. Also, the height of the cellsite antenna can affect the area and shape of the coverage in the system.

Switching Equipment:

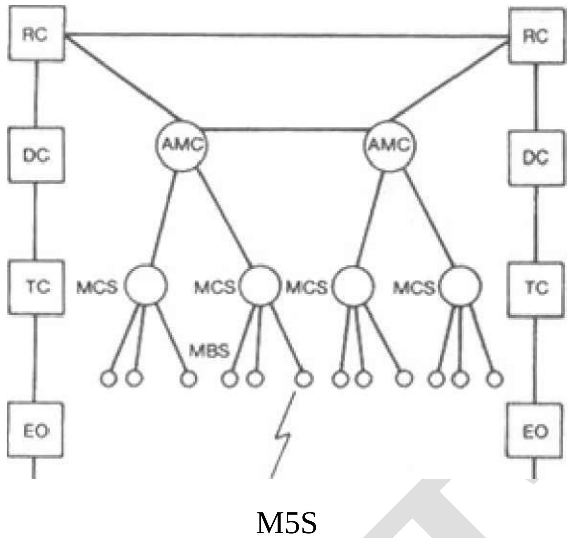
The capacity of switching equipment in cellular systems is not based on the number of switch ports but on the capacity of the processor associated with the switches. In a big cellular system, this processor should be large. Also, because cellular systems are unlike other systems, it is important to consider when the switching equipment would reach the maximum capacity. The service life of the switching equipment is not determined by the life cycle of the equipment but by how long it takes to reach its full capacity. If the switching equipment is designed in modules, or as distributed switches, more modules can be added to increase the capacity of the equipment. For decentralized systems, digital switches may be more suitable. The future trend seems to be the utilization of system handoff. This means that switching equipment can link to other switching equipment so that a call can be carried from one system to another system without the call being dropped.

Data Links:

The data links are shown in Fig 1. Although they are not directly affected by the cellular system, they are important in the system. Each data link can carry multiple channel data (10 kbps data transmitted per channel) from the cell site to the MTSO. This fast-speed data transmission cannot be passed through a regular telephone line. Therefore, data bank devices are needed. They can be multiplexed, many-data channels passing through a wideband T-carrier wire line or going through a microwave radio link where the frequency is much higher than 850MHz. Leasing T1-carrier wire lines through telephone companies can be costly. Although the use of microwaves may be a long-term money saver, the availability of the microwave link has to be considered.

2. Explain about NMT & NTT Systems.
Answer:

NTT: Nippon Telegraph and Telephone Corporation (NTT) developed an 800-MHz land mobile telephone system and put it into service in the Tokyo area in 1979. The general system operation is similar to the AMPS system. It accesses approximately 40,000 subscribers in 500 cities. It covers 75 percent of all Japanese cities, 25 percent of inhabitable areas, and 60 percent of the population. In Japan, 9 automobile switching centers (ASCs), 51 mobile control stations (MCSs), 465 mobile base stations (MBSs), and 39,000 mobile subscriber stations (MSSs) were in operation as of February 1985.



ftC Switching Cantor Reg«™J Onuer AMt Autcyrrtbil*
DC: DiitrKi Ontm FJCS Mobile Conbol SUtnon
TC: Toll OnlBf MBS Mo&ile Sa» Stollo^
EÒ $nton End Odi» MSS: Mobil« ButscnCw

Fig.2 Japanese mobile telephone service network configuration

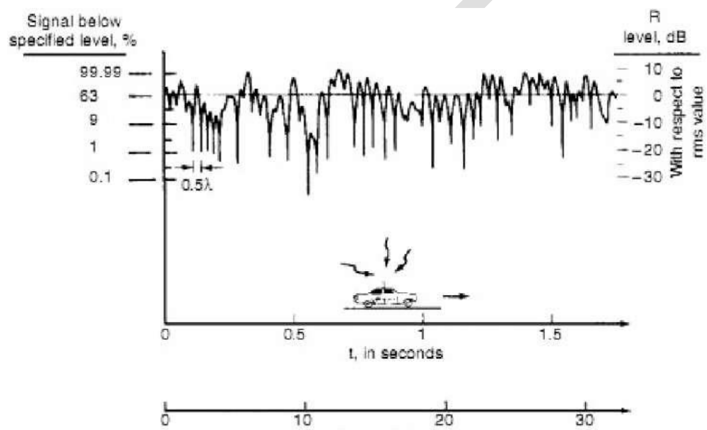
The Japanese mobile telephone service network configuration is shown in Fig.2. In the metropolitan Tokyo area, about 30,000 subscribers are being served. The 1985 system operated over a spectrum of 30 MHz. The total number of channels was 600, and the channel bandwidth was 25 kHz. This system comprised an automobile switching center (ASC), a mobile control station (MCS), a mobile base station (MBS), and a mobile subscriber station (MSS). At present there is no competitive situation set up by the government. However, the Japanese Ministry of Post and Telecommunication (MFT) is considering providing a dual competitive situation similar to that in the United States.

NMT: Nordic System: This system was built mostly by Scandinavian countries (Denmark, Norway, Sweden, and Finland) in cooperation with Saudi Arabia and Spain and is called the NMT network. It is currently a 450-MHz system. But an 800-MHz System will be implemented soon since the frequency transparent concept as the AURORA 800 system is used to convert the 450-MHz system to the 800-MHz System. The total bandwidth is 10 MHz, which has 200 channels with a bandwidth of 25 kHz per channel. This system does have handoff and roaming capabilities. It also uses repeaters to increase the coverage in a low traffic area. The total number of subscribers is around 100,000.

3. Explain the phenomena of severe fading?

Answer:

Severe Fading: If the antenna height of the mobile unit is lower than its typical surroundings, and the carrier frequency wavelength is much less than the sizes of the surrounding structures, multipath waves are generated. At the mobile unit, the sum of the multipath waves causes a signal-fading phenomenon. The signal fluctuates in a range of about 40 dB (10 dB above and 30 dB below the average signal). We can visualize the nulls of the fluctuation at the baseband at about every half wavelength in space, but all nulls do not occur at the same level, as Fig.3 shows. If the mobile unit moves fast, the rate of fluctuation is fast. For instance, at 850 MHz, the wavelength is roughly 0.35 m (1 ft). If the speed of the mobile unit is 24 km/h (15 mi/h), or 6.7 m/s, the rate of fluctuation of the signal reception at a 10-dB level below the average power of a fading signal is 15 nulls per second.



$\bar{n}_R$	$\bar{t}_R$	$CDF = \bar{n}_R \times \bar{t}_R$
0.00014	7142.14	0.9999
0.36788	1.71	0.6291
0.28593	0.31476	0.09
0.1	0.1	0.01
0.0315	0.03168	0.001

(from Fig. 2.10)

$P(r \le R) = \int_0^R P(r)dr$ cumulative probability distribution (CDF) $= \bar{n}_R \cdot \bar{t}_R$

$\bar{n}(R) = \frac{\beta V}{\sqrt{2\pi}} \times n_R$ level crossing rate

$\bar{t}(R) = \frac{\sqrt{2\pi}}{\beta V} \times \bar{t}_R$ average duration of fades

$p(r) = re^{-r^2}$ Rayleigh distribution

Fig.3 A typical fading signal received while the mobile unit is moving.

4. Distinguish between the permanent splitting and dynamic splitting?

Answer: There are two kinds of cell-splitting techniques:

1. **Permanent splitting:** The installation of every new split cell has to be planned ahead of time; the number of channels, the transmitted power, the assigned frequencies, the choosing of the cell-site selection, and the traffic load consideration should all be considered. When ready, the actual service cutover should be set at the lowest traffic point, usually at midnight on a weekend. Hopefully, only a few calls will be dropped because of this cut-over, assuming that the downtime of the system is within 2 h.

2. **Dynamic splitting:** This scheme is based on using the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a tedious job, as we cannot afford to have one single cell unused during cell splitting at heavy traffic hours.

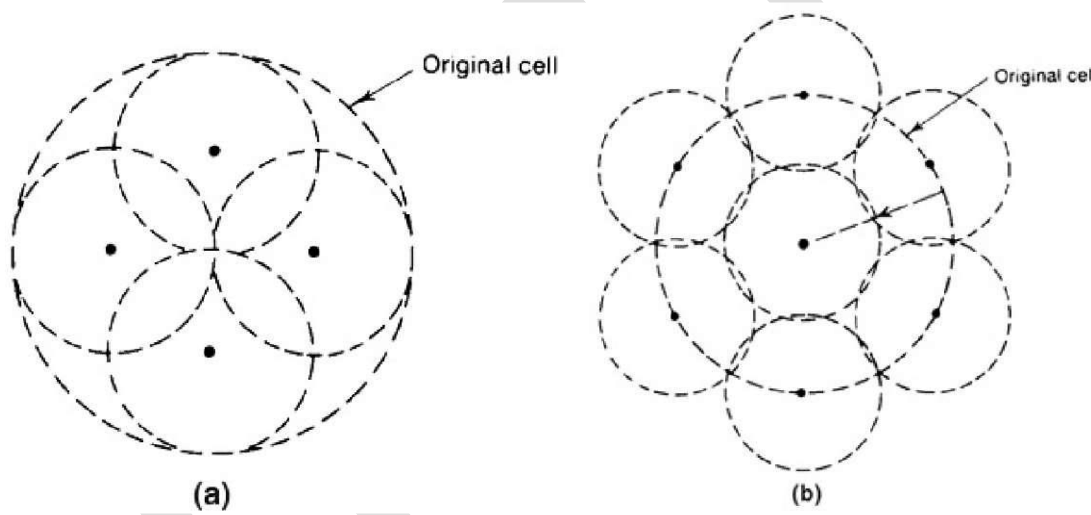


Fig.4 Cell splitting

5. What are the limitations of conventional mobile systems and how are they overcome by cellular mobile systems?

Answer:

Limitations of conventional mobile telephone systems: One of many reasons for developing **a** cellular mobile telephone system and deploying it in many cities is the operational limitations of conventional mobile telephone systems: limited service capability, poor service performance, and inefficient frequency spectrum utilization.

1. Limited service capability: A conventional mobile telephone system is usually designed by selecting one or more channels from a specific frequency allocation for use in autonomous geographic zones, as shown in Fig. 5. The communications coverage area of each zone is normally planned to be as large as possible, which means that the transmitted power should be as high as the federal specification allows. The user who starts a call in one zone has to reinitiate the call when moving into a new zone because the call will be dropped. This is an undesirable radio telephone system since there is no guarantee that a call can be completed without a handoff capability. The handoff is a process of automatically changing frequencies as the mobile unit moves into a different frequency zone so that the conversation can be continued in a new frequency zone without redialing. Another disadvantage of the conventional system is that the number of active users is limited to the number of channels assigned to a particular frequency zone.

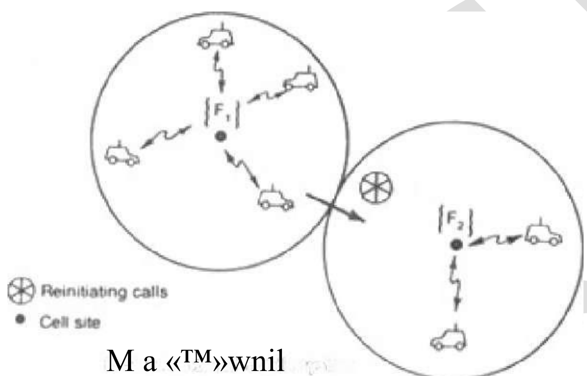


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Fig.5 Conventional Mobile System

Poor Service Performance: In the past, a total of 33 channels were all allocated to three mobile telephone systems: Mobile Telephone Service (MTS), Improved Mobile Telephone Service (IMTS) MJ systems, and Improved Mobile Telephone Service (IMTS) MK systems. MTS operates around 40 MHz and MJ operates at 150 MHs; both provide 11 channels; IMTS MK operates at 450 MHz and provides 12 channels. These 33 channels must cover an area 50 mi in diameter. In 1976, New York City had 6 channels of(MJ serving 320 customers, with another 2400 customers on a waiting list. New York City also had 6 channels of MK serving 225 customers, with another 1300 customers on a waiting list. The large number of subscribers created a high blocking probability during busy hours. Although service performance was undesirable, the demand was still great. A high-capacity system for mobile telephones was needed.

Inefficient Frequency Spectrum Utilization: In a conventional mobile telephone system, the frequency utilization measurement Mo, is defined as the maximum number of customers that could be served by one channel at the busy hour.

Mo = Number of customers/channel

Mo = 53 for MJ

37 for MK

The offered load can then be obtained by

A = Average calling time (minutes) x total customers / 60 min (Erlangs)

Assume average calling time = 1.76 min.

A1 = 1.76 * 53 * 6 / 60 = 9.33 Erlangs (MJ system)

A2 = 1.76 * 37 * 6 / 60 = 6.51 Erlangs (MK system)

If the number of channels is 6 and the offered loads are A1 = 9.33 and A2 = 6.51, then from the Erlang B model the blocking probabilities, B1 = 50 percent (MJ system) and B2 =30 percent (MK system), respectively. It is likely that half the initiating calls will be blocked in the MJ system, a very high blocking probability. As far as frequency spectrum utilization is concerned, the conventional system does not utilize the spectrum efficiently since each channel can only serve one customer at a time in a whole area. This is overcomed by the new cellular system.

6. Explain about basic cellular system. Answer:

Basic Cellular System: A basic cellular system consists of three parts: a mobile unit, a cell site, and a mobile telephone switching office (MTSO), as Fig.6 shows, with connections to link the three sub systems.

1. **Mobile units:** A mobile telephone unit contains a control unit, a transceiver, and an antenna system.

2. **Cell site:** The cell site provides interface between the MTSO and the mobile units. it has a control unit, radio cabinets, antennas, a power plant, and data terminals.

3. **MTSO:** The switching office, the central coordinating element for all cell sites, contains the cellular processor and cellular switch. It interfaces with telephone company zone offices, controls call processing, and handles billing activities.

4. **Connections:** The radio and high-speed data links connect the three subsystems. Each mobile unit can only use one channel at a time for its communication link. But the channel is not fixed: it can be any one in the entire band assigned by the serving area, with each site having multichannel capabilities that can connect simultaneously to many mobile units.

The MTSO is the heart of the cellular mobile system. Its processor provides central coordination and cellular administration. The cellular switch, which can be either analog or digital, switches calls to connect mobile subscribers to other mobile subscribers and to the nationwide telephone network. It uses voice trunks similar to telephone company interoffice voice trunks. It also contains data links providing supervision links between the processor and the switch and between the cell sites and the processor. The radio link carries the voice and signaling between the mobile unit and the cell site. The high-speed data links cannot be transmitted over the standard telephone trunks and therefore must use either microwave links or T-carriers (wire lines). Microwave radio links or T-carriers carry both voice and data between the cell site and the MTSO.

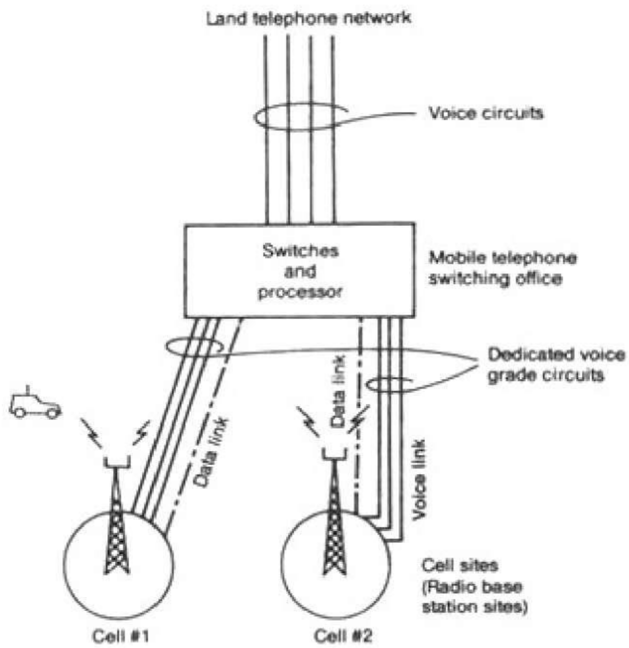


Fig.6 Basic cellular system

7. Explain the direct wave path, line of sight path, out of sight path, and obstructive path?
Answer:

A direct wave path is a path clear from the terrain contour. The line-of-sight path is a path clear from buildings. In the mobile radio environment, we do not always have a line-of-sight condition. When a line- of-sight condition occurs, the average received signal at the mobile unit at a 1-mi intercept is higher, although the 40 dB/dec path-loss slope remains the same. In this case the short-term fading is observed to be a rician fading. It results from a strong line-of-sight path and a ground-reflected wave combined, plus many weak building-reflected waves.

When an out-of-sight condition is reached, the 40-dB/dec path-loss slope still remains. However, all reflected waves, including ground reflected waves and building-reflected waves, become dominant. The short-term received signal at the mobile unit observes a Rayleigh fading. The Rayleigh fading is the most severe fading. When the terrain contour blocks the direct wave path, we call it the obstructive path. In this situation, the shadow loss from the signal reception can be found by using the knife-edge diffraction curves.

8. What are the different types of noises in cellular frequency ranges Explain in detail?

Answer:

Noise level in cellular frequency band: The thermal noise kTB at a temperature T of 290 K (17°C) and a bandwidth B of 30 kHz is -129 dBm, where k is Boltzmann's constant. Assume that the received frontend noise is 9 dB, and then the noise level is -120 dBm.

There are two kinds of man-made noise, the ignition noise generated by the vehicles and the noise generated by 800-MHz emissions.

The ignition noise: In the past, 800 MHz was not widely used. Therefore, the man-made noise at 800 MHz is merely generated by the vehicle ignition noise. The automotive noise introduced at 800 MHz with a bandwidth of 30 kHz can be deduced from Fig.7.

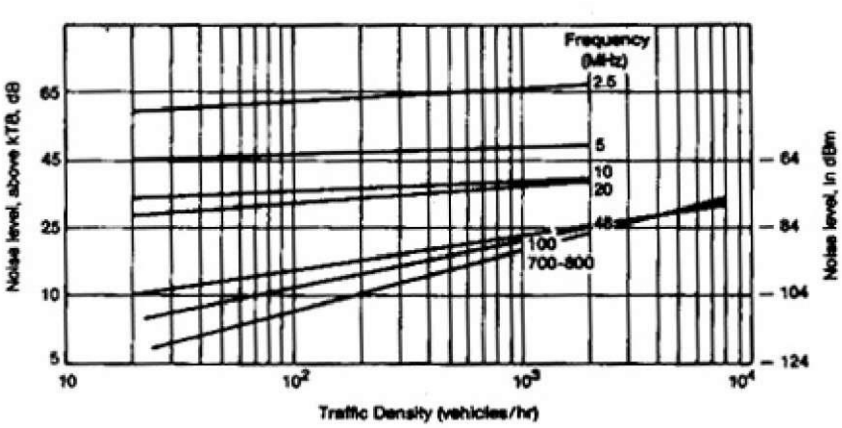


Fig.7 Noise in Cellular Networks

The 800-MHz emission noise: As a result of the cellular mobile systems operating in all the major cities in the United States and the spurious energy generated outside each channel bandwidth, the early noise data measurements are no longer valid. The 800-MHz-emission noise can be measured at an idle channel (a forward voice channel) in the 869- to 894-MHz region while the mobile receiver is operating on a car battery in a no-traffic spot in a city. In this Case, no automotive ignition noise is involved and no channel operation is in the proximity of the idle-channel receiver. We found that in some areas the noise level is 2 to 3 dB higher than -120 dBm at the cell sites and 3 to 4 dB higher than -120 dBm at the mobile stations.

Amplifier noise: A mobile radio signal received by a receiving antenna, either at the cell site or at the mobile unit, will be amplified by an amplifier. We would like to understand bow the signal is affected by the amplifier noise. Assume that the amplifier baa an available power gain g and the available noise power at the output is N. The input signal-to-noise (S/N) ratio is Ps/Ni, the output signal-to-noise ratio is Po/No, and the internal amplifier noise is Na. Then the output Po/No becomes

P» &P,

The noise figure F is defined as

maximum possible S/N ratio actual S/N ratio at output

Where, the maximum possible S/N ratio is measured when the load is an open circuit.

The noise figure of the amplifier is

$$F = \frac{P_s/kTB}{P_o/N_o} = \frac{N_o}{(P_o/P_s)kTB} = \frac{N_o}{g(kTB)}$$

F =

PJkTB _ N, + (NJB) P_m/iNi + (Njg)ì kTB

The term kTB is the thermal noise. The noise figure is a reference measurement between a minimum noise level due to thermal noise and the noise level generated by both the external and internal noise of an amplifier.

9. Explain about the marketing of hexagonal cells?

Answer:

Marketing Image of Hexagonal-shaped cells: The hexagonal-shaped communication cells are artificial and that such a shape cannot be generated in the real world. Engineers draw hexagonal-shaped cell on a layout to simplify the planning and design of a cellular system because it approaches a circular shape that is the ideal power coverage area. The circular shapes have overlapped areas which make the drawing unclear. The hexagonal-shaped cells fit the planned area nicely, as shown in Fig.8 with no gap and no overlap between the hexagonal cells. The ideal cell shapes as well as the real cell shapes are also shown in Fig.8.

A simple mechanism which makes the cellular system implement- able based on hexagonal cells will be illustrated in later chapters. Otherwise, a statistical approach will be used in dealing with a real-world situation. Fortunately, the outcomes resulting from these two approaches are very close, yet the latter does not provide a clear physical picture, as shown later. Besides, today these hexagonal-shaped cells have already become a widely promoted symbol for cellular mobile systems. An analysis using hexagonal cells, if it is desired, can easily be adapted by the reader.

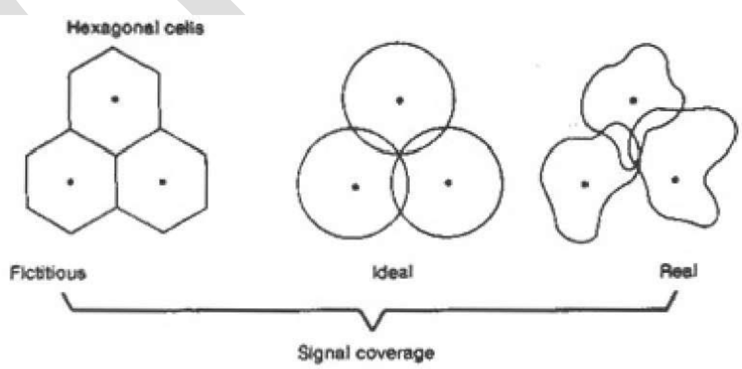


Fig.8 Hexagonal Cells and the real shapes of their coverages

10. Differentiate the generations in the cordless phones and cellular phones?

Answer:

Cellular Phones: In 1945 the Zero Generation (0G) of mobile telephones was introduced. 0G mobile phones like mobile telephone service, were not cellular, and so did not feature 'handover' from one base station to the next and reuse of radio frequency channels. Like other technologies of the time it involved a single powerful base station covering a wide area and each telephone would effectively monopolize a channel over that whole area while in use. The concepts of frequency reuse and handoff as well as a number of other concepts that formed the basis of modem cell phone technology arc first described in U .S. patent 4.152.647 issued on May 1. 1979 to Charles A Gladden and Marlin H Parelman, and assigned by them to the United States Government. This is the first embodiment of all the concepts that formed the basis of the next major step in mobile telephony, the analog cellular telephone.

The first commercial city wide cellular network was launched in Japan by NTT in 1979. Fully automatic cellular networks were first introduced in the early to mid 1980s (the 1G generation). The Nordic Mobile Telephone (NMT) system went on-line in Denmark, Finland, Norway and Sweden in 1981.

Personal Handy phone system and modems used in Japan around 1997-2003. In 1983, Motorola DynaTAC was the first approved mobile phone by FCC in the United States. In 1984, Bell Labs developed modern commercial cellular technology, which employed multiple, centrally controlled base stations (cell sites), each providing service to a small area (a cell). The cell sites would be set up such that cells partially overlapped. In a cellular system a signal between a base station (cell SIC) and a terminal phone) only need, be s[ring enough to reach between the two, so the same channel can be used simultaneously for separate conversations in different cells. The first "modern' network technology on digital 20 (Second Generation) cellular technology was launched by Radiolinja in 199) in Finland on the OSM standard which also marked the introduction of competition in mobile telecoms when Radiolinja challenged incumbent Telecom Finland who ran a 1-G NMT network.

The first data services appeared on mobile phones starting with person-to-person SMS text messaging in Finland in 1993. First trial payments using a mobile phone to pay for a Coca Cola vending machine were set in Finland in 1998. The first commercial payment system to mimic banks and credit cards was launched in the Philippines in 1999 simultaneously by mobile operators Glove and Smart. The first content sold to mobile phones was the ringing tone, first launched in 1998 in Finland. The first full Internet service on mobile phones was i-mode introduced by NTT's DoCoMo in Japan in 1999. In 2001 the first commercial launch of 3G (third generation) was again in Japan by NTT DoCoMo on the WCDMA standard.

Until the early 1990's, most mobile phones were too large to be carried in a Jacket pocket, so they were typically installed in vehicles as car phones. With the miniaturization of digital components and development of more sophisticated batteries, mobile phones have become smaller and lighter.

Cordless phones: George Sweigert an amateur radio operator and inventor from Cleveland Ohio, is largely recognized as the father of the cordless phone. He submitted a patent application in 1966 for a "full duplex wireless communication apparatus'. The U.S. patent and trademark office awarded him a patent in June of 1969. Sweigert a radio operator in World War II stationed at the south pacific islands of Guadalcanal and Bougainville, developed the full duplex-concept for untrained personnel, to improve battlefield communications for senior commanders. He was also licensed as W8ZIS and N9LC in the amateur radio service. He also held a first class radio telephone operator's permit issued by the Federal Communication Commission.

In the 1980s a number of manufacturers including Sony introduced cordless phones for the consumer market. They used a base station that was connected to a telephone line and a handset with a microphone, speaker, keypad and telescoping antenna. The handset contained a rechargeable battery typically NiCd. The base unit is powered by household current via a wall socket. The base included a charging cradle, which as generally a form of trickle charger, on which the handset rested when not in use. Some cordless phones now utilize two rechargeable AA or AAA batteries in place of the more expensive traditional proprietary telephone batteries.

11. Briefly explain the evaluation of the analog and digital cellular mobile system?

Answer:

Cellular telephone systems can be "Analog" or "Digital". Older Cellular Systems (AMPS, TACS, NMT) are analog and newer systems (GSM, CDMA, PCS) are "Digital".

The major difference between the two systems is how the voice signal is transmitted between the phone and base station. Analog and Digital refer to this transmission mechanism. It is like audio cassettes and CDs. Audio cassettes are analog and CDs are digital.

In either system, the audio at the microphone always starts out as a voltage level that varies continuously over time. High frequencies cause rapid changes and low frequencies cause slow changes. With analog system the audio is directly modulated on to a carrier. This is very much like FM (not identical) radio where the audio signal is translated to the RF signal.

With digital systems, the audio is converted to digitized samples at about 8000 samples per second or so. The digital samples are numbers that represent the time varying voltage level at specific points in time. These samples are now transmitted as 1s and 0s. At the other end the samples are converted back to voltage levels and smoothed out so that you get about the same audio signal.

With analog transmissions, interference (RF noise or some other anomaly that affects the transmitted signal) gets translated directly in to the recovered signal and there is no check that the received signal is authentic. The neat thing about the digital is that the 1s and 0s cannot be easily confused or distorted during transmission plus extra data is typically included in the transmission to help, detect and correct any errors.

12. Write notes on Digital Cellular System.

Answer:

Digital Cellular System: Digital cellular systems are the cellular systems that use the digital communication techniques like in modulation, transmission format and demodulation and so on. The characteristics of these systems are

1. These offer an effective data transmission compared to the conventional analog cellular systems. These systems employ the packet switched communication technique which is faster than the circuit switching technique.
2. These systems employ powerful error detection and Correction techniques, which can country the debilitating effect of noise, fading and interference on the signal.
3. These systems also provide the security on transmitting data through encryption and decryption techniques authentication.
4. These systems also require very less transmit power, this properly increases the battery life (in portable mobile units).
5. The range of services provided by the digital cellular system is quite large compared to that provided by the analog cellular systems.

6. The speed of services provided by digital systems is quite high and thus, they support high capacity data transfers.
7. The digital cellular systems employ TDMA technique for communication.

Some examples of the digital cellular systems are:

(i) GSM
(ii) NA-TDMA (North American TDMA)
(iii) CDMA
(iv) PDC
(v) 1800-DCS.

In 1992, the first digital cellular system, GSM was developed in Germany. GSM is a European standard system. In the United States, an NA-TDMA system and a CDMA system have been developed. A Japanese system, PDC (Personal Digital Cellular) was deployed in Osaka in June 1994.

13. Explain the Trunking Efficiency.
Answer:

Trunking Efficiency: To explore the trunking efficiency degradation inherent in licensing two or more carriers rather than one, compare the trunking efficiency between one cellular system per market operating 666 channels and two cellular systems per market each operating 333 channels. Assume that all frequency channels are evenly divided into seven subareas called cells. In each cell, the blocking probability of 0.02 is assumed. Also the average calling time is assumed to be 1.76 min.

With N1=666/7 = 95 and B= 0.02 to obtain the offered load A1 =83.1 and with N2=333/7=47.5 and B=0.02 to obtain A2= 38. Since two carriers each operating 333 channels are considered, the total offered load is 2A. We then realize that

Ai ^ 2Aj

By converting above eqn. to the number of users who can be served in a busy hour, the average calling time of 1.76 mm is introduced.

The trunking efficiency factor can be calculated as

$$\eta_c = \frac{2832.95 - 2590.9}{2832.95} = 8.5\%$$

For a blocking probability of 2 percent, Figure 13 shows, by comparing one carrier per market with more than one carrier per market situations with different blocking Probability conditions. The degradation of trunking efficiency decreases as the blocking probability increases. As the number of carriers per market increases the degradation increases. However, when a high percentage of blocking probability, say more than 20 percent, occurs, the performance of one carrier per market is already so poor that further degradation becomes insignificant, as Fig.9 shows.

For a 2 percent blocking probability, the trunking efficiency of one carrier per market does show a greater advantage when compared to other scenarios.

14. Explain about the model of transmission medium.
Answer:

Model of transmission medium: A mobile radio signal r(t), illustrated in Fig.14, can be artificially characterized by two components m(t) and r(t) based on natural physical phenomena.

r(t) = m(t) ro(t)

The component m(t) is called local mean, long-term fading, or lognormal fading and its variation is due to the terrain contour between the base station and the mobile unit. The factor r0 is called multipath fading, short term fading, or Rayleigh fading and its variation is due to the waves reflected from the surrounding buildings and other structures. The long-term fading m(t) can be obtained from Eq. below

Where 2T is the time interval for averaging r(t). T can be determined based on the fading rate of r(t), usually 40 to 80 fades. Therefore, m(t) is the envelope of r(t), as shown in Fig.10. Equation also can be expressed in spatial scale as

The length of 2L has been determined to be 20 to 40 wavelengths. Using 36 or up to 50 samples in an interval of 40 wavelengths is an adequate averaging process for obtaining the local means.

The factor m(t) or m(x) is also found to be a lognormal distribution based on its characteristics caused by the terrain contour. The short- term fading r0 is obtained by

r_0 {in dB) = **rit) - mil)** dB

The factor ro(t) follows a Rayleigh distribution, assuming that only reflected waves from local surroundings are the ones received (a normal situation for the mobile radio environment). Therefore, the term Rayleigh fading is often used.

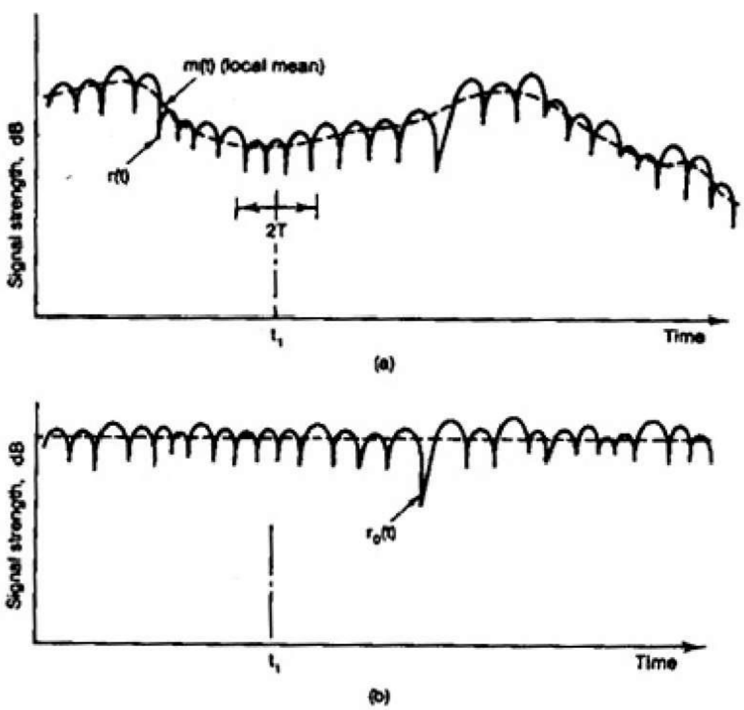


Fig.10 A mobile radio signal fading representation.

15. Explain about planning of cellular system in detail. Answer:

How to start planning: Assume that the construction permit for a cellular system in a particular market area is granted, the planning stage becomes critical. A great deal of money can be spent and yet poor service may be provided if we do not know how to create a good plan. First, we have to determine two elements: regulations and the market situation.

Regulations: The federal regulations administered by the FCC are the same throughout the United States. The state regulations may be different from state to state, and each city and town may have its own building codes and zoning laws. Become familiar with the rules and regulations. Sometimes waivers need to be applied for ahead of time. Be sure that the plan is workable.

Market situation: There are three tasks to be handled by the marketing department.

1. Prediction of gross income: We have to determine the population, average income, business types, and business zones so that the gross income can be predicted.
2. Understanding competitors: We also need to know the competitor's situation, coverage, system performance, and number of customers. Any system should provide a unique and outstanding service to overcome the competition.
3. Decision of geographic coverage: What general area should ultimately be covered? What near-term service can be provided in a limited area? These questions should be answered and the decisions passed on to the engineering department.

The engineer's role: The engineers follow the market decisions by

1. Initiating a cellular mobile service in a given area by creating a plan that uses a minimum number of cell sites to cover the whole area. It is easy for marketing to request but hard for the engineers to fulfill.
2. Checking the areas that marketing indicated were important revenue areas. The number of radios (number of voice channels) required to handle the traffic load at the busy hours should be determined.

3. Studying the interference problems, such as co-channel and adjacent channel interference, and the inter modulation products gene rated at the cell sites, and finding ways to reduce them.
4. Studying the blocking probability of each call at each cell site, and trying to minimize it.
5. Planning to absorb more new customers. The rate at which new customers subscribe to a system can vary depending on the service charges, system performance, and seasons of the year. Engineering has to try to develop new technologies to utilize fully the limited spectrum assigned to the cellular system. The analysis of spectrum efficiency due to the natural limitations may lead to a request for a larger spectrum.

Unit II: Tutorial Class

- Cell splitting
- handoff mechanisms
- Switching equipments

UNIT-II

1. Explain the concept of frequency reuse channels. Answer:

Concept of Frequency Reuse Channels: A radio channel consists of a pair of frequencies one for each direction of transmission that is used for full-duplex operation. Particular radio channels, say F1, used in one geographic zone to call a cell, say C1, with a coverage radius R can be used in another cell with the same coverage radius at a distance D away.

Frequency reuse is the core concept of the cellular mobile radio system. In this frequency reuse system users in different geographic locations (different cells) may simultaneously use the same frequency channel (see Fig.1.). The frequency reuse system can drastically increase the spectrum efficiency, but if the system is not properly designed, serious interference may occur. Interference due to the common use of the same channel is called co-channel interference and is our major concern in the concept of frequency reuse.

C,

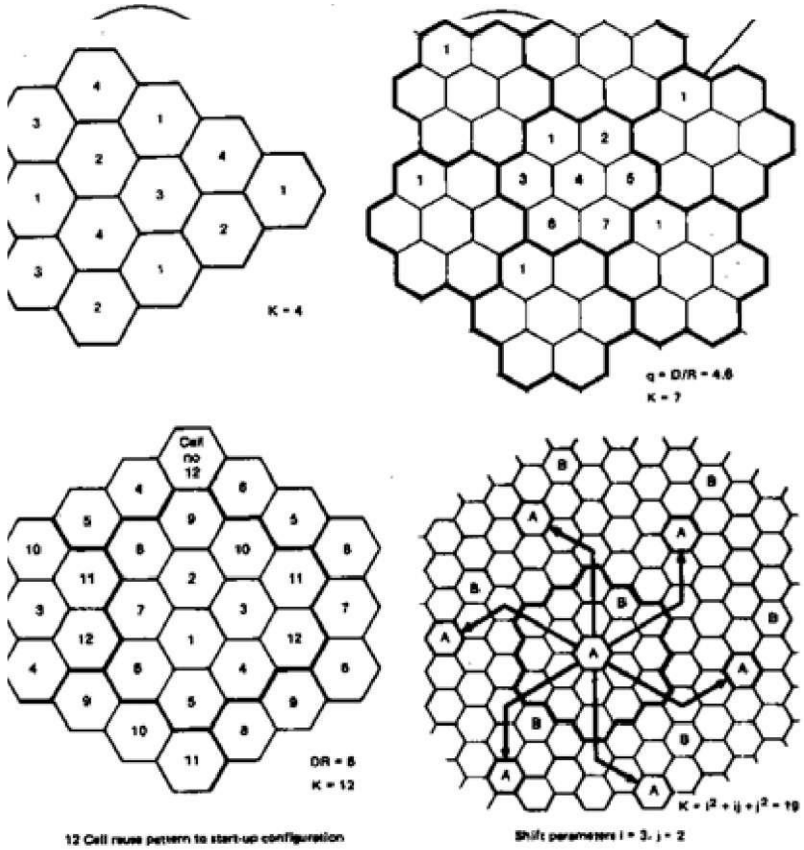


Fig.2 N- cell reuse pattern

Frequency reuse scheme: The frequency reuse concept can be used in the time domain and the space domain. Frequency reuse in the time domain results in the occupation of the same frequency in different time slots. It is called time division multiplexing (TDM). Frequency reuse in the space domain can be divided into two categories.

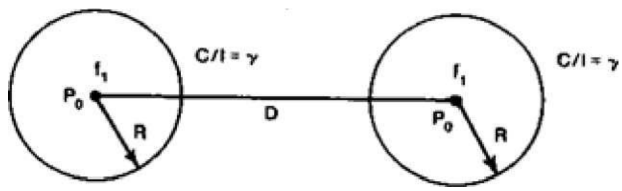
1. Same frequency assigned in two different geographic areas, such as A.M or FM radio stations using the same frequency in different cities.
2. Same frequency repeatedly used in a same general area in one system - the scheme is used in cellular systems. There are many co-channel cells in the system. The total frequency spectrum allocation is divided into K frequency reuse patterns, as illustrated in Fig. 2 for K — 4, 7, 12, and 19.

2. Explain the frequency reuse distance in cellular radio system. Answer:

Frequency reuse distance: The minimum distance which allows the same frequency to be reused will depend on many factors, such as the number of co-channel cells in the vicinity of the center cell, the type of geographical terrain contour, the antenna height and the transmitted power at each cell site. The frequency reuse distance can be determined from

Where K is the frequency reuse pattern shown in Fig.3, then

C,



q - DJ H

Fig.3.The ratio of D/R

If all the cell sites transmit the same power, then K increases and the frequency reuse distance D increases. This increased D reduces the chance that cochannel interference may occur. Theoretically, a large K is desired. However, the total number of allocated channels is fixed. When K is too large, the number of channels assigned to each of K cells becomes small. It is always true that if the total number of channels in K cells is divided as K increases, trunking inefficiency results. The same principle applies to spectrum inefficiency: if the total numbers of channels are divided into two network systems serving in the same area, spectrum inefficiency increases.

Obtaining the smallest number K involves estimating cochannel interference and selecting the minimum frequency reuse distance D to reduce cochannel interference. The smallest value of K is K = 3, obtained by setting i = 1, j = 1 in the equation.

3. Explain the hand-off mechanism. Answer:

Hand-off Mechanism: Hand-off is the process of automatically changing the frequencies. When the mobile unit moves out of the coverage areas of a particular cell site, the reception becomes weak. At this instant the present cell site requests Hand-off, then system switches the call to a new frequency channel in a new cell site without interrupting either call or user. This phenomenon is known as "hand -off' or 'handover'. Hand -off processing scheme is an important task for any successful mobile system. This concept can he applied to one dimensional as well as two dimensional cellular configurations. By the reception of weak signals from the mobile unit by the cell site, the Hand-off is required in the following two situations. They are

1. The level for requesting a Hand-off in a noise limited environment is at the cell boundary say-l00 dBm.
2. In a particular cell site, when the mobile unit is reaching the signal strength holes (gaps).

Figure 4 shows the usage of frequency F1 in two cochannel cells which arc separated by a distance D. Now, we have to provide a communication system in the whole area by filling other frequency channels F2,F3 and F4 between two co-channel cells.

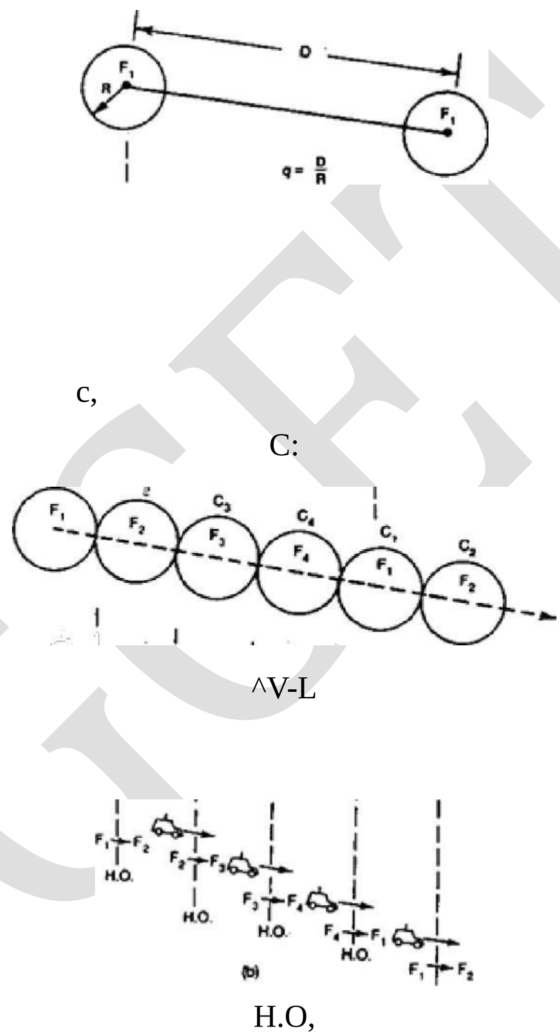


Fig.4 (a). cochannel interference reduction ratio 2, (b) fill in frequency

Depending on the same value of q the cells C2 ,C3 and C4 to which the above fill-in frequencies F2, F3 and F4 are assigned respectively as shown in figure.

Initially a mobile unit is starting a call in cell with fill-in frequency F1 and then moves to a cell with fill- in frequency F2. The mobile unit moves from cell C1 to cell C2, meanwhile however the call being dropped and reinitiated in the frequency channel from F1 to F2. This process of changing frequencies can be done automatically by the system without the user's intervention. In the cellular system the above mentioned Hand-off process is used.

4. Explain the cochannel interference reduction factor. Answer:

Reusing an identical frequency channel in different cells is limited by cochannel interference between cells, and the cochannel interference can become a major problem.

Assume that the size of all cells is roughly the same. The cell size is determined by the coverage area of the signal strength in each cell. As long as the cell size is fixed, cochannel interference is independent of the transmitted power of each cell. It means that the received threshold level at the mobile unit is adjusted to the size of the cell. Actually, cochannel interference is a function of a parameter q defined as

$$q = D/R$$

The parameter q is the cochannel interference reduction factor. When the ratio q increases, cochannel interference decreases. Furthermore, the separation D is a function of K, and C/I,

$$D=f(K,C/I)$$

Where K, is the number of cochannel interfering cells in the first tier and C/I is the received carrier-to- interference ratio at the desired mobile receiver.

In a fully equipped hexagonal-shaped cellular system, there are always six cochannel interfering cells in the fist tier, as shown in Fig.5 ; that is, K = 6. The maximum number of K, in the first tier can be shown as six. Cochannel interference can be experienced both at the cell site and at mobile units in the center cell. If the interference is much greater, then the carrier-to-interference ratio C/I at the mobile units caused by the six interfering sites is (on the average) the same as the C/I received at the center cell site caused by interfering mobile units in the six cells. According to both the reciprocity theorem and the statistical summation of radio propagation, the two C/I values can be very close. Assume that the local noise is much less than the interference level and can be neglected. C/I then can be expressed as

$$\frac{C}{I} = \frac{1}{\sum_{k=1}^{K_I} \left(\frac{D_k}{R}\right)^{-\gamma}} = \frac{1}{\sum_{k=1}^{K_I} (q_k)^{-\gamma}}$$

Where q_k is the cochannel interference reduction factor with *Kth* cochannel interfering cell

$$q_k = \frac{D_k}{R}$$

$$\frac{C}{I} = \frac{R^{-\gamma}}{\sum_{k=1}^{K_I} D_k^{-\gamma}}$$

Where ^ is a propagation path-loss slope determined by the actual terrain environment. In a mobile radio medium, ^ usually is assumed to be 4. K is the number of cochannel interfering cells and is equal to 6 in a fully developed system, as shown in Fig. 5. The six cochannel interfering cells in the second tier cause weaker interference than those in the first tier. Therefore, the cochannel interference from the second tier of interfering cells is negligible

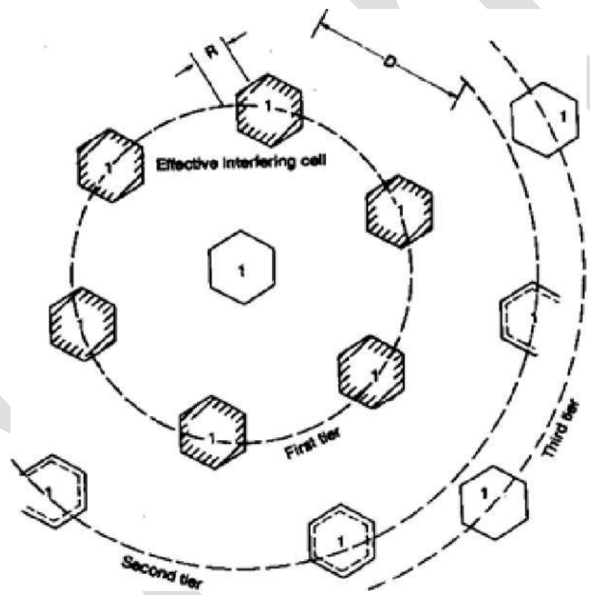


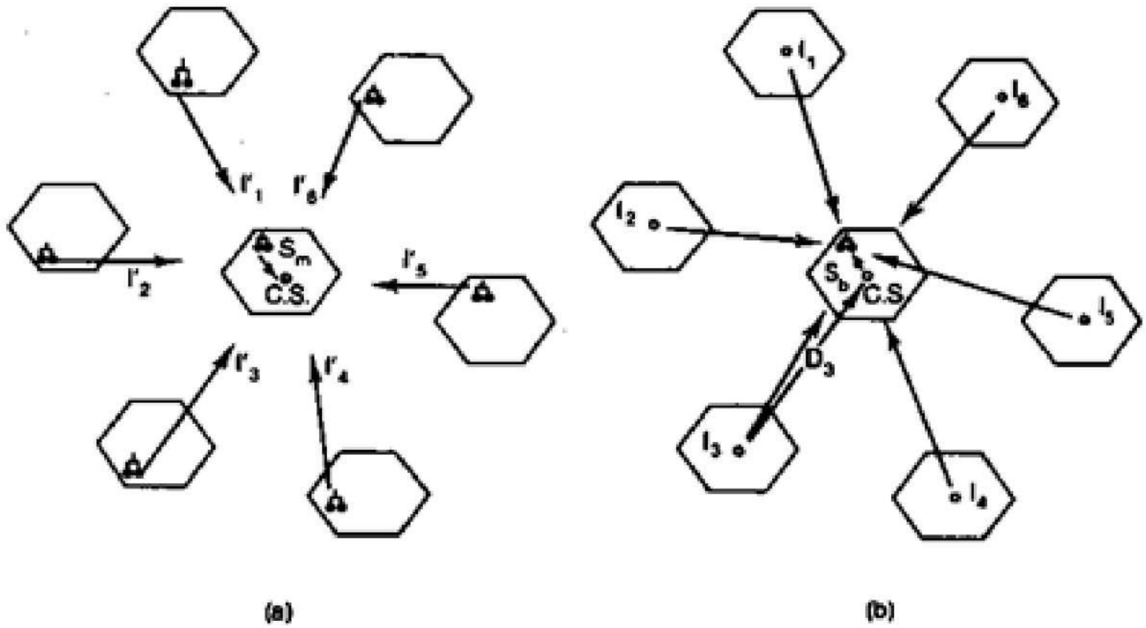
Fig 5 Six effective interfering cells of cell 1

5. Derive the C/I for normal case in an omnidirectional antenna system. Answer:

There are two cases to be considered: (1) the signal and cochannel interference received by the mobile unit and (2) the signal and cochannel interference received by the cell site. Both cases are shown in Fig.6. Nm and Nb are the local noises at the mobile unit and the cell site, respectively. Usually Nm and Nb are small and can be neglected as compared with the interference level. As long as the received carrier-to- interference ratios at both the mobile unit and the cell site are the same, the system is called a balanced system. In a balanced system, we can choose either one of the two cases to analyze the system requirement; the results from one case are the same for the others. Assume that all Dk are the same for simplicity, then D = Dk and q = qk,

The value of C/I is based on the required system performance and the specified value of is based on the terrain environment. With given values of C/I and ^ , the cochannel interference reduction factor q can be determined. Normal cellular practice is to specify C/I to be 18 dB or higher based on subjective tests. Since a C/I of 18 dB is measured by the acceptance of voice quality from present cellular mobile receivers, this acceptance implies that both mobile radio multipath fading and cochannel interference become ineffective at that level. The path-loss slope is equal to about 4 in a mobile radio environment.

The 90th percentile of the total covered area would each cell; increasing the same amount of transmitted because q is not a function of transmitted power.



r'1
r'6
r'2
Sm
C.S.
r'5
r'3
r'4
(a)
I1
I6
I2
Sb
C.S.
I5
D3
I3
I4
(b)

Fig 6 Cochannel interference from six interferers. (a).receiving at the cell site; (b) receiving at the mobile unit.

6. Draw the general view of telecommunication and explain the function of the each unit? Answer:

The components of cellular systems are mobile radios, antennas, cell-site controller, and MTSO. They would affect the system design if they are not chosen rightly. The general view of the cellular system is shown in Fig.7. The issues affecting choice of antennas, switching equipment, and data links are briefly described.

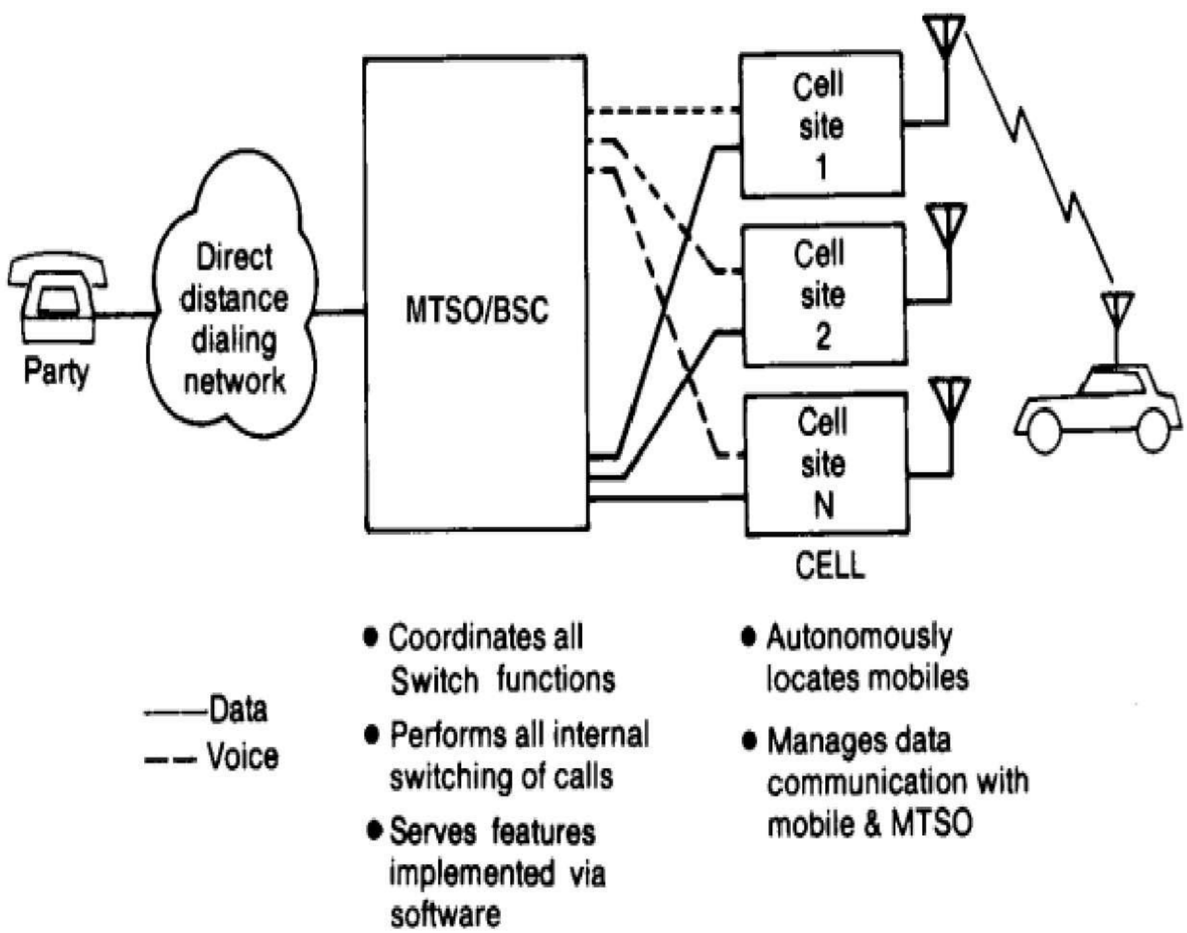


Fig.7. A general view of cellular telecommunications system

Antenna: Antenna pattern, antenna gain, antenna tilting, and antenna height 6 all affect the cellular system design. The antenna pattern can be omnidirectional, directional, or any shape in both the vertical and the horizon planes. Antenna gain compensates for the transmitted power. Different antenna patterns and antenna gains at the cell site and at the mobile units would affect the system performance and so must be considered in the system design. The antenna patterns seen in cellular systems are different from the patterns seen in free space. If a mobile unit travels around a cell site in areas with many buildings, the omnidirectional antenna will not duplicate the omnipattern. In addition, if the front-to-back ratio of a directional antenna is found to be 20 dB in free space, it will be only 10 dB at the cell site. Antenna tilting can reduce the interference to the neighboring cells and enhance the weak spots in the cell. Also, the height of the cell-site antenna can affect the area and shape of the coverage in the system.

Switching Equipment: The capacity of switching equipment in cellular systems is not based on the number of switch ports but on the capacity of the processor associated with the switches. In a big cellular system, this processor should be large. Also, because cellular systems are unlike other systems, it is important to consider when the switching equipment would reach the maximum capacity. The service life of the switching equipment is not determined by the life cycle of the equipment but by how long it takes to reach its full capacity. If the switching equipment is designed in modules, or as distributed switches, more modules can be added to increase the capacity of the equipment. For decentralized systems, digital switches may be more suitable. The future trend seems to be the utilization of system handoff. This means that switching equipment can link to other switching equipment so that a call can be carried from one system to another system without the call being dropped.

Data Links: The data links are shown in Fig 7. Although they are not directly affected by the cellular system, they are important in the system. Each data link can carry multiple channel data (10 kbps data transmitted per channel) from the cell site to the MTSO. This fast-speed data transmission cannot be passed through a regular telephone line. Therefore, data bank devices are needed. They can be multiplexed, many-data channels passing through a wideband T-carrier wire line or going through a microwave radio link where the frequency is much higher than 850 MHz. Leasing T1-carrier wire lines through telephone companies can be costly. Although the use of microwaves may be a long-term money saver, the availability of the microwave link has to be considered.

7. What is the need of splitting and explain the cell splitting. Answer:

The motivation behind implementing a cellular mobile system is to improve the utilization of spectrum efficiency. The frequency reuse scheme is one concept, and cell splitting is another concept. When traffic density starts to build up and the frequency channels Fi in each cell Ci cannot provide enough mobile calls, the original cell can be split into smaller cells. Usually the new radius is one-half the original radius. There are two ways of splitting: In Fig. 8 a, the original cell site is not used, while in Fig. 8 b, it is

New cell radius = Old cell radius/2

Then,

New cell area = Old cell area/4 Let each new cell carry the same maximum traffic load of the old cell, then

New traffic load/Unit area = 4 X Traffic load/Unit area.

There are two kinds of cell-splitting techniques:

1. **Permanent splitting:** The installation of every new split cell has to be planned ahead of time; the number of channels, the transmitted power, the assigned frequencies, the choosing of the cell-site selection, and the traffic load consideration should all be considered. When ready, the actual service cutover should be set at the lowest traffic point, usually at midnight on a weekend. Hopefully, only a few calls will be dropped because of this cut-over, assuming that the downtime of the system is within 2 h.

2. **Dynamic splitting:** This scheme is based on using the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a tedious job, as we cannot afford to have one single cell unused during cell splitting at heavy traffic hours.

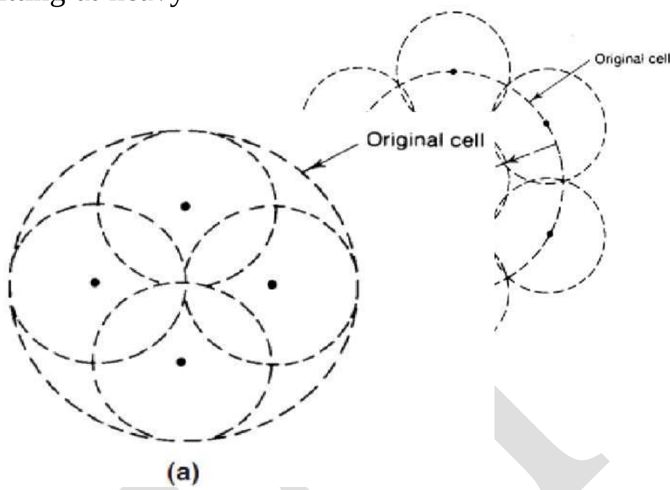


Fig.8 Cell splitting

8. Write about maximum number of frequency channels per cell. Answer:

The maximum number of frequency channels per cell N is closely related to an average calling time in the system. The standard user's calling habits may change as a result of the charging rate of the system and the general income profile of the users If an average calling time T is 1.76 min and the maximum calls per hour per cell is Qi, then the offered load can be derived as A = Qi*T/60 (Erlangs)

If the blocking probability is given, then it is easy to find the required number of radios in each cell. If a large area is covered by 28 cells, Kt = 28; the total number of customers in the system increases. Therefore, we may assume that the number of subscribers per cell Mi is somehow related to the percentage of car phones used in the busy hours and the number of calls per hour per cell Qi as

$$w, = m, ti_c)$$

Where the value Qi is a function of the blocking probability B, the average calling time T, and the number of channels N.

$$Qi= f(B, T, N)$$

If the K = 7 frequency reuse pattern is used, the total number of required channels in the system is Nt = 7 X N.

9. Explain the importance of Answer:

For hexagonal cells i.e. with "honeycomb" cell layouts commonly used in mobile radio with possible cluster sizes are

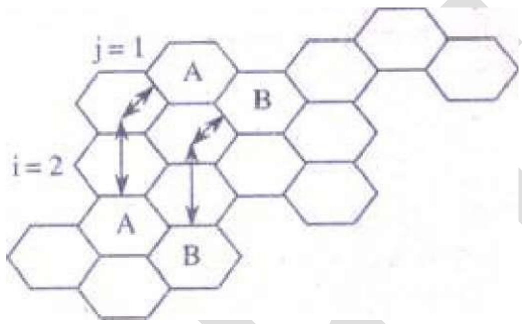
Where i, j — Non negative integers

The integers i, j determine the relative location of co channels. The main reason for obtaining the above expression is to calculate the smallest number K which can still meet our system performance requirements. This process involves estimating co-channel interference and selecting the minimum frequency reuse distance D to reduce cochannel interference. Thus, the smallest possible value for K is 3, obtained by putting i=1,j=1 in above eq.

The nearest co-channel neighbors of a particular cell can be obtained by the following two steps

(i) Moving i cells along any chain of hexagons.
(ii) Turn 60 degrees counter-clockwise and move j cells.

The method of locating co channel cells in a 7-cell reuse pattern with i=2 and j=1 is shown figure



Unit III: Tutorial Class

- Co-Channel Interference
- Non-Co-Channel Interference-different types
- Diversity receiver

UNIT-III

1. Define cochannel interference. How is it measured at the mobile unit and cell site? Answer:

Cochannel Interference: The frequency-re method is useful for increasing the efficiency of spectrum usage but results in cochannel interference because the same frequency channel is used repeatedly in different cochannel cells. Application of the cochannel interference reduction factor q= D/R = 4.6 for a seven-cell reuse pattern (K = 7). In most mobile radio environments, use of a seven-cell reuse pattern is not sufficient to avoid cochannel interference. Increasing K > 7 would reduce the number of channels per cell, and that would also reduce spectrum efficiency. Therefore, it might be advisable to retain the same number of radios as the seven-cell system but to sector the cell radially, as if slicing a pie. This technique would reduce cochannel interference and use channel sharing and channel borrowing schemes to increase spectrum efficiency.

When customer demand increases, the channels which are limited in number, have to be repeatedly reused in different areas, which provides many cochannel cells, which increases the system's capacity. But cochannel interference may be the result, in this situation the received voice quality is affected by both the grade of coverage and the amount of cochannel interference. For detection of serious channel interference areas in a cellular system, two tests are suggested.

Test 1—find the cochannel interference area from a mobile receiver:

Cochannel interference which occurs in one channel will occur equally in all the other channels in a given area. We can then measure cochannel interference by selecting any one channel (as one channel represents all the channels) and transmitting on that channel at all cochannel sites at night while the mobile receiver is traveling in one of the cochannel cells. While performing this test we watch for any change detected by a field-strength recorder in the mobile unit and compare the data with the condition of no cochannel sites being transmitted. This test must be repeated as the mobile unit travels in every cochannel cell. To facilitate this test, we can install a channel scanning receiver in one car. One channel (f1) records the signal level (no- cochannel condition), another channel (f2) records the interference level (six-cochannel condition is the maximum), while the third channel receives f, which is not in use. Therefore the noise level is recorded only in f3.

We can obtain, in decibels, the carrier to interference ratio C/I by subtracting the result obtained from f2 from the result obtained from f1 (carrier minus interference C - I) and the carrier-to- noise ratio C/N by subtracting the result obtained from f3 from the result obtained from f2 (carrier minus noise C — N). Four conditions should be used to compare the results.

1. If the carrier-to-interference ratio C / I is greater than 18 dB throughout most of the cell, the system is properly designed.

2. If C/I is less than 18 dB and C/N is greater than 18 dB in some areas, there is cochannel interference

3. If both C/N and C/I are less than 18 dB and C/N =C/I in a given area, there is a coverage problem.

4. If both C/N and C/I are less than 18 dB and C/N> C/I in a given area, there is a coverage problem and cochannel interference.

1

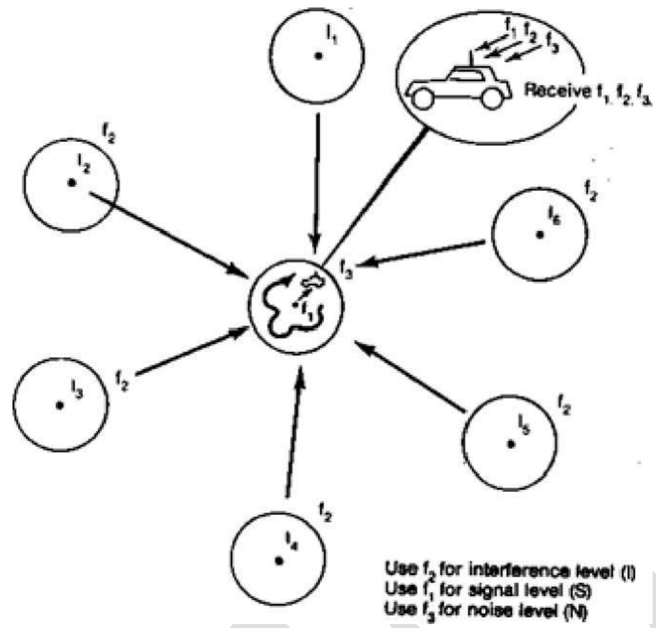


Fig.1 Test -1 cochannel interference at mobile unit.

Test 2—find the cochannel interference area which affects a cell site:

The reciprocity theorem can be applied for the coverage problem but not for cochannel interference. Therefore, we cannot assume that the first test result will apply to the second test condition. We must perform the second test as well. Because it is difficult to use seven cars simultaneously, with each car traveling in each cochannel cell for this test, an alternative app roach may be to record the signal strength at every cochannel cell site while a mobile unit is traveling either in its own cell or in one of the cochannel cells shown in Fig. 1.2.

First we find the areas in an interfering cell in which the top 10 percent level of the signal transmitted from the mobile unit in those areas is received at the desired site (Jth cell in Fig. 1.1). This top 10 percent level can be distributed in different areas in a cell. The average value of the top 10 percent level signal strength is used as the interference level from that particular interfering cell. The mobile unit also travels in different interfering cells. Up to six interference levels are obtained from a mobile unit running in six interfering cells. We then calculate the average of the bottom 10 percent level of the signal strength which is transmitted from a mobile unit in the desired cell (Jth cell) and received at the desired cell site as a carrier reception level.

Then we can reestablish the carrier-to-interference ratio received at a desired cell, say, the Jth cell site as follows.

The number of cochannel cells in the system can be less than six. We must be aware that all Cj and Ii were read in decibels, Therefore, a translation from decibels to linear is needed before summing all the interfering sources. The test can be carried out repeatedly for any given cell. We then compare

$$C_j/I \text{ and } C_j/N$$

and determine the cochannel interference condition, which will be the same as that in test 1. Nj is the noise level in the Jth cell assuming no interference exists,

3. Explain the designing of an omnidirectional antenna system in the worst case scenario.

Answer:

Design of an Omnidirectional Antenna System in the Worst Case: **The value of q = 4.6 is**

valid for a normal interference case in a K=7 cell pattern. In this section we would like to prove that a K=7 cell pattern does not provide a sufficient frequency re-use distance separation eyen when an ideal condition of flat terrain is assumed. The worst case is at the location where the weakest signal from its own cell site but strong interferences from all interfering cell sites. In the worst case the mobile unit is at the cell boundary R, as shown in Fig. 3. The distances from all six cochannel interfering sites are also shown in the figure: two distances of D - R, two distances of D, and two distances of D + R.

Following the mobile radio propagation rule of 40 dB/dec, we obtain

$$C*Fr^4 \quad It- D *$$

Then the carrier-to-interference ratio is

$$\frac{C}{I} = \frac{R^{-4}}{2(D - R)^{-4} + 2(D)^{-4} + 2(D + R)^{-4}}$$

$$= \frac{1}{2(q - 1)^{-4} + 2(q)^{-4} + 2(q + 1)^{-4}}$$

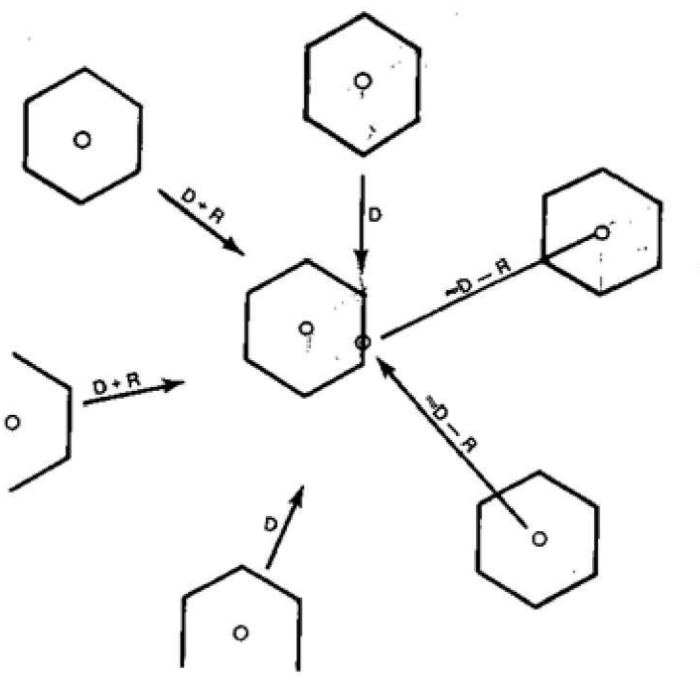


Fig.3. Cochannel interference (a worst case)

Where q=4.6 is derived from the normal case. Substituting q=4.6 into above eqn. we obtain C/I =54 or 17 dB, which is lower than 18 dB. To be conservative, we may use the shortest distance D - R for all six interferers as a worst case; then we have

$$\frac{C}{I} = \frac{R^{-4}}{6(D - R)^{-4}} = \frac{1}{6(q - 1)^{-4}} = 28 = 14.47 \text{ dB}$$

In reality, because of the imperfect site locations and the rolling nature of the terrain configuration, the C/I received is always worse than 17 dB and could be 14 dB and lower. Such an instance can easily our in a heavy traffic situation; therefore, the system must be designed

Therefore, in an omnidirectional-cell system, K = 9 or K 12 would be a correct choice. Then the values of q are

$$q = \begin{cases} \frac{D}{R} = \sqrt{3K} \\ 5.2 & K = 9 \\ 6 & K = 12 \end{cases}$$

Substituting these values in Eq. (6.4-1), we obtain

$$\frac{C}{I} = 84.5 \ (=) \ 19.25 \text{ dB} \qquad K = 9$$

$$\frac{C}{I} = 179.33 \ (=) \ 22.54 \text{ dB} \qquad K = 12$$

4. Explain the designing of the directional antenna under the practical case conditions for K=4, K=7 and K=12 with all suitable values and explaining each of them.

Answer:

Design of a Directional Antenna System: When the call traffic begins to increase, we need to use the frequency spectrum efficiently and avoid increasing the number of cells K in a seven-cell frequency reuse pattern. When K increases, the number of frequency channels assigned in a cell must become smaller (assuming a total allocated channel divided by K) and the efficiency of applying the frequency reuse scheme decrease.

Instead of increasing the number K in a set of cells, let us keep K =7 and introduce a directional antenna arrangement. The cochannel interference can be reduced by using directional antenna. This means that each cell is divided into three or six sectors and uses three or six directional antennas at a base station. Each sector is assigned a set of frequencies (channels). The interference between two cochannel cells decreases as shown Fig.4.2

Directional antennas in K=7 cell patterns:

Three sector case: The three-sector case is shown in Fig.4.2. To illustrate the worst case situation, two cochannel cells are shown in Fig. 4.3(a). The mobile unit at position E will experience greater interference in the lower shaded cell sector than in the upper shaded cell- sector site. This is because the mobile receiver receives the weakest signal from its own cell but fairly strong interference from the interfering cell.

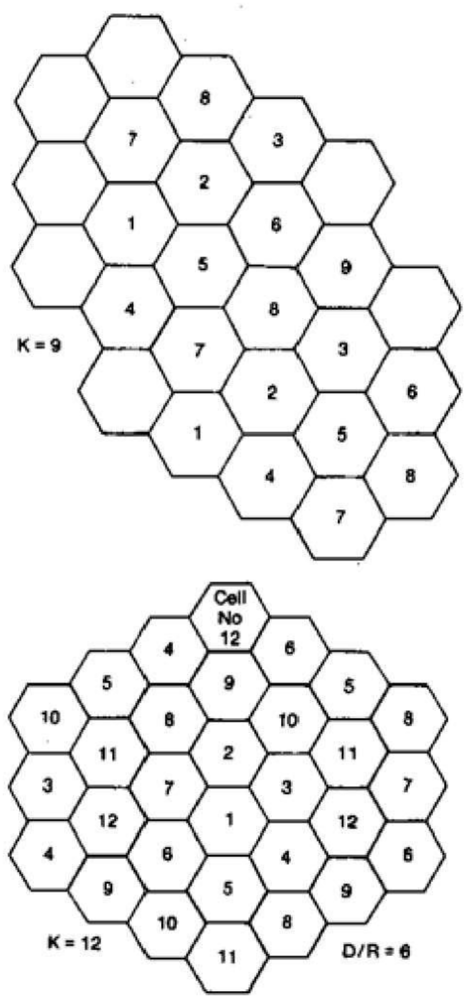


Fig.4.1 Interference with frequency-reuse patterns K=7 and K=12.

In a three-sector case, the interference is effective in only one direction because the front-to-back ratio of a cell-site directional antenna is at least 10 dB or more in a mobile radio environment. The worst-case cochannel interference in the directional-antenna sectors in which interference occurs may be calculated. Because of the use of directional antennas, the number of principal interferers is reduced from six to two (Fig.4.2). The worst case of C/I occurs when the mobile unit is at position E, at which point the distance between the mobile unit and the two interfering antennas is roughly D + (R/2); however, C/I can be calculated more precisely as follows. The value of C/I can be obtained by the following expression (assuming that the worst case is at position E at which the distances from two interferers are D + 0.7R and D).

$$\frac{C}{I}\text{(worst case)} = \frac{R^{-4}}{(D + 0.7R)^{-4} + D^{-4}}$$

$$= \frac{1}{(q + 0.7)^{-4} + q^{-4}}$$

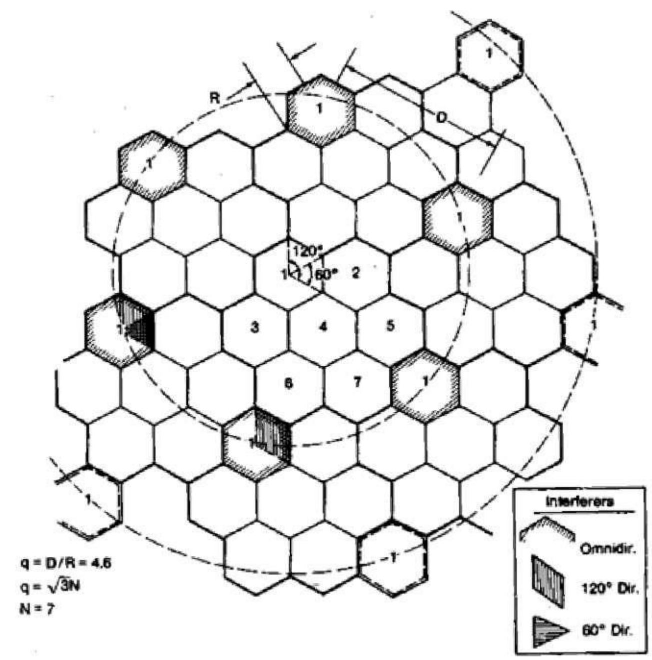
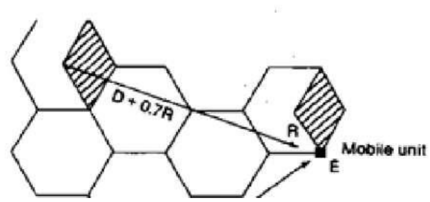
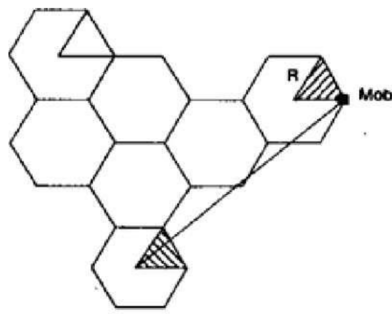


Fig.4.2.Interfering cells shown in a seven cell system (two-tiers)





(b)

Fig.4.3. Determination of C/I in a directional antenna system. (a)Worst case in a 120 directional antenna system(N=7); (b) worst case in a 60 directional antenna system(N=7).

The C/I received by a mobile unit from the 120° directional antenna sector system expressed in Eq. above greatly exceeds 18 dB in a worst case. Equation above shows that using directional antenna sectors can improve the signal-to-interference ratio, that is, reduce the cochannel interference. However, in reality, the C/I could be 6 dB weaker than in Eq. given above in a heavy traffic area as a result of irregular terrain contour and imperfect site locations. The remaining 18.5 dB is still adequate.

Six-sector case: We may also divide a cell into six sectors by using six 60°-beam directional antennas as shown in Fig.4.2. In this case, only one instance of interference can occur in each sector as shown in Fig, 4.2. Therefore, the carrier-to-interference ratio in this case is which shows a further reduction of cochannel interference. If we use the same argument as we did for Eq. above and subtract 6 dB from the result of Eq. the remaining 23 dB is still more than adequate. When heavy traffic occurs, the 60°-sector configuration can be used to reduce cochannel interference. However, fewer channels are generally allowed in a 60° sector and the trunking efficiency decreases. In certain cases, more available channels could be assigned in a 60° sector.

Directional antenna in K = 4 cell pattern:

Three-sector case: To obtain the carrier-to-interference ratio, we use the same procedure as in the K = 7 cell-pattern system. The 120° directional antennas used in the sectors reduced the interferers to two as in K = 7 systems, as shown in Fig.4.4. We can apply Eq. here. For K = 4, the value of q = 3.46; therefore, Eq. becomes

$$\frac{C}{I}\text{ (worst case)} = \frac{1}{(q+0.7)^{-4} + q^{-4}} = 97 = 20\text{ dB}$$

If, using the same reasoning used with Eq. above, 6 dB is subtracted from the result of Eq. above, the remaining 14 dB is unacceptable.

Six-sector case: There is only one interferer at a distance of D + R shown in Fig.4.4. With q=3.46, we can obtain

If 6 dB is subtracted from the above result, the remaining 20 dB is adequate.

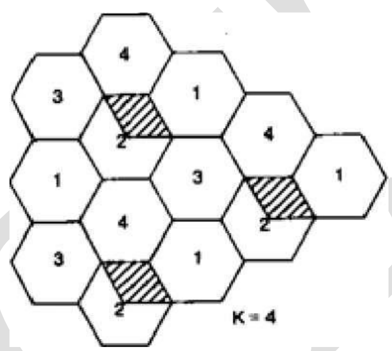


Fig. 4.4 Interference with frequency reuse pattern K=4.

Under heavy traffic conditions, there is still a great deal of concern over using a K =4 cell pattern in a 60° sector.

Comparing K =7 and N =4 systems:

A K =7 cell pattern system is a logical way to begin an omnicell system. The co-channel reuse distance is more or less adequate, according to the designed criterion. When the traffic increases, a three sector system should be implemented, that is, with three 120° directional antennas in place. In certain hot spots, 60° sectors can be used locally to increase the channel utilization.

If a given area is covered by both K=7 and K=4 cell patterns and both patterns have a six-sector configuration, then the K=7 system has a total of 42 sectors, but the K=4 system has a total of only 24 sectors and, of course, the system of K=7 and six sectors has less cochannel interference.

One advantage of 60° sectors with K=4 is that they require fewer cell sites than 120 sectors with K=7. Two disadvantages of 60 deg sectors are that (1) they require more antennas to he mounted on the antenna mast and (2) they often require more frequent handoffs because of the increased chance that the mobile units will travel across the six sectors of the call. Furthermore, assigning the proper frequency channel to the mobile unit in each sector is more difficult unless the antenna height at the cell site is increased so that the mobile unit can be located more precisely. In reality the terrain is not flat, end coverage is never uniformly distributed; in addition, the directional antenna front-to-back power ratio in the field is very difficult to predict. In small cells, interference could become uncontrollable; then the use of a K = 4 pattern with 60 deg sectors in small cells needs to be considered only for special implementations such an portable cellular systems or narrow beam applications. For small cells, a better alternative scheme is to use a K =7 pattern with 120° sectors plus the underlay-overlay configuration.

5. Explain the concept of lowering the antenna height to decrease the co-channel interference.

Answer:

Lowering the Antenna Height: Lowering the antenna height does not always reduce the co- channel interference. In some circumstances, such as on fairly flat ground or in a valley situation, lowering the antenna height will be very effective for reducing the cochannel and adjacent- channel interference, However, there are three cases where lowering the antenna height may or may not effectively help reduce the interference.

On a high hill or a high spot: The effective antenna height, rather than the actual height, is always considered in the system design. Therefore, the effective antenna height varies according to the location of the mobile unit. When the antenna site is on a bill, as shown in Fig. 5.1(a), the effective antenna height is hi + H.

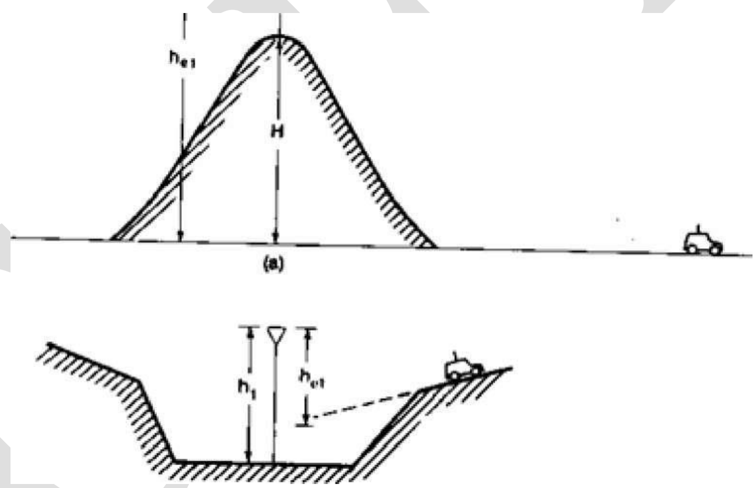


Fig. 5.1.Lowering the antenna height (a) on a high hill and (b) in a valley

If we reduce the actual antenna height to 0.5h1, the effective antenna height becomes 0.5h1 + H. The reduction in gain resulting from the height reduction is

$$G = \text{gain reduction} = 20 \log_{10} \frac{0.5h_1 + H}{h_1 + H}$$

$$= 20 \log_{10} \left(1 - \frac{0.5h_1}{h_1 + H}\right)$$

If h1<<H, then the above equation becomes

G *- 20 lf>g10 1 = 0 (IB*

This simply proves that lowering antenna height on the kill does not reduce the received power at either the cell site or the mobile unit.

In a valley: The effective antenna height as seen from the mobile unit shown in Fig. 5.1(b) is he1, which is less than the actual antenna height h1. If he1= 2/3 h1, and the antenna is lowered to h1, then the new effective antenna height is

Then the antenna gain is reduced by

Vih

O - 20 log —' - -12 dB

This simply proves that the lowered antenna height in a valley is very effective in reducing the radiated power in a distant high elevation area. However, in the area adjacent to the cell-site antenna the effective antenna height is the same as the actual antenna height. The power reduction caused by decreasing antenna height by half is only

Yih,

20 Jog —^ = -6 dB

In a forested area: In a forested area, the antenna should clear the tops of any trees in the vicinity, especially when they are very close to the antenna. In this case decreasing the height of the antenna would not be the proper procedure for reducing cochannel interference because excessive attenuation of the desired signal would occur in the vicinity of the antenna and in its cell boundary if the antenna were below the treetop level.

6. Write a note on power control.

Answer:

Power Control: The power level can be controlled only by the mobile transmitting switching office (MTSO), not by the mobile units, and there can be only limited power control by the cell sites as a result of system limitations.

The reasons are as follows. The mobile transmitted power level assignment must be controlled by the MTSO or the cell site, not the mobile unit or, alternatively, the mobile unit can lower the power level but cannot arbitrarily increase it. This is because the MTSO is capable of monitoring the performance of the whole system and can increase or decrease the transmitted power level of those mobile units to render optimum performance. The MTSO will not optimize performance for any particular mobile unit unless a special arrangement is made.

Function of the MTSO: The MTSO controls the transmitted power levels at both the cell sites and the mobile units. The advantages of having the MSTO control the power levels are described here.

1. Control of the mobile transmitted power level. When the mobile unit is approaching the cell site, the mobile unit power level should be reduced for the following reasons.

a) Reducing the chance of generating inter-modulation products from a saturated receiving amplifier.
b) Lowering the power level is equivalent to reducing the chance of interfering with other cochannel cell sites.
c) Reducing the near-end-far-end interference ratio.

Reducing the power level if possible is always the best strategy.

2. Control of the cell-site transmitted power level. When the signal received from the mobile unit at the cell site is very strong, the MTSO should reduce the transmitted power level of that particular radio at the cell site and, at the same time, lower the transmitted power level at the mobile unit. The advantages are as follows.

a) For a particular radio channel, the cell size decreases significantly, the cochannel reuse distance increases, and the cochannel interference reduces further. In other words, cell size and cochannel interference are inversely proportional to cochannel reuse distance.

b) The adjacent channel interference in the system is also reduced. However, in most cellular systems, it is not possible to reduce only one or a few channel power levels at the cell site because of the design limitation of the combiner. The channel isolation in the combiner is 18 dB. If the transmitted power level of one channel is lower, the channels having high transmitted power levels will interfere with this low-power channel. The manufacturer should design an unequal power combiner for the system operator so that the power level of each channel can be controlled at the cell site.

3. The power transmitted from a small cell is always reduced, and so is that from a mobile unit. The MTSO can facilitate adjustment of the transmitted power of the mobile units as soon as they enter the cell boundary.

7. Discuss the diversity schemes for interference reductions at both mobile unit and cell site.

Answer

Diversity Receiver: The diversity scheme applied at the receiving end of the antenna is an effective technique for reducing interference because any measures taken at the receiving end to improve signal performance will not cause additional interference. The diversity scheme is one of these approaches. We may use a selective combiner to combine two correlated signals as shown in Fig. 7.1. The performance of other kinds of combiners can be at most 2 dB better than that of selective combiners. However, the selective combining technique is the easiest scheme to use.

Figure 7 shows a family of curves representing this selective combination. Each curve has an associated correlation coefficient p; when using the diversity scheme, the optimum result is obtained when p = 0.

We have found that at the cell site the correlation coefficient p < 0.7 should be used for a two- branch space diversity; with this coefficient the separation of two antennas at the cell site meets the requirement of h / d= 11, where h is the antenna height and d is the antenna separation.

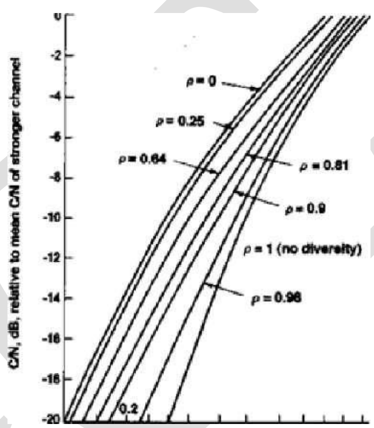


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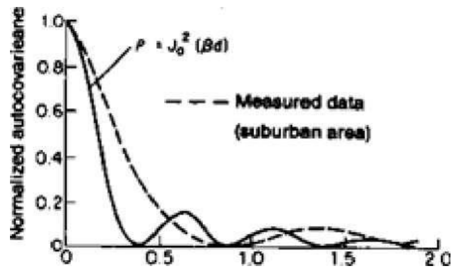
Fig. 7.1.Selective combining of two correlated signals

At the mobile unit we can use p =0, which implies that the two roof-mounted antennas of the mobile unit are 0.5 Lambda or more apart. This is verified by the measured data shown in Fig. 7.2. Now we may estimate the advantage of using diversity. First, let us assume a threshold level of 10 dB below the average power level.



dtt

Fig. 7.2 Autocorrelation coefficient versus spacing for uniform angular distribution (applied to diversity receiver)

Then compare the percent of signal below the threshold level both with and without a diversity scheme.

1. **At the mobile unit:** The comparison is between curves p = 0 and the p=1. The signal below the threshold level is 10 percent for no diversity and 1 percent for diversity. If the signal without diversity were 1 percent below the threshold, the power would be increased by 10 dB. In other words, if the diversity scheme is used, the power can be reduced by 10 dB and the same performance can be obtained as in the non diversity scheme. With 10 dB less power transmitted at the cell site, cochannel interference can be drastically reduced.

2. **At the cell site:** The comparison is between curves of p=0.7 and p =1. We use curve p=0.64 for a close approximation as shown in Fig. 7.1. The difference is 10 percent of the signal is below threshold level when a non diversity scheme is used versus 2 percent signal below threshold level when a diversity scheme is used. If the non diversity signal were 2 percent below the threshold, the power would have to increase by 7 dB (see Fig.7.1). Therefore, the mobile transmitter (for a cell-site diversity receiver) could undergo a 7dB reduction in power and attain the same performance as a non diversity receiver at the cell site. Thus, interference from the mobile transmitters to the receivers can be drastically reduced.

8. Explain different methods to reduce the co-channel interferences. Answer:

The different methods used to reduce co-channel interference are broadly classified into three. They

are

1. By providing large separation among the two co-channel cells.
2. By reducing the antenna heights at the base station.
3. By the usage of directional antennas at the base station.

The first two techniques ne not employed because they have disadvantageous effects i.e., method 1 is responsible for reducing the system efficiency for increase in number for frequency range channels. While method 2 is responsible for reducing the reception level at the mobile unit. The method 3 is most commonly used because, along with reducing co-channel interference, it also increases the channel capacity (during heavy traffic).

There are different techniques to generate directional antennas

1. Tilting the antenna and creating a notch along the unwanted space.
2. Using umbrella patterns.
3. Using parasitic elements.

1. Tilting the Antenna: The tilting of an antenna in a desired manner produces an energy pattern with a notch in the desired direction. Hence, ibis notch prevents the co-channel interference problem. The tilting of the antenna is done in two ways.

(1) Electrically
(ii)
Mechanically

In the electronic down tilting, the phases between the elements of a co-linear array antenna are varied. In the mechanical down tilting the physical rotation of antenna is occurred.

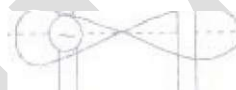
2. Umbrella Pattern: The umbrella pattern is obtained with the help of a staggered discone antenna. The umbrella pattern reduces the long distance co-channel interference problems, particularly cross talk. Even though, the umbrella pattern is not used for a directional antenna pattern, it can be used for an omnidirectional antenna pattern. In hilly areas, where the height of antenna cannot be increased to cover weak signal spots, results in co-channel interference. In this case also we can use umbrella pattern. The umbrella pattern allows us to increase the antenna height but, we can still decrease cochannel interference.

3. Parasitic Elements: The use of parasitic elements provides the desired pattern and hence we can avoid the cochannel interference. This antenna combination has a parasitic antenna and a driving antenna, the driving antenna is the source of current flowing in the parasitic antenna. The different combinations of their arrangements produce different patterns as described below.

When the lengths of the elements are identical and closely spaced the current flowing through the parasitic clement is strong. This creates equal level of patterns.

When the length of parasite is more than drive antenna, the parasite act as reflector and the pattern in the reflected direction is more.

When the length of parasite is less than drive antenna, the parasite acts as a director and the pattern is more inclined in the forward direction. These three patterns are illustrated in figure (a) figure (b) and figure (c) respectively.



9. Write notes on channel combiners.
Answer:

Channel Combiner:

1. A Fixed Tuned Channel Combiner: At the travelling side, a fixed tunable combined unit is used. In every cell site, a channel combiner circuit is installed. The transmitted channels have to be combined based on the following two criteria,

a) The signal isolation between the radio channels must be maximum
b) The insertion loss should be minimum. However, the usage of channel combiner can be avoided by feeding each channel to its corresponding antenna.

But, if there are I6 channels available in a cell site, there will be requirement of 16 antennas for operation which is bottle neck for real time functionalities. It is not economical to hive huge hardware setups. Thus, a conventional combiner can he used, which has 16 channel combining capacity and it is based on the frequency subset of 16 channels of cell site.

The channel combiner would be responsible for each of the 16 channels to exhibit a 3 dB loss due to the signal insertion in to the channel combiner. The signal isolation would be 17dB, if every channel is separated from its neighboring channels by 630 kHz frequency.

2. Tunable Combiner: Tunable combiner is also referred as frequency agile combiner. The frequency agile combiner is an advanced combiner circuit with additional features. It can return any frequency in real time by remote control device, namely microprocessor. This combiner is essentially a waveguide resonator with a tuning bar facility. A motor makes the tuning bar to rotate and once the motor starts rotating, the Voltage Standing Wave Ratio (VSWR) can be measured.

The controller unit has self-adjusting feature and it accepts an optimum value of VSWR as the motor complete, a full turn. The controller is compatible only with dynamic frequency assignment.

The cell-sites should be flexible to change their operating frequency 'f that is controlled by MTSO/MSC. Thus, we can use this frequency agile combiner in the cell site transceiver setup.

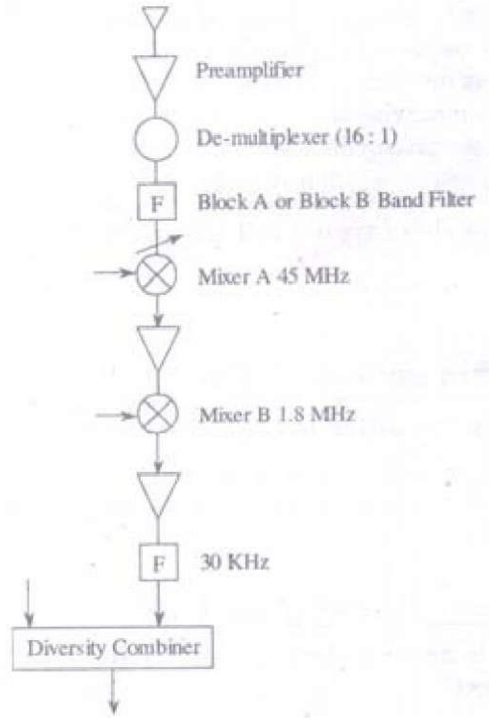
3. Ring Combiner: Ring combiner is used to combine two groups of channels to give one output. This combiner has an insertion loss of 3 dB. For example, using a ring combiner two 16 channel groups into one 32 channel output. Even 64 channels can be used with this combiner if two antennas arc available in the cell site. In case of low transmitter power more than one ring combiner can be used for combining. However, the demerits of ring combiners are.

a) It reduces adjacent-channel separation.
b) They may be affected from the problem of power limitations.

10. Explain the importance of demultiplexer at the receiver to reduce the non-co-channel interference.

Answer:

The main theme of using demultiplexer at the receiver end is to reduce the non co-channel interference. A 16:1 demultiplexer is used in between the pre-amplifier stage and filter stage as shown in figure below.



Particularly, 16:1 demultiplexer is used in order to receive 16 channels from a single antenna. The output of each antenna reaches demultiplexer after passing through a 25 dB gain amplifier. The total split loss of demultiplexer output and due to 16 channels is given by.

$$S = 10 \log 16$$

$$= 12.04$$

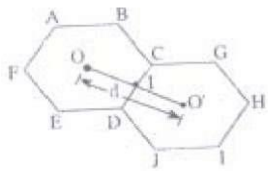
$$S = 12.04 \text{ dB}$$

Care must be taken such that the intermodulation product at the demultiplexer output is 65 dB down and the space diversity antennas connected to an umbrella filter must have a 55 dB rejection from other systems band, otherwise in case. if a dummy mobile unit is close to the cell site then the preamplifier generates intermodulation frequency at the amplifiers output which may lead to cross talk.

11. Prove that for hexagonal geometry the co-channel reuse ratio is given by Q= V3N Answer:

Cochannel Reuse Ratio: Let us consider that the radius of each cell be 'R', the distance between center of adjacent cells is d and he distance between center of cochannel cells is 'D' for

an hexagonal geometry.



From Fig. (11). we have,

$$CI = \frac{R}{2},\ OI = \frac{d}{2} \text{ and } OC = R$$

By using the Pythagoras theorem.

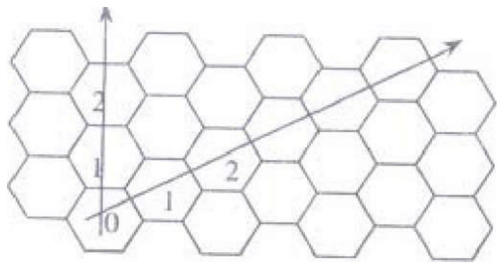
$$OC^2 = OI^2 + CI^2$$

$$\Rightarrow \quad R^2 = \left(\frac{d}{2}\right)^2 + \left(\frac{R}{2}\right)^2$$

$$\Rightarrow \quad d = \sqrt{3}R$$

Then figure (2) shows the most convenient set of Coordinates for hexagonal geometry. The positive halves of the two axes intersect at a 60 angle and the Unit distance along any of the axis equals the cell radius.

The radius is defined as the distance from the center of a cell to any of its vertices. Based on this, the center of each cell falls on a point specified by a pair of integer coordinates.


2
1
0
1
2

12. What is near-end-far-end interference ratio and explain its effects? Answer:

Near-End—Far-End Interference:

In one cell: Because motor vehicles in a given cell are usually moving, some mobile units are close to the cell site and some are not. The close-in mobile unit has a strong signal which causes adjacent-channel interference (see Fig. 12(a)). In this situation, near-end-far-end interference can our only at the reception point in the cell site.

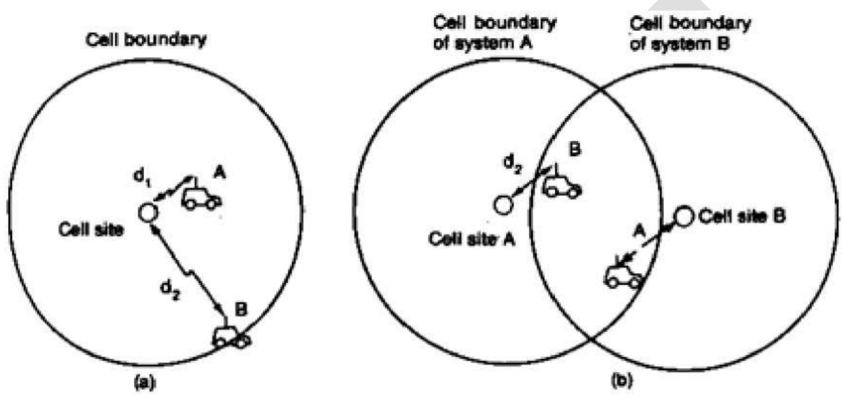


Fig.12. Near-end-far-end interference (a) In one cell (b) In two-systems.

If a separation of 5dB (five channel bandwidths) is needed for two adjacent channels in a cell in order to avoid the near-end-far-end interference, it is then implied that a minimum separation of 5dB required between each adjacent channel used with one cell.

Because the total frequency channels are distributed in a set of N cell, each cell only has I/N of total frequency channels. We denote {Fl}, {F2},{F3},{F4} for the sets of frequency channels assigned in their corresponding cells C1.,C2, C3, C4.

The issue here is how can we construct a good frequency management chart to assign the N sets of frequency channels properly and thus avoid the problems indicated above. The following section addresses how cellular system engineers solve this problem in two different systems.

In cells of two systems: Adjacent-channel interference can occur between two systems in a duopoly-market system. In this situation, adjacent-channel interference can occur at both the cell site and the mobile unit.

For instance, mobile unit A can be located at the boundary of its own home cell A in system A but very close to cell B of system B as shown in the figure 12(b). The other situation would occur if the mobile unit B were at the boundary of cell B of system B but very close to cell A of system A. Following the definition of near-end-far-end interference , the solid arrow indicates that interference may our at cell site A and the dotted arrow indicates that interference may occur at mobile unit A. Of course, the same interference will be introduced at cell site B and mobile unit B.

Thus, the frequency channels of both cells of the two systems must be coordinated in the neighborhood of the two-system frequency bands. This phenomenon will be of greater concern in the future, as indicated in the additional frequency-spectrum allocation charts in Fig. 12.1.

The two causes of near-end—far-end interference of concern here are

1. Interference caused on the set-up channels. Two systems try to avoid using the neighborhood of the set-up channels as shown in Fig. 12.1.

2. Interference caused on the voice channels. There are two clusters of frequency sets as shown in Fig. 12.1 which may cause adjacent-channel interference and should be avoided. The cluster can consist of 4 to 5 channels on each side of each system, that is, 8 to 10 channels in each cluster. The channel separation can be based on two assumptions.

a. Received interference at the mobile unit. The mobile unit is located away from its own cell site but only 0.25 ml away from the cell site of another system.

b. Received interference at the cell site. The cell site is located 10 ml away from its own mobile unit but only 0.25 mi from the mobile unit of another system.

Unit IV: Tutorial Class

- phase difference between direct & reflected paths
- Antenna height gain

UNIT-IV

1. Explain ground incident angle, elevation angle, ground reflection and reflection point.

Answer:

The ground incident angle and the ground elevation angle over a communication link are described as follows. The ground incident angle 0 is the angle of wave arrival incidently pointing to the ground as shown in Fig. 1.1. The ground elevation angle is the angle of wave arrival at the mobile unit as shown in Fig. 1.1

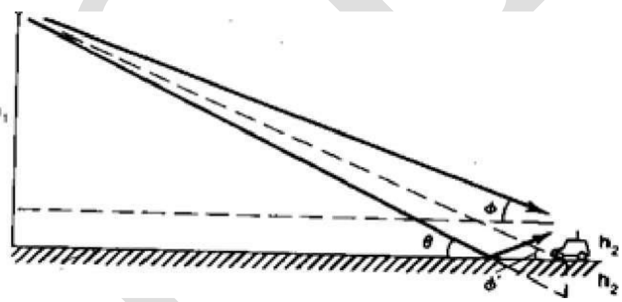
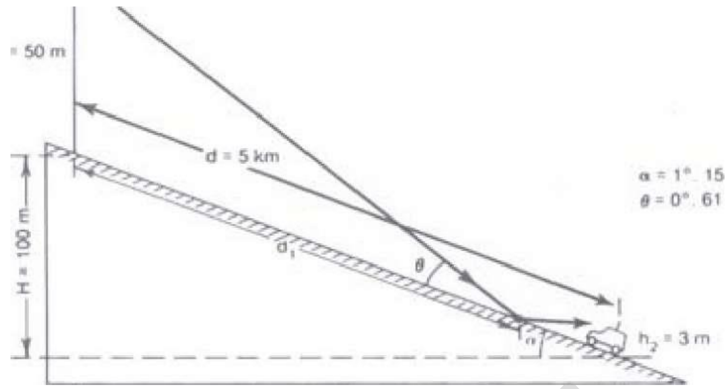


Figure 1.1 Representation of Ground Incident Angle 0 and Ground Elevation Angle ^

Based on Snell's law, the reflection angle and incident angle are the same. Since in graphical display we usually exaggerate the hilly slope and the incident angle by enlarging the vertical scale, as shown in Fig. 1.2, then as long as the actual hilly slope is less than 100, the reflection point on a hilly slope can be obtained by following the same method as if the reflection point were on flat ground. Be sure that the two antennas (base and mobile) have been placed vertically, not perpendicular to the sloped ground. The reason is that the actual slope of the hill is usually very small and the vertical stands for two antennas are correct. The scale drawing in Fig. 1.2 is somewhat misleading however, it provides a clear view of the situation.



d" <= 5 M

Fig 1.2 Ground reflection angle and reflection point 2.

Write about the phase difference between the direct path and the ground reflected path.

Answer:

Based on a direct path and a ground reflected path, the equation

$$P_r = P_0 \left(\frac{1}{4\pi d/\lambda}\right)^2 \left|1 + a_v e^{j\Delta\phi}\right|^2$$

whore — the reflection coefficient

A<i> ■ the phase difference between a direct path and a reflected

indicates a two-wave model which is used to understand the path-loss phenomenon in a mobile radio environment. It is not the model for analyzing the multipath fading phenomenon. In a mobile environment av = - 1 because of the small incident angle of the ground wave caused by a relatively low cell-site antenna height. Thus,

$$P_r = P_0 \left(\frac{1}{4\pi d/\lambda}\right)^2 \left|1 - \cos\Delta\phi - j\sin\Delta\phi\right|^2$$

$$= P_0 \frac{2}{(4\pi d/\lambda)^2}(1 - \cos\Delta\phi) = P_0 \frac{4}{(4\pi d/\lambda)^2}\sin^2\frac{\Delta\phi}{2}$$

where $\Delta\phi = \beta\,\Delta d$

and Δd is the difference, $\Delta d = d_1 - d_0$, from Fig. 4.4.

$$d_1 = \sqrt{(h_1 + h_2)^2 + d^2}$$

and $d_2 = \sqrt{(h_1 - h_2)^2 + d^2}$

Since Δd is much smaller than either d_1 or d_2,

$$\Delta\phi = \beta\,\Delta d \approx \frac{2\pi}{\lambda}\frac{2h_1h_2}{d}$$

Then the received power of Eq. (4.2-3) becomes

$$P_r = P_0 \frac{\lambda^2}{(4\pi)^2 d^2}\sin^2\frac{4\pi h_1 h_2}{\lambda d}$$

[f ¿4. is less than 0.6 rad, then sin <A4>/2) » A<f>/2, **coaiA^/2) " I** thgn

Pr » P_0

l&TT H d f \ f

, thus

$$\Delta P = 40 \log\frac{d_1}{d_2} \quad \text{(a 40 dB/dec path loss)}$$

$$\Delta G = 20 \log\frac{h'_1}{h_1} \quad \text{(an antenna height gain of 6 dB/oct)}$$

Where P is the power difference in decibels between two different path lengths and G is the gain (or loss) in decibels obtained from two different antenna heights at the cell site. From these measurements, the gain from a mobile antenna height is only 3 dB/oct, which is different from the 6 dB/oct . Then h\

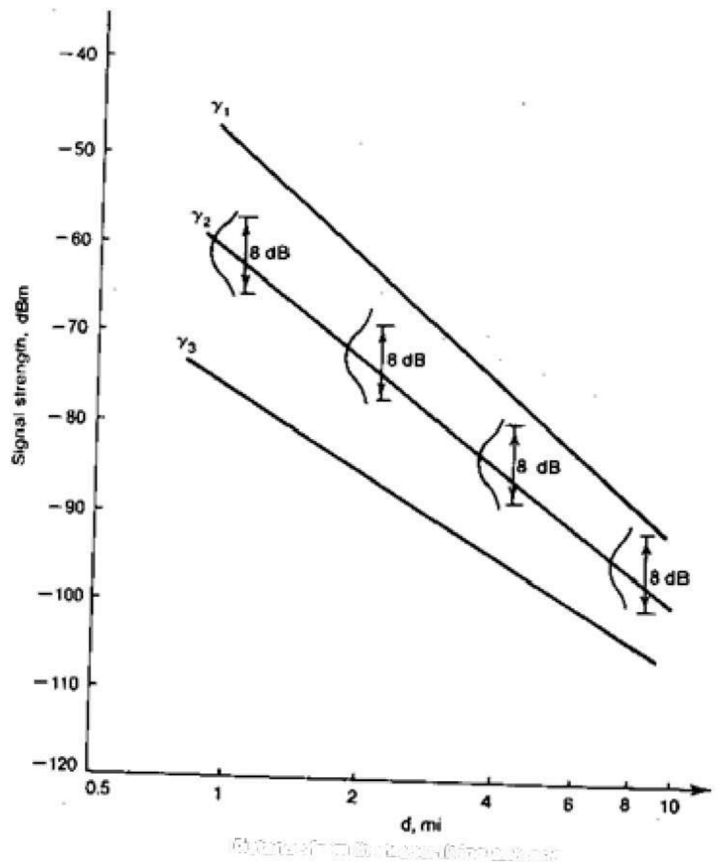
JG - 10 lüg

3. Why there is a constant standard deviation along a path-loss

curve. Answer:

When plotting signal strengths at any given radio-path distance, the deviation from predicted value. is approximately 8 dB.1012 This standard deviation of 8 dB is roughly true in many different areas. The explanation is as follows. When a line-of-sight path exists, both the direct wave path and reflected wave path are created and are strong. When an out-of-sight path exists, both the direct wave path and the reflected wave path are weak. In either case, according to the theoretical model, the 40-dB/dec path-loss slope applies. The difference between these two conditions is the 1-mi intercept (or 1-km intercept) point. It can be seen that in the open area, the 1-mi intercept is high. In the urban area, the 1-mi intercept is low. The standard deviation obtained from the measured data remains the same along the different path-loss curves regardless of environment.

Support for the above argument can also be found from the observation that the standard deviation obtained from the measured data along the predicted path-loss curve is approximately 8 dB. The explanation is that at a distance from the cell site, some mobile unit radio paths are line-of-sight, some are partial line-of-sight, and some are out-of-sight. Thus the received signals are strong, normal, and weak, respectively. At any distance, the above situations prevail. If the standard deviation is 8 dB at one radio-path distance, the same 8dB will be found at any distance. Therefore a standard deviation of 8 dB is always found along the radio path as shown in Fig.3. The standard deviation of 8 dB from the measured data near the cell site is due mainly to the close-in buildings around the cell site. The same standard deviation from the measured data at a distant location is due to the great variation along different radio paths.



[>aance from Vto ItirVmniiting antenna

Fig 3 An 8-dB local mean spread

4. Discuss the merits of point-to-point

model. Answer:

The area-to-area model usually only provides an accuracy of prediction with a standard deviation of 8 dB, which means that 68 percent of the actual path-loss data are within the ± 8 dB of the predicted value. The uncertainty range is too large. The point-to-point model reduces the uncertainty range by including the detailed terrain contour information in the path-loss predictions.

The differences between the predicted values and the measured ones for the point-to-point model were determined in many areas. In the following discussion, we compare the differences shown in the Whippany, N.J., area and the Camden-Philadelphia area. First, we plot the points with predicted values at the x-axis and the measured values at the y-axis, shown in Fig. 4. The 450 line is the line of prediction without error. The dots are data from the Whippany area, and the crosses are data from the Camden- Philadelphia area. Most of them, except the one at 9 dB, are close to the line of prediction without error.

The mean value of all the data is right on the line of prediction without error. The standard deviation of the predicted value of 0.8 dB from the measured one.

In other areas, the differences were slightly larger. However, the standard deviation of the predicted value never exceeds the measured one by more than 3 dB. The standard deviation range is much reduced as compared with the maximum of 8 dB from area-to-area models. The point-to-point model is very useful for designing a mobile cellular system with a radius for each cell of 10 mi or less. Because the data follow the log-normal distribution, 68 percent of predicted values obtained from a point-to-point prediction model are within 2 to 3 dB. This point-to-point prediction can be used to provide overall coverage of all cell sites and to avoid cochannel interference. Moreover, the occurrence of handoff in the cellular system can be predicted more accurately.

The point-to-point prediction model is a basic tool that is used to generate a signal coverage map, an interference area map, a handoff occurrence map, or an optimum system design configuration, to name a few applications.

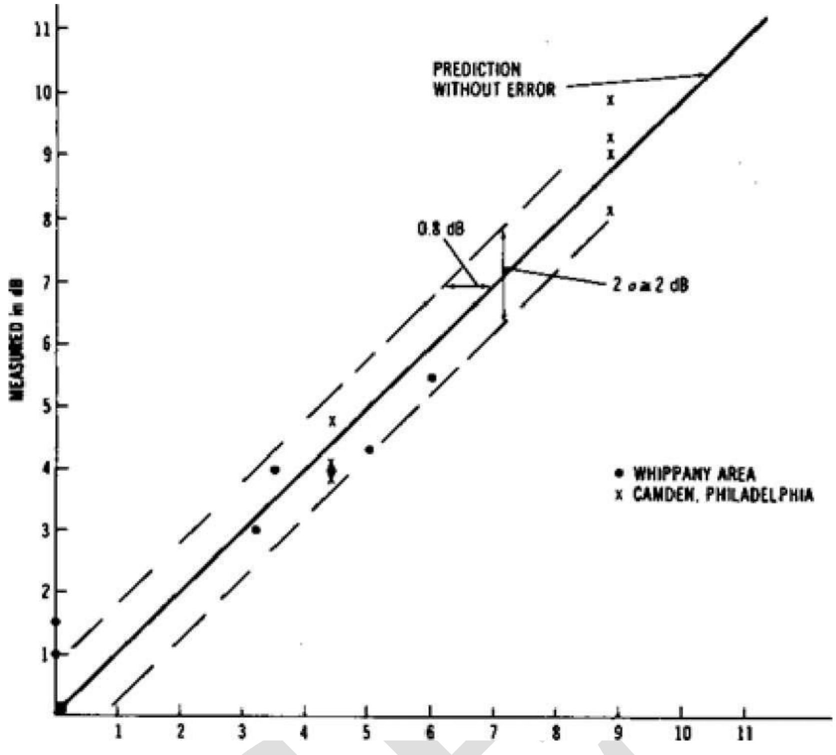


Fig .4. Indication of errors in point-to-point predictions under non obstructive conditions.

5. Explain about foliage loss

Answer:

Foliage loss is a very complicated topic that has many parameters and variations. The sizes of leaves, branches, and trunks, the density and distribution of leaves, branches, and trunks, and the height of the trees relative to the antenna heights all be considered. An illustration of this prvlem is shown in Fig. 5.1. There are three levels: trunks, branches, and leaves. In each level, there is a distribution of sizes of trunks, branches, and leaves and also of the density and spacing between adjacent trunks, branches, and leaves. The texture and thickness of the leaves also count. This unique problem can become very complicated and is beyond the scope of this book. For a system design, the estimate of the signal reception due to foliage loss does not need any degree of accuracy.

Furthermore, some trees, such as maple or oak, lose their leaves in winter, while others, such as pine, never do. For example, in Atlanta, Georgia, there are oak, maple, and pine trees. In summer the foliage is very heavy, but in winter the leaves of the oak and maple trees fall and the pine leaves stay. In addition, when the length of pine needles reaches approximately 6 in., which is the half wavelength at 800 MHz, a great deal of energy can be absorbed by the pine trees. In these situations, it is very hard to predict the actual foliage loss.

However, a rough estimate should be sufficient for the purpose of system design. In tropic zones, the sizes of tree leaves are so large and thick that the signal can hardly penetrate. In this case, the signal will propagate from the top of the tree and deflect to the mobile receiver. We will include this calculation also.

Sometime the foliage loss can be treated as a wire-line loss, in decibels per foot or decibels per meter, when the foliage is uniformly heavy and the path lengths are short. When the path length is long and the foliage is non uniform, then decibels per octaves or decibels per decade are used. In general, foliage lose occurs with respect to the frequency to the fourth power. Also, at 800 MHz the foliage Lou along the radio path is 40 dB/dec, which is 20 dB more than the free- space loss, with the same amount of additional loss for mobile communications. Therefore, if the situation involves both foliage loss and mobile communications, the total loss would be 60 dB/dec (=20 dB/ dec of free-space loss + additional 20 dB due to foliage loss + additional 20 dB due to mobile communication).

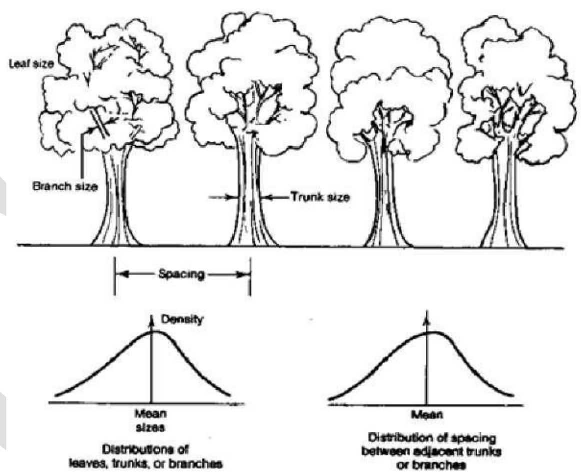


Fig.5.1. A characteristic of foliage environment

This situation would be the case if the foliage would line up along the radio path. A foliage loss in a suburban area of 58.4 dB/dec is shown in Fig.5.2. As demonstrated from the above two examples, close- in foliage at the transmitter site always heavily attenuates signal reception. Therefore, the cell site should be placed away from trees.

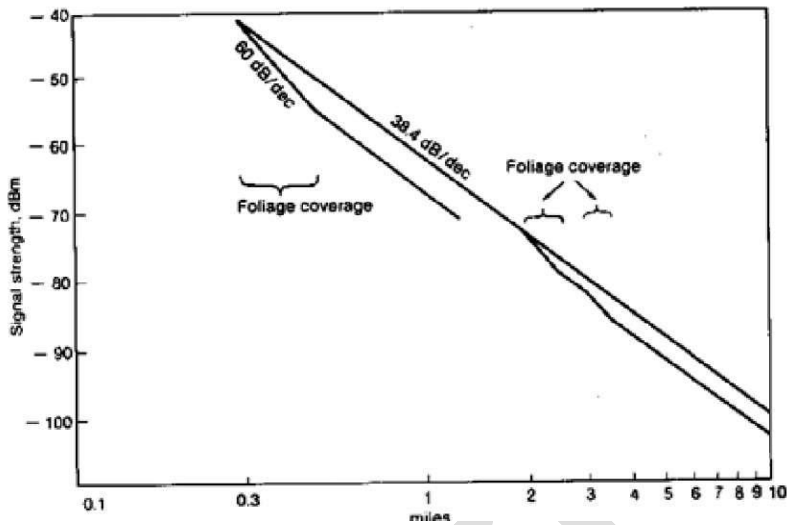


Fig.5.2. Foliage loss calculation in suburban areas

6. Discuss the "Lee model" for point to point propagation.

Answer:

In general, the mobile point-to-point model can be obtain in three steps.

(i) Generate a standard condition.
(ii) Obtain an Area-to-Area prediction model.
(iii) Obtain a mobile Point-to-Point model using Area-to-Area prediction

model. The purpose of developing this model is try to separate two effects.

(a) Natural terrain contour.

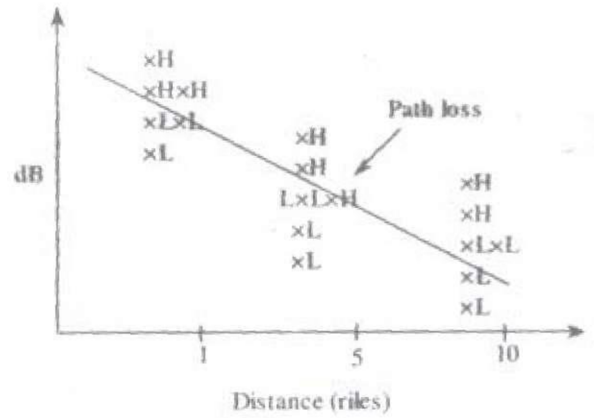
(b) Human made structures.

(i) Standard Condition: To generate the standard condition, transmitted power and antenna height at base station and mobile unit should satisfy the following requirements.

	Standard Condition At the mobile Unit	Correction Factors
1.	Antenna height $h_2 = 10$ ft (3m)	$\alpha_1 = 10\log\left(\frac{h_2'}{h_2}\right)$
2.	Antenna gain $g_m = 0$ dB/dipole	$\alpha_2 = g_m'$
	At the Base Station	
1.	Transmitted power $p_t = 10$ w (40 dBm)	$\alpha_3 = 10\log\left(\frac{p_t'}{10}\right)$
2.	Antenna height $h_1 = 100$ ft (30 m)	$\alpha_4 = 20\log\left(\frac{h_1'}{h_1}\right)$
3.	Antenna gain $g_t = 6$ dB/dipole	$\alpha_5 = g_{t2}' - 6$

(ii) Obtain Area-to-Area Predication Curves for Human Made Structures: In the Area-to-Area prediction model, all the areas are considered. as flat even though the data may be received from non flat area

(iii) Effect of the Human Made Structures: The terrain configuration of each city is different, and the human made structure of the each city unique. So that, try to separate the two effects. The path loss curve obtained on virtually flat ground indicates the effects of the signal loss due to solely human made structures. The average path loss slope shown below which is a combination of measurements from high spots and low spots along different radio paths.



The Area-to-A prediction curve is obtained from the mean value of the measured data and used for further prediction in that area The Area-to-Area prediction model can be used as a first step towards achieving the point-to-point prediction model. The performance of d Area-to-Area prediction model can be represented by two parameters.

1. 1 mi intercept point.
2. The path loss slope.

The 1 ml intercept point is the power received at a distance of 1 mi from the transmitter. The 1 mi intercept point is depends upon the effective antenna height gain.

AG = Effective antenna - height gain = 20 log(he/h1)

Where, he= Effective antenna height

h1= Actual height

7. Derive the relation for the maximum coverage distance in mobile

environment. Answer:

The structure of a mobile environment is shown in below figure

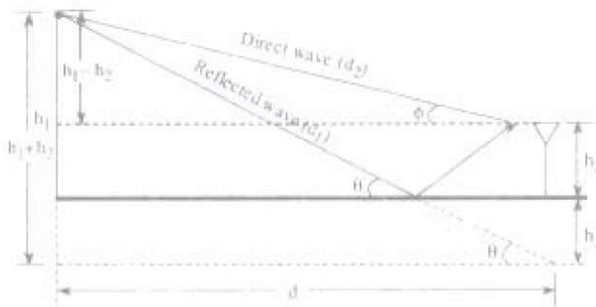


Figure: Mobile Unit Environment

Consider a cell site antenna of height 'hi' and a mobile antenna of height 'h2' is moving away from cell site. The maximum distance up to which, the mobile antenna receives the signal is the maximum coverage distance.

Let the maximum coverage distance is 'd'. So when mobile antenna moving away from the cell site we can observe two waves of propagation, i.e., direct wave and reflected wave.

Direct wave is the direct propagation from cell site to mobile antenna, without any deviation and the distance travelled by this wave is considered to be (d2), a range *'9'* with surface angle *9* is known as elevation angle.

Reflected wave is the wave propagated from cell site to surface and then surface to mobile antenna, let the distance travelled by it is 'di' angle done by it with surface is *'0'.*

Based on direct path and ground reflected path the received power 'Pr' is given by

$$P_r = P_0 \left(\frac{1}{4\pi d / \lambda} \right)^2 \left| 1 + a_v . e^{j\Delta\phi} \right|^2$$

P0 = Transmitted Power, d = Maximum coverage distance, av = Reflection coefficient.

A9 = The phase difference between direct path and reflected path X=Wave length.

We know that,

$e^{j\theta} = \cos\theta + j\sin\theta$

∴ By substituting this value in equation (2), we get,

$$\therefore \quad P_r = P_0 \cdot \frac{2}{\left(\frac{4\pi d}{\lambda}\right)^2} (1 - \cos\Delta\phi)$$

$$= P_0 \frac{2}{(4\pi d/\lambda^2)} \left[1 - \left(1 - 2\sin^2\frac{\Delta\phi}{2}\right)\right]$$

$$\Rightarrow \boxed{P_r = P_0 \frac{4}{(4\pi d/\lambda)^2} \sin^2\frac{\Delta\phi}{2}} \quad \text{... (3)}$$

Where,

$\Delta\phi = \beta\Delta d$ and Δd is the path difference,

i.e., $\Delta d = d_1 - d_2$

But from figure, $d_1 = \sqrt{(h_1 + h_2)^2 + d^2}$

$$d_2 = \sqrt{(h_1 - h_2)^2 + d^2}$$

and also Δd is much smaller than d_1 and d_2.

$$\therefore \quad \text{As } \Delta\phi = \beta\,\Delta d \simeq \frac{2\pi}{\lambda} \cdot \frac{2h_1h_2}{d}$$

Then the received power from equation (3) becomes,

$$P_r = P_0 \frac{\lambda^2}{(4\pi)^2 d^2} \sin^2 \frac{4\pi\, h_1h_2}{\lambda d}$$

If $\Delta\phi$ is very small then $\sin\left(\frac{\Delta\phi}{2}\right) = \left(\frac{\Delta\phi}{2}\right)$

$$\Rightarrow P_r = P_0 \frac{4}{16\pi^2 (d/\lambda)^2} \left(\frac{2\pi h_1 h_2}{\lambda d}\right)^2$$

$$= P_0 \left(\frac{h_1 h_2}{d^2}\right)^2$$

$$\therefore \quad P_r = P_0 \left(\frac{h_1 h_2}{d^2}\right)^2$$

Where, 'd' is maximum coverage distance and is given by.

$$d = \sqrt{\frac{h_1 h_2}{\left(P_r / P_0\right)^{1/2}}} \quad \text{... (4)}$$

From equation (4), we can deduce two relationships.

First

$$\Delta p = 40 \log \frac{d_1}{d_2}$$ (a 40 dB/dec path loss)

When ΔP is the power difference in decibels between two different path lengths.

AG = 20 log (he/h1) ....(5)

Where, h1= Height of the cell antenna he = Effective antenna height = (h1 + h2) and

*A*G is the gain in decibels obtained from two different antenna heights at the cell site.

Hence, equation (5) represents, equation for the system gain.

Second

8. What are the factors that effect accuracy of prediction

Answer:

Factors effecting the Accuracy of Prediction
The standard deviation is constant along a path loss curve. The path-loss slope is 40dB/dec in case of both line-of-sight path and out-of-sight path. However, the direct path and reflected path in case of line-of- sight path are strong and in out-of-sight path is weak. By media ting these two conditions, 1-mi intercept is obtained, which is strong in open area but weak in urban areas.

The standard deviation obtained from the predicted path-loss curve is almost equal to S dB and is constant throughout the radio path. But the received signals vary based on the type of path. i.e. for line-of-sight path the received signal is strong for partial line-of-sight path it is norm al and for out-of-sight path the received signal is weak. These are few factors, which affect the accuracy of the prediction.

9. Discuss in detail about small scale multipath

propagation. Answer:
Small Scale Multipath Propagation: The multipath propagation of radio signals over a short period of time or to travel a distance is considered to be the small scale multipath propagation. As every type of multipath propagation results in generating a faded signal at receiver, the small scale multipath propagation also results in small scale fading. Hence, the signal at the receiver is obtained by combining the various multipath waves. These waves will vary widely in amplitude and phase depending on the distribution of the intensity and relative propagation time of the waves and bandwidth of the transmitted signal.

The three fading effects that are generally observed due to the small scale multipath propagation are,

1. Fast variations in signal strength of the transmitted signal for a lesser distance or time interval.
2. The variations in Doppler shift on various multipath signals are responsible for random frequency modulation
3 The time dispersed signals are resulted due to multipath propagation delays.

In order to determine the small scale fading effects, we employ certain techniques. They are,

1. Direct RF pulse measurement
2. Spread spectrum sliding correlator measurement.
3. Swept frequency measurement.

The first technique provides a local average power delay profile.

The second technique detects the transmitted signal with the help of a narrow band receiver preceded by a wide band mixer though the probing (or received) signal is wide band.

The third technique is helpful in finding the impulse response of the channel in frequency domain. By knowing the impulse response we can easily predict the signal obtained at the receiver from the transmitter.

10. Explain the effect of propagation of mobile signals over water.

Answer:

Propagation over Water or Flat Open Area: Propagation over water or fiat open area is becoming a big concern because it is very easy to interfere with other cells if we do not make the correct arrangements. Interference resulting from propagation over the water can be controlled if we know the cause. In general, the permittivities Er of seawater and fresh water are the same, but the conductivities of seawater and fresh water are different. We may calculate the dielectric constants Ec where Ec = Er - j60d. The wavelength at 850MHz is 0.35m. Then Eo (sea water) = 80 - j84 and Ec (fresh water)=80-
jO.021.

However, based upon the reflection coefficients formula with a small incident angle both the reflection coefficients for horizontal polarized waves and vertically polarized waves approach 1. Since the 180* phase change occurs at the ground reflection point, the reflection coefficient is -1. Now we can establish a scenario, as shown in Fig 10.1 Since the two antennas, one at the cell site and the other at the mobile unit, are well above sea level, two reflection points are generated. The one reflected from the ground is close to the mobile unit; the other reflected from the water is away from the mobile unit. We recall that the only reflected wave we considered in the land mobile propagation is the one reflection point which is always very close to the mobile unit. We are now using the formula to find the field strength under the circumstances of a fixed point-to-point transmission and a land-mobile transmission over a water or flat open land condition.

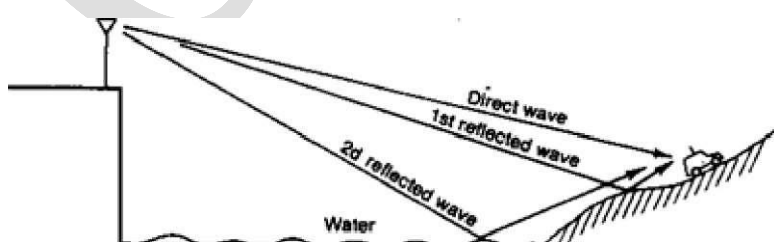


Fig 10.1.A model for propagation over water

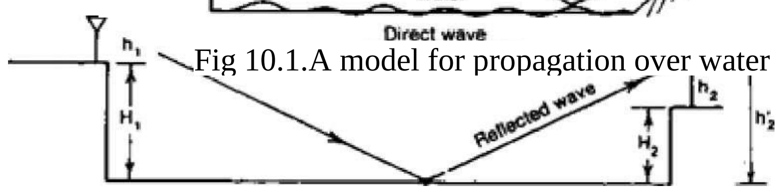


Fig 10.2.Propagation between two fixed stations over water or flat open land.

Between fixed stations: The point-to-point transmission between the fixed stations over the water or flat open land can be estimated as follows. The received power **P,** can be expressed as (see Fig. 10.2)

J+aX** exp (j Ai()) v4trd/A **j**

whore **Pt ~** transmitted power
d - distance tHitween two statioiu ****
~ wavelength
<5*,. = amplitude and phase of a complex reflection
coefficient, respectively

A9 is the phase difference caused by the path difference M between the direct wave and the reflected
wave, or

The first part of i.e. the free-space loss formula which shows the 20 dB/dec slope; that is, a 20-dB loss will be seen when propagating from 1 to 10 km.

The complex reflection co-efficients and can be found from the formula

$$a_v e^{-j\phi_v} = \frac{\epsilon_c \sin\theta_1 - (\epsilon_c - \cos^2\theta_1)^{1/2}}{\epsilon_c \sin\theta_1 + (\epsilon_c - \cos^2\theta_1)^{1/2}}$$

When the vertical incidence is small, 0 is very small and

a. « -1 and = 0

can be found from equation. Ec is a dielectric constant that is different for different media. The reflection coefficient remains -1 regardless of whether the wave le propagated over water dry land, wet land, Ice, and so forth. The wave propagating between fixed stations is illustrated in Fig. 10.2.

$$P_r = \frac{P_t}{(4\pi d/\lambda)^2} |1 - \cos \Delta\phi - j \sin \Delta\phi|^2$$
$$= P_0(2 - 2 \cos \Delta\phi)$$

since A9 is a function of d and d can be obtained from the following calculation. The effective antenna height at antenna 1 is the height above the sea level.

h'j — **Aj +** Ffy

The effective antenna height at antenna 2 is the height above the sea level.

As shown in Fig.10.2 where h1 and h2 are actual heights and H1and H2 are the heights of hills. In general, both antennas at fixed stations are high, so the resection point of the wave will be found toward the middle of the radio path. The path difference d can be obtained from Fig. 10.2 as

$$\Delta d = \sqrt{(h_1' + h_2')^2 + d^2} - \sqrt{(h_1' - h_2')^2 + d^2}$$

Since $d \gg h_1'$ and h_2', then

$$\Delta d \approx d\left[1 + \frac{(h_1' + h_2')^2}{2d^2} - 1 - \frac{(h_1' - h_2')^2}{2d^2}\right] = \frac{2h_1'h_2'}{d}$$

The
n

$$\Delta\phi = \frac{2\pi}{\lambda}\frac{2h_1'h_2'}{d} = \frac{4\pi h_1'h_2'}{\lambda d}$$

We can setup five conditions:

1. **P, <P0.** The received power is less than the power received in free space; that is, **2 - 2 cob** M.

< 1 or Ad? < |

2. **P_r =** 0; that ie,

2 - 2 cos A<5> 0 or **AÒ -**

JSt

3. J=$_r$ = that is.

2 - **2** co* = 1 or A<b - ¿60" = ±-

o

4. **P_r** > P^ that is,

2 - 2 A<J> > 1 or ^ < M < "T
u J

5, $F_r = 4P_C$; that is,

2 - 2 eoa Act* = max or A<j> = fl

11. Write short notes on mobile-to-mobile

propagation. Answer:

Mobile-to-Mobile Propagation: In mobile-to-mobile land communication, both the transmitter and the receiver are in motion. The propagation path in this case is usually obstructed by buildings and obstacles between the transmitter and receiver. The propagation channel acts like a filter with a time-varying transfer function H (f, t) which can be found in this section.

The two mobile units M1 and M2 with velocities V1 and V2 respectively are shown in Fig.11.1. Assume that the transmitted signal from Ml is

s(t) = u(t)ft*

The receiver signal at the mobile unit M_a from an ith path ia

g — f u^f ^

>vher* it(i) - signal
iitj, = RF carrier

- Rayieigh-distributid random variable
- uniformly distributed random phase

$t_($ — time delay on ith path

and

tui; - Doppler shift of transmitting mobile unit on ith path

= — "j a_u

tdfc - Dopplcr shift of receiving mobile unit on ith path
2ir ,, = — V% cos Qji

where a1i and a2i are random angles as shown in Fig.11.1. Now assume that the received signal is the summation of n paths uniformly distributed around the azimuth.

$$s_r = \sum_{i=1}^{n} s_i(t) = \sum_{i=1}^{n} r_i u(t - \tau_i)$$

$$\times \exp\{j[(\omega_0 + \omega_{1i} + \omega_{2i})(t - \tau_i) + \phi_i]\}$$

$$= \sum_{i=1}^{n} Q(\alpha_{i,t}) u(t - \tau_i) e^{j\omega_0(t - \tau_i)}$$

where $$Q(\alpha_i, t) = r_i \exp\{j[(\omega_{1i} + \omega_{2i})t + \phi_i']\}$$

$$\phi_i' = \phi - (\omega_{1i} + \omega_{2i})\tau_i$$

The above equation can be represented as a statistical model of the channel, as shown in Fig 11.2.

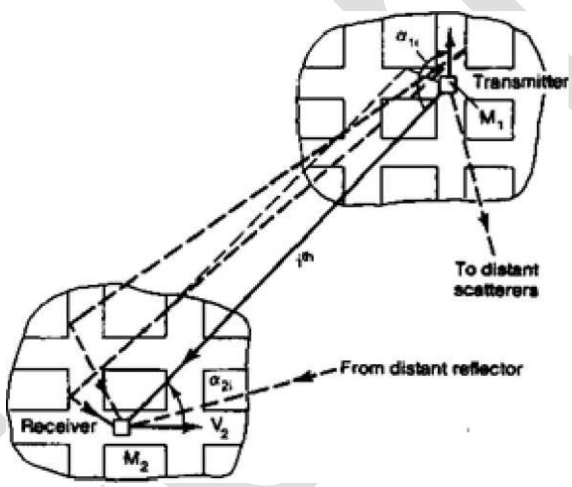


Fig.11.1. Vehicle-to-vehicle transmission

Ut w(i) -

then the above equation becomes

A

Therefbre **H(f$_t$** i) **= £** Qf^,

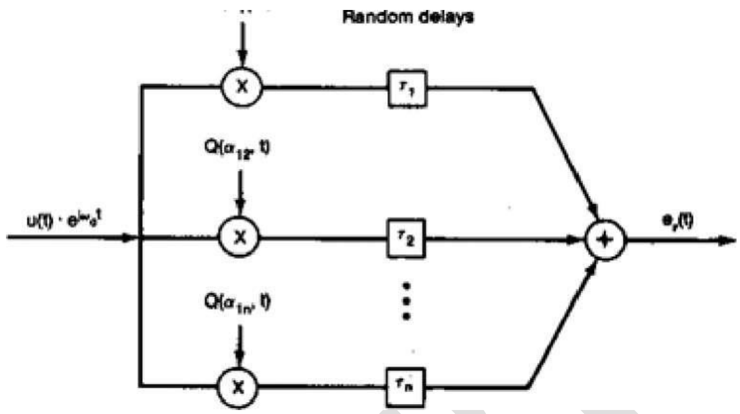


Fig.11.2. Statistical model for mobile-to-mobile channel

where the signal frequency is w = 2nf. Equation is expressed in Fig.11.2. Let f=0; that is only a sinusoidal carrier frequency is transmitted. The amplitude of the received signal envelope from the equation is

r = TO f)|

where r is also a Rayleigh-distributed random variable with its average power of **2cr⁴** shown in the probability density function as

Pir) ~ -3 e

CT

UNIT-V

Unit V: Tutorial Class

- omni directional antennas
- Minimum Separation of cell site antennas

1.Obtain the free space path loss from the transmitting end and the receiving end of the antenna. Derive the received power in dBm. How is the measured field strength converted into the receiver power?

Equivalent circuits of antennas:

The operating conditions of an actual antenna (Fig.1.1a) can be expressed in an equivalent circuit for both receiving (Fig. 1.lb) and transmitting (Fig.1.1c). In Fig. 1.1, Za is the antenna impedance; Zl is the load impedance, and Zt is the impedance at the transmitter terminal.

From the transmitting end (obtaining free-space path-loss formula):

Power Pt originates at a transmitting antenna and radiate out into space. (Equivalent circuit of a transmitting antenna is shown in Fig. 1.1b.) Assume that an isotropic source Pt is used and that the power in the spherical space will be measured as the power per unit area. Thus power density, called the Poynting vector p or the outward flow of electromagnetic energy through a given surface area, is expressed as

$$\rho = \frac{P_t}{4\pi r^2} \quad \text{W/m}^2$$

A receiving antenna at a distance r from the transmitting antenna with an aperture A will receive power

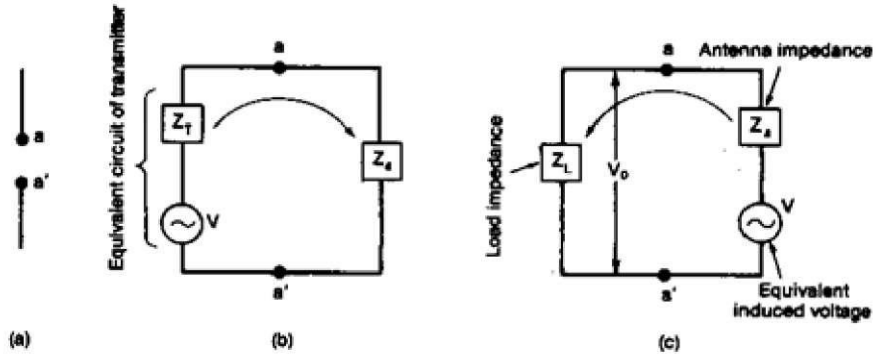


Fig.1.1 (a) An actual antenna;(b) equivalent circuit of transmitting antenna;(c) equivalent circuit of a receiving antenna

$$P_r = \rho A = \frac{P_t A}{4\pi r^2} \qquad \mathrm{W}$$

Figure 1.2 is a schematic representation of received power in space.

From the above equation we can derive the free-apace path-lose formula because we know the relationship between the aperture A and the gain G.

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

For a short dipole, G=1. Then

$$A = \frac{\lambda^2}{4\pi}$$

Substitution of the above equation yields the free-space formula

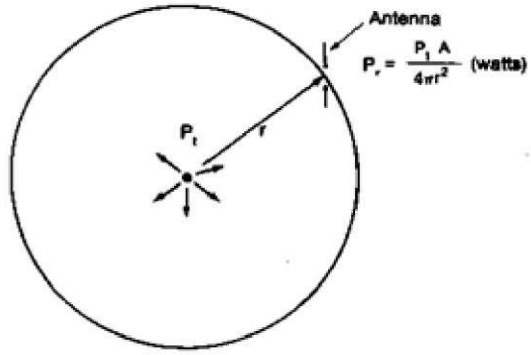


Fig.1.2 Received power in space

$$P_r = P_t \frac{1}{(4\pi r/\lambda)^2}$$

At the receiving end dBp,V - dBm (decibels above 1p,V - decibels above 1mW):

We can obtain the received power from the Fig. 1.1c r _ V* ^ (Z_r f Z_ef

where V is the induced voltage in volts. For a maximum power delivery Zl=Za*, where the notation indicates complex conjugate. Then we obtain ZL + Z 2RL, where R1 is the real-load resistance. Equat ion (5.14) becomes

Assume that a dipole or a monopole is used as a receiving antenna. The induced voltage V can be related to field strength E as

il

where E is expressed in volts or micro meter volts per

P_r =

$E^S X^2$
$4«^s fi_t$

If we set RL=50Q, Pr in decibels above 1mW, and E in decibels (micro volts per meter)

P_r <d6m) - E (dB|iV> - 113 dBm + 10 log ^

The notation "dB^V" in Eq. is a simplification of decibels above 1 (iV/m, and has been accepted by the Institute of Radio Engineers. We can find the equivalent aperture A because the Poynting vector p can be expressed as

$$\rho = \frac{E^2}{Z_0}$$

Where Zo is the intrinsic impedance of the space (=120n). By substituting we get the equivalent aperture A.

$$A = \frac{\lambda^2 Z_0}{4\pi^2 R_L}$$

Measuring field strength and converting it to received power:

Converting field strength in decibels above 1 (iV/m to power received in decibels above 1mW at 850 MHz by a dipole with a 50-Q load is -132 dB.

The notation "39-dB^V contour" is commonly used to mean 39 dB (^V/m) in cellular system design. Equation is valid only at a given frequency (850 MHz), for a given antenna (rnonopole or dipole E,, antenna), and for a given antenna load (50 Q). Otherwise the field strength and the power have to be adjusted accordingly.

Measuring the voltage Vo at the load terminal (Fig. 1.lc) and converting to received power:

Given Pr = (Vo/RL), where RL = 50 Q we can obtain a relationship

0 dHfLVM -107 dBrrt

For example, if a voltage meter at Vo is 7 dB^V, then the received power is -100 dBm. Equation expresses a voltage-to-power antenna array ratio which varies with the load impedance but is independent of the frequency and the type of antenna.

2. What do you understand by engineering antenna pattern? Explain the corresponding pattern.

Sum-and-Difference Patterns - Engineering Antenna Pattern:

After obtaining a predicted field-strength contour we can engineer an antenna pattern to conform to uniform coverage. Far different antennae pointing in different directions and with different spacings, we can use any of a number of methods. If we know the antenna pattern and the geographic configuration of the antennae, a computer program can help us to find the coverage. Several synthesis methods can be used to generate a desired antenna configuration.

General formula:

Many applications of linear arrays are based on sum-and-difference patterns. The main beam of the pattern is always known as the sum pattern pointing at an angle 9o. The difference pattern produces twin main beams straddling 9o. When 2N elements are in in array, equispaced by a separation d, the general pattern for both sum and difference is where 3 ■= wavenumber = 2tt/a

= normalized current distributions

n 2n — 1

= 2 h «*P J —ö— 6 "" cow 0₀1

$$+ I_{-n} \exp\left[-j\,\frac{2n-1}{2}\,\beta d(\cos\theta - \cos\theta_0)\right]$$

N = tutal number of elements

For a sum pattern, all the current amplitudes are the same.

For a difference pattern, the current amplitudes of one side (half of the total elements) are positive and the current amplitudes of the other side (half of the total elements) are negative.

Most pattern synthesis problems can be solved by determining the current distribution In. A few solutions follow.

Synthesis of sum patterns:

Dolph-Chebyshev synthesis of sum patterns: This method can be used to reduce the level of sidelobes; however, one disadvantage of further reduction of sidelobe level is broadening of the main beam.

Taylor synthesis: A continuous line-source distribution or a distribution for discrete arrays can give a desired pattern which contains a single main beam of a prescribed beamwidth and pointing direction with a family of sidelobes at a common specified level. The Taylor synthesis is derived from the following equation, where an antenna pattern F(9) is determined from an aperture current distribution g(l)

$$F(\theta) = \int_{-a}^{a} g(l) e^{j\beta l \cos\theta}\, dl$$

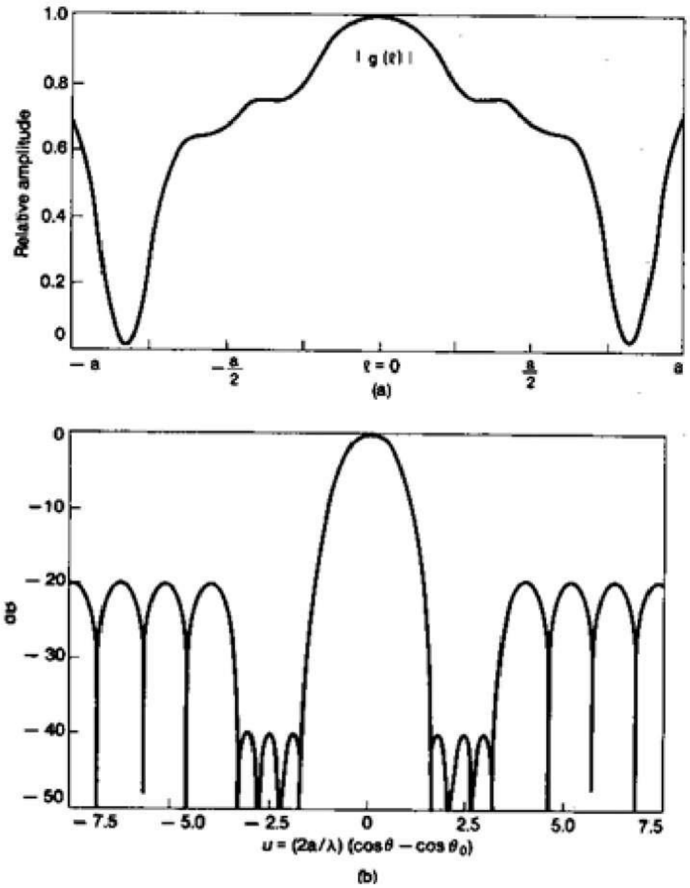


Fig.2.1. A symmetrical sum pattern (a) The aperture distribution for the two- antenna arrangement; (b) The evolution of a symmetrical sum pattern with reduced inner side lobes.

Symmetrical pattern: For production of a symmetrical pattern at the main beam, the current-amplitude distribution g(l) is the only factor to consider. The phase of the current distribution can remain constant. A typical pattern (Fig.2.1a) would be generated from a current-amplitude distribution (Fig.2.1b).

Asymmetrical pattern: For production of an asymmetrical pattern, both current amplitude g(l) and phase arg g(1) should be considered.

Synthesis of difference patterns (Bayliss synthesis):

To find a continuous line source that will produce a symmetrical difference pattern, with twin main beam patterns and specified sidelobes, we can set

öiB) - f giDe™«*'dl

For a desired difference pattern such as that shown in Fig. 2.2a, the current-amplitude distributions g(l) should be designed as shown in Fig. 2.2b and the phase arg g(1) as shown in Fig. 2.2c.

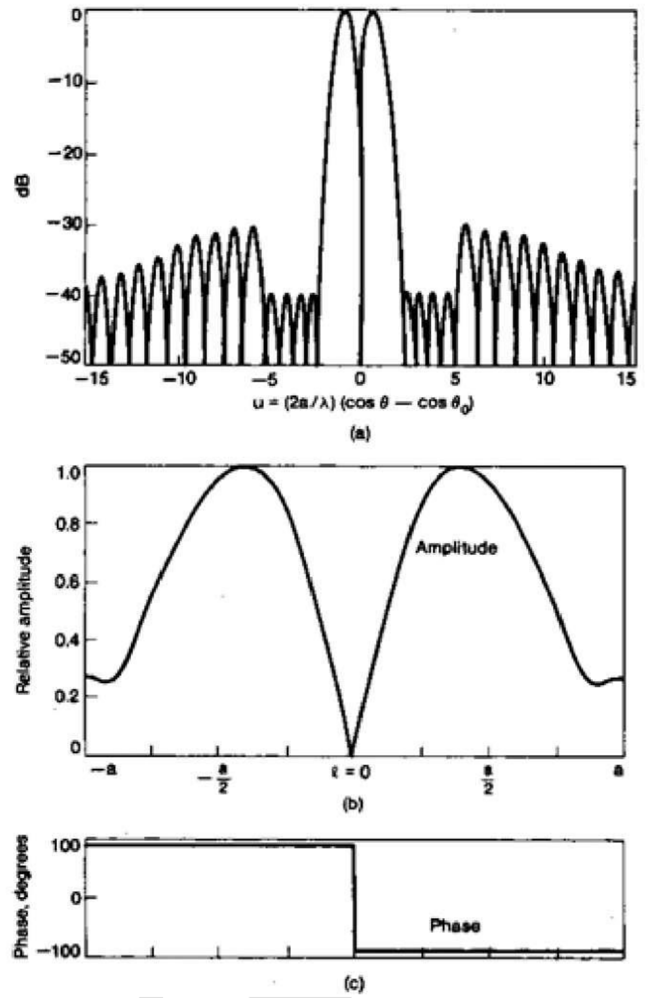


Fig.2.2 A symmetrical difference pattern (a) A modified Bayliss difference pattern; (b,c) Aperture distribution for the pattern

Null-free patterns:

In mobile communications applications, field-strength patterns without nulls are preferred for the antennas in a vertical plane. The typical vertical pattern of most antennas is shown in Fig. 2.3a. The field pattern can be represented as

where u = (2a/A)(cos 9 — cos 9n). The concept is to add all (sin nu)/(Qu) patterns at different pointing angles as shown in Fig. 2.3a. K is the maximum signal level. The resulting pattern does not contain nulls. The null-free pattern can be applied in the field as shown in Fig. 2.3b.

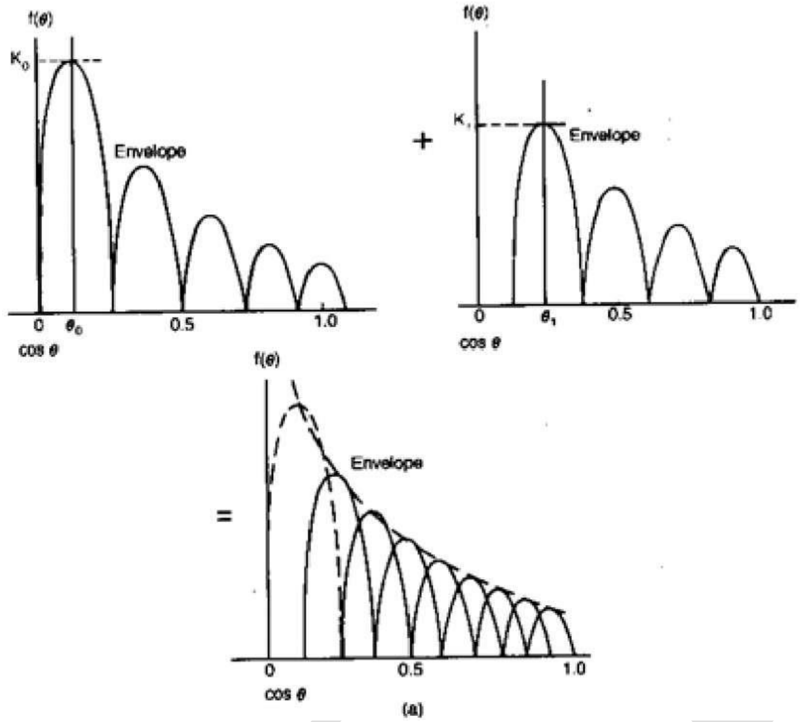


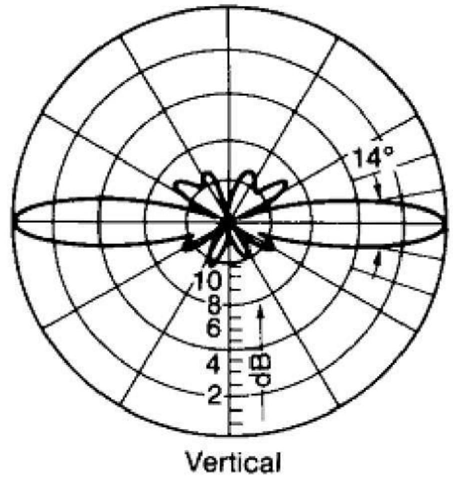
Fig.2.3. Null-free patterns (a) Formation of a null-free pattern

3. Concern to the cell site antennas explain start up configuration and abnormal antenna configuration of start up systems?

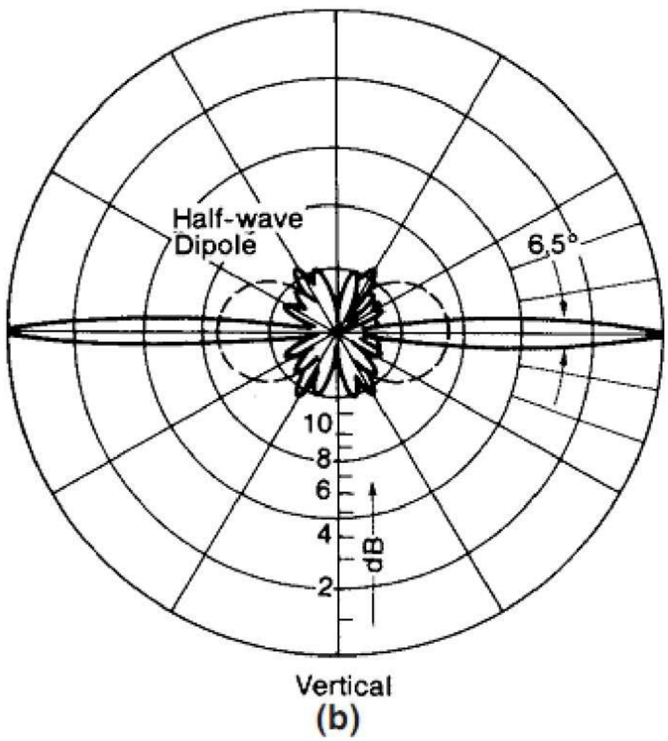
For Coverage Use: Omnidirectional Antennas

High-Gain Antennas: There are standard 6-dB and 9-dB gain omnidirectional antennas. The antenna patterns for 6-dB gain and 9-dB gain are shown in Fig.3.1

Start-Up System Configuration: In a start-up system, an omnicell, in which all the transmitting antennas are omnidirectional, is used. Each transmitting antenna can transmit signals from N radio transmitters simultaneously using a N-channel combiner or a broadband linear amplifier. Each cell normally can have three transmitting antennas which serve 3N voice radio transmitters simultaneously



(a)



(b)

Fig.3.1 High-gain omnidirectional antennas (a) 6 dB (b) 9 dB

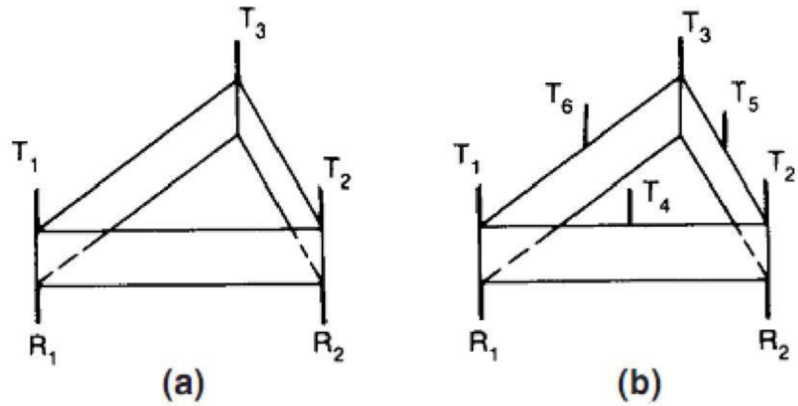


Fig.3.2. Cell site antennas for omni cells (a) for 3N channels; (b) for 6N channels

Each sending signal is amplified by its own channel amplifier in each radio transmitter, or N channels (radio signals) pass through a broadband linear amplifier and transmit signals by means of a transmitting antenna (see Fig.3.2a).

Two receiving antennas commonly can receive all 3N voice radio signals simultaneously. Then in each channel, two identical signals received by two receiving antennas pass through a diversity receiver of that channel. The receiving antenna configuration on the antenna mast is shown in Fig.3.2.cFor serving 6N voice radio transmitters from six transmitting antennas is shown in Fig.3.2(b).

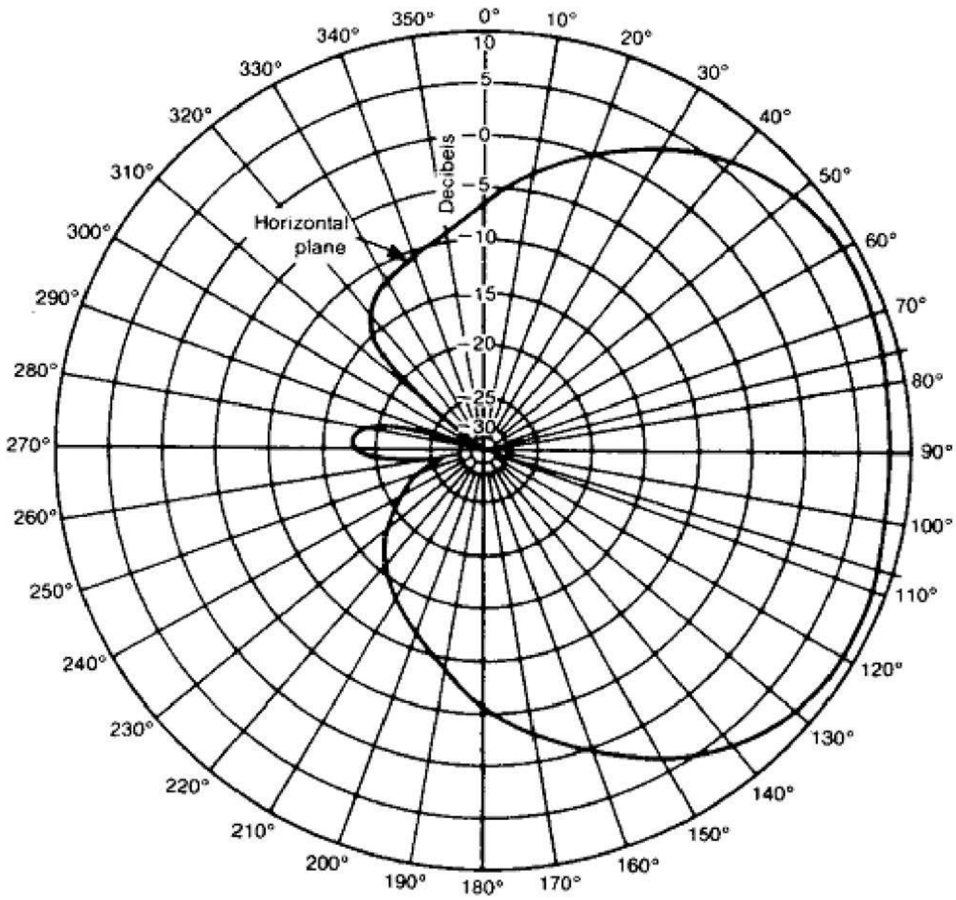
Abnormal Antenna Configuration: Usually, the call traffic in each cell increases as the number of customers increases. Some cells require a greater number of radios to handle the increasing traffic. An omnicell site can be equipped with up to 90 voice radios for AMPS systems. In such cases six transmitting antennas should be used as shown in Fig. 3.2b. In the meantime, the number of receiving antennas is still two. In order to reduce the number of transmitting antennas, a hybrid ring combiner that can combine two 16-channel signals is found. This means that only three transmitting antennas are needed to transmit 90 radio signals. However, the ring combiner has a limitation of handling power up to 600 W with a loss of 3 dB.

4. How interference can be reduced by using the directional antennas at the cell site?

For Interference Reduction Use: Directional Antennas

When the frequency reuse scheme must be used in AMPS, cochannel interference will occur. The cochannel interference reduction factor q = D/R = 4.6 is based on the assumption that the terrain is flat. Because actual terrain is seldom flat, we must either increase q or use directional antennas.

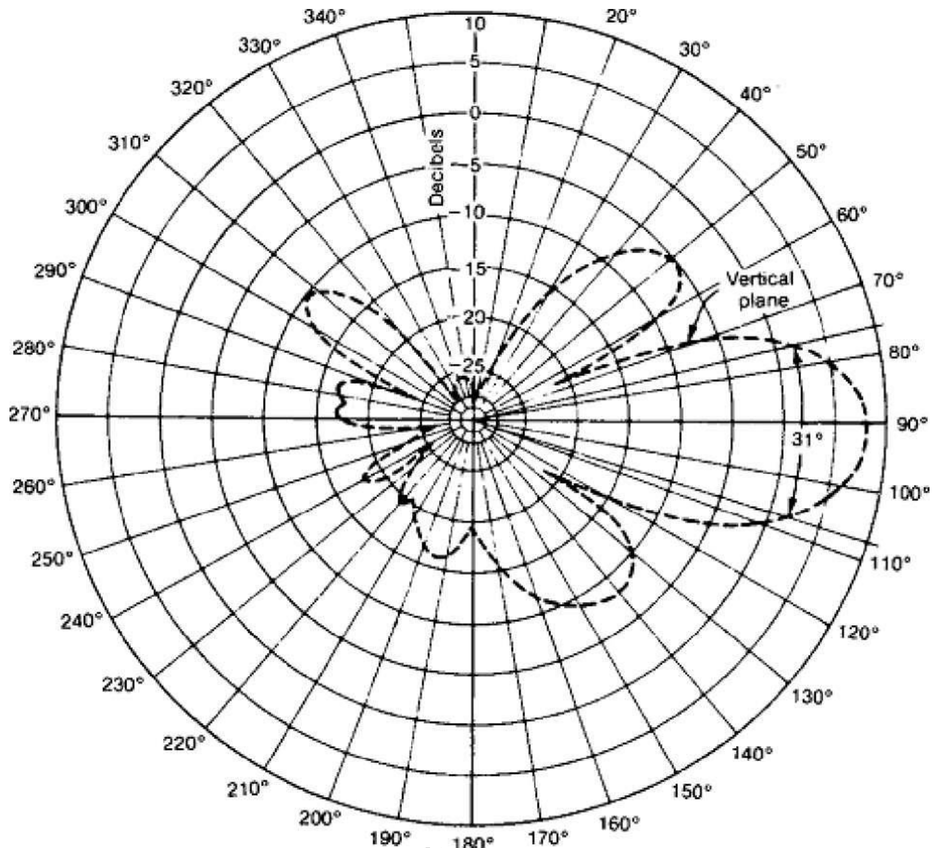
Directional Antennas: A 120°-corner reflector or 120°-plane reflector can be used in a 120°- sector cell. A 60°-corner reflector can be used in a 60°-sector cell. A typical pattern for a directional antenna of 120° beamwidth is shown in Fig.4.1.



0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
10
5
0
-5
-10
-15
-20
-25
-30
Decibels
Horizontal plane

(a)

0ᵁ 10'



(b)

Fig.4.1. Typical 8dB directional antenna pattern (a) Azimuthal pattern of 8dB directional antenna; (b) Vertical pattern of 8dB directional antenna

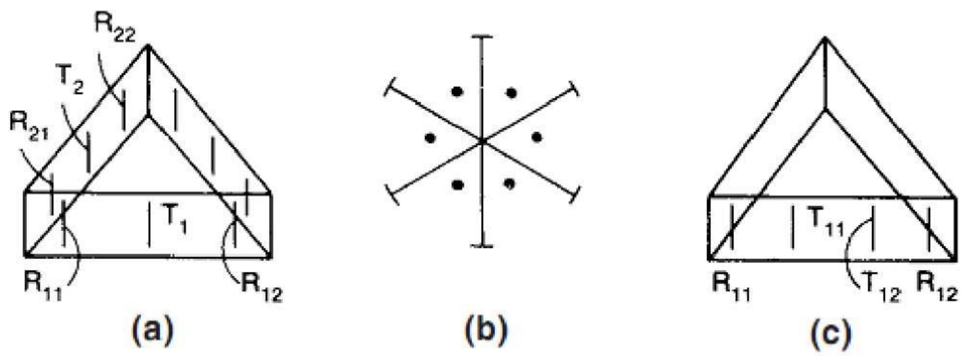


Fig.4.2. Directional antenna arrangement (a) 120◦ sector (45 radios); (b) 60◦ sector; (c) 120◦ sector (90 radios)

Normal Antenna (Mature System) Configuration:

1. K = 7 cell pattern (120°sectors). In a K = 7 cell pattern for frequency reuse, if 333 channels are used, each cell would have about 45 radios. Each 120° sector would have one transmitting antenna and two receiving antennas and would serve 16 radios. The two receiving antennas are used for diversity (see Fig. 4.2a).

2. K = 4 cell pattern (60°sectors). We do not use K = 4 in an omnicell system because the cochannel reuse distance is not adequate. Therefore, in a K = 4 cell pattern, 60° sectors are used. There are 24 sectors. In this K = 4 cell-pattern system, two approaches are used.

a. Transmitting-receiving 60°sectors. Each sector has a transmitting antenna carrying its own set of frequency radios and hands off frequencies to other neighboring sectors or other cells. This is a full K = 4 cell-pattern system. If 333 channels are used, with 13 radios per sector, there will be one transmitting antenna and one receiving antenna in each sector. At the receiving end, two of six receiving antennas are selected for angle diversity for each radio channel (see Fig.4.2b).

b. Receiving 60°sectors. Only 60°-sector receiving antennas are used to locate mobile units and handoff to a proper neighboring cell with a high degree of accuracy. All the transmitting antennas are omnidirectional within each cell. At the receiving end, the angle diversity for each radio channel is also used in this case.

Abnormal Antenna Configuration: If the call traffic is gradually increasing, there is an economic advantage in using the existing cell systems rather than the new splitting cell system (splitting into smaller cells). In the former, each site is capable of adding more radios. In a K = 7 cell pattern with 120° sectors, two transmitting antennas at each sector are used (Fig.4.2c). Each antenna serves 16 radios if a 16-channel combiner is used. One observation from Fig. 4.2c should be mentioned here. The two transmitting antennas in each sector are placed relatively closer to the receiving antennas than in the single transmitting antenna case. This may cause some degree of desensitization in the receivers. The technology cited can combine 32 channels in a combiner; therefore, only one transmitting antenna is needed in each sector. However, this one transmitting antenna must be capable of withstanding a high degree of transmitted power. If each channel transmits 100 W, the total power that the antenna terminal could withstand is3.2 kW.

The 32-channel combiner has a power limitation which would be specified by different manufacturers. Two receiving antennas in each 120° sector remain the same for space diversity use.

5. Explain the antenna arrangement of space diversity used at cell site.

Space-Diversity Antennas Used at Cell Site:

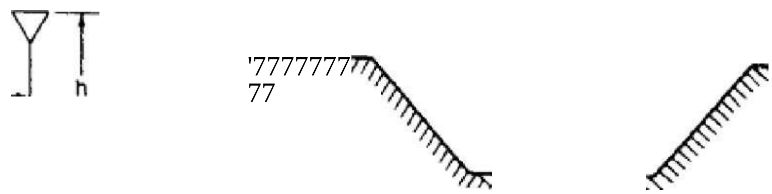
Two-branch space-diversity antennas are used at the cell site to receive the same signal with different fading envelopes, one at each antenna. The degree of correlation between two fading envelopes is determined by the degree of separation between two receiving antennas. When the two fading envelopes are combined, the degree of fading is reduced. Here the antenna setup is shown in Fig. 5a.

Equation is presented as an example for the designer to use.

$$n = h/D = 11 \quad (8.13\text{-}1)$$

where h is the antenna height and D is the antenna separation. From Eq., the separation d > 8X is needed for an antenna height of 100 ft (30 m) and the separation d > 14A, is needed for an antenna height of 150 ft (50 m). In any omnicell system, the two space-diversity antennas should be aligned with the terrain, which should have a U shape as shown in Fig.5b. Space-diversity antennas can separate only horizontally, not vertically; thus, there is no advantage in using a vertical separation in the design.

V



'77777777
77

(a)

Arilenna A h Antenna g
f=ì
h

(b)

Fig.5.Diversity antenna spacing at cell site: (a) n=h/d (b) Proper arrangement with two antennas

6. Explain how umbrella pattern antennas are used as the cell site antennas. Umbrella-Pattern

Antennas:
In certain situations, umbrella-pattern antennas should be used for the cell-site antennas.

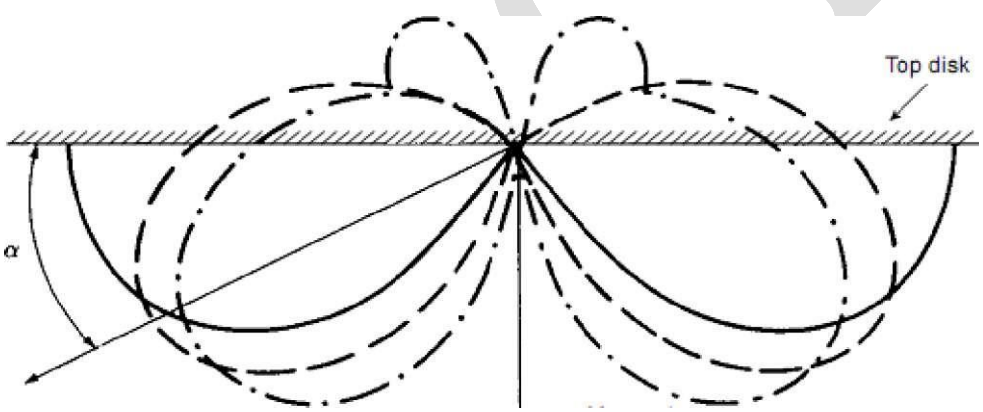


Fig.6.1.Vertical-plane patterns of quarter-wavelength stub antenna on infinite ground plane (solid) and on finite ground planes several wavelengths in diameter (dashed line) and about one wavelength in diameter (dotted line).

■*- Monopole

Normal Umbrella-Pattern Antenna:

For controlling the energy in a confined area, the umbrella-pattern antenna can be developed by using a monopole with a top disk (top-loading) as shown in Fig. 6.1. The size of the disk determines the tilting angle of the pattern. The smaller the disk, the larger the tilting angle of the umbrella pattern.

Broadband Umbrella-Pattern Antenna:

The parameters of a discone antenna (a bio conical antenna in which one of the cones is extended to 180° to form a disk) are shown in Fig.6.2a. The diameter of the disk, the length of the cone, and the opening of the cone can be adjusted to create an umbrella-pattern antenna.

High-Gain Broadband Umbrella-Pattern Antenna: A high-gain antenna can be constructed by vertically stacking a number of umbrella-pattern antennas as shown in Fig.6.2b.

$$E_0 = \frac{\sin[(Nd/2\lambda)\cos\phi]}{\sin[(d/2\lambda)\cos\phi]} \cdot \text{(individual umbrella pattern)}$$

where ϕ = direction of wave travel
N = number of elements
d = spacing between two adjacent elements

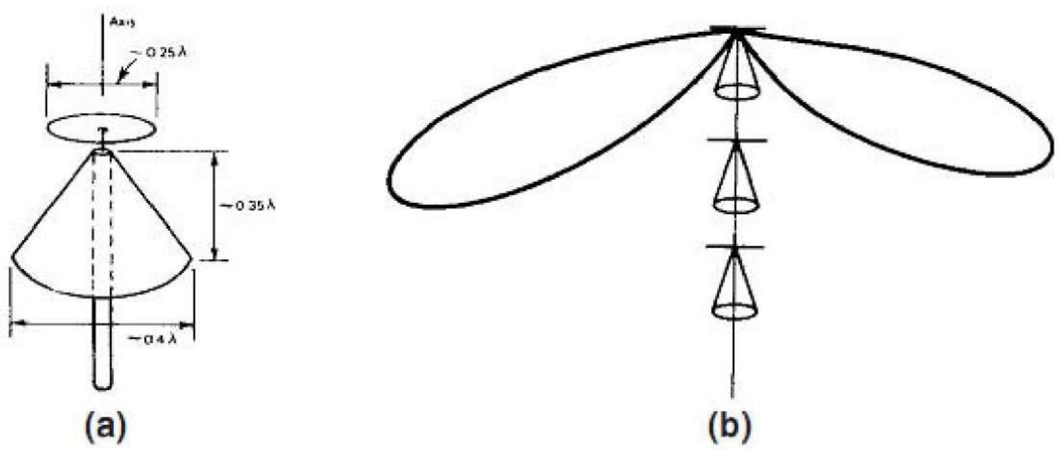


Fig.6.2. Discone antennas (a) Single antenna; (b) An array of antenna

Interference Reduction Antenna:

A design for an antenna configuration that reduces interference in two critical directions (areas) is shown in Fig.6.3. The parasitic (insulation) element is about 1.05 times longer than the active element.

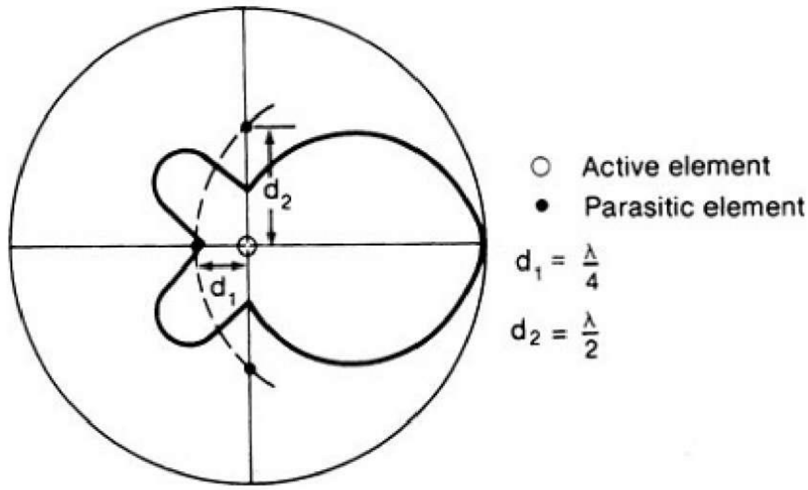


Fig.6.3. Application of parasitic elements

7. Explain in detail the unique situation of the antenna with neat diagram. Antenna Pattern in Free Space and in Mobile Environments:

The antenna pattern we normally use is the one measured from an antenna range (open, nonurban area) or an antenna dark room. However, when the antenna is placed in a suburban or urban environment and the mobile antenna is lower than the heights of the surroundings, the cell-site antenna pattern as a mobile unit received in a circle equidistant around the cell site is quite different from the free-space antenna pattern. Consider the following facts in the mobile radio environment.

1. The strongest reception still coincides with the strongest signal strength of the directional antenna.

2. The pattern is distorted in an urban or suburban environment.

3. For a 120° directional antenna, the back lobe (or front-to-back ratio) is about 10 dB less than the front lobe, regardless of whether a weak sidelobe pattern or no sidelobe pattern is designed in a free-space condition. This condition exists because the strong signal radiates in front, bouncing back from the surroundings so that the energy can be received from the back of the antenna. The energy-reflection mechanism is illustrated in Fig.7.

4. A design specification of the front-to-back ratio of a directional antenna (from the manufacturer's catalog) is different from the actual front-to-back ratio in the mobile radio environment. Therefore the environment and the antenna beamwidth determine how the antenna will be used in a mobile radio environment. For example, if a 60°directional antenna is used in a mobile radio environment, the actual front-to-back ratio can vary

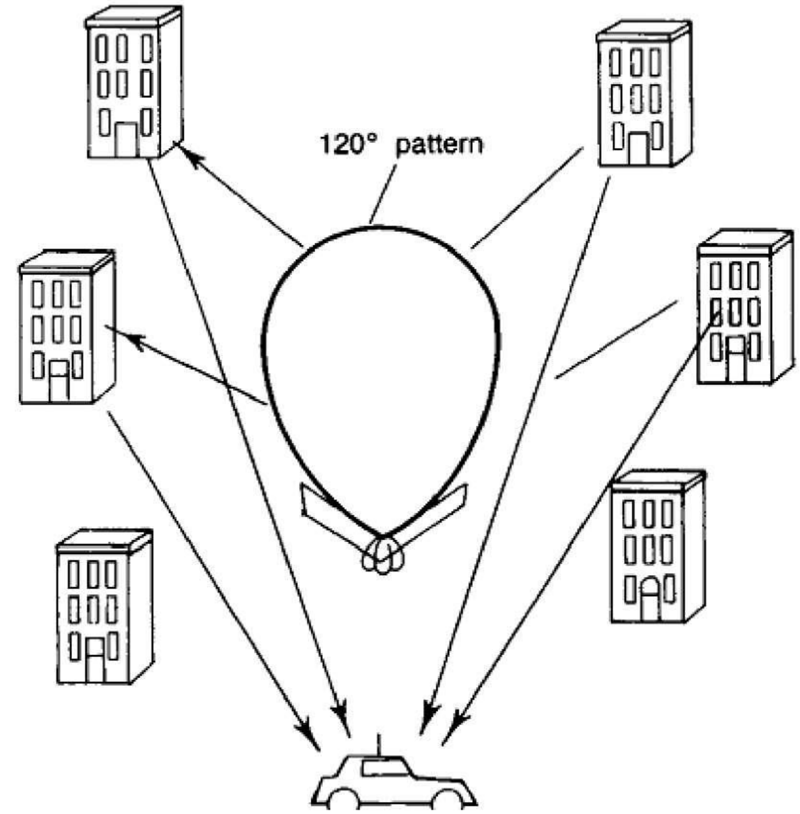


Fig.7. Front-to-back ratio of a directional antenna in a mobile radio environment

depending on the given environment. If the close-in man-made structures in front of the antenna are highly reflectable to the signal, then the front-to-back ratio of a low-master directional antenna can be as low as 6 dB in some circumstances. In this case, the directional antenna beamwidth pattern has no correlation between it measured in the free space and it measured in the mobile radio environment. If all the buildings are far away from the directional antenna, then the front-to-back ratio measured in the field will be close to the specified antenna pattern, usually 20 dB.

Regular Check of the Cell-Site Antennas:

Air-pressurized cable is often used in cell-site antennas to prevent moisture from entering the cable and causing excessive attenuation. One method of checking the cell-site antennas is to measure the power delivered to the antenna terminal; however, few systems have this capability. The other method is to measure the VSWR at the bottom of the tower. In this case the loss of reflected power due to the cable under normal conditions should be considered. For a high tower, the VSWR reading may not be accurate. If each cable connector has 1 -dB loss due to energy leakage and two midsection 1-dB loss connectors are used in the transmitted systems, the reflected power Pb indicated in the VSWR would be 4 dB less than the real reflected power.

Choosing an Antenna Site:

In antenna site selection we have relied on the point-to-point prediction method, which is applicable primarily for coverage patterns under conditions of light call traffic in the system. Reduction of interference is an important factor in antenna site selection. When a site is chosen on the map, there is a 50 percent chance that the site location cannot be acquired. A written rule states that an antenna location can be found within a quarter of the size of cell R/4. If the site is an 8-mi cell, the antenna can be located within a 2-mi radius. This hypothesis is based on the simulation result that the change in site within a 2-mi radius would not affect the coverage pattern at a distance 8 mi away. If the site is a 2-mi cell, the antenna can be located within a 0.5- mi radius. The quarter-radius rule can be applied only on relatively flat terrain, not in a hilly area. To determine whether this rule can be applied in a general area, one can use the point-to- point prediction method to plot the coverage at different site locations and compare the differences. Usually when the point-to-point prediction method (tool) can be used to design a system, the quarter-radius rule becomes useless.

8. Explain in detail about minimum separation of cell-site receiving antennas. Minimum Separation of Cell-

Site Receiving Antennas:

Separation between two transmitting antennas should be minimized to avoid the intermodulation. The minimum separation between a transmitting antenna and a receiving antenna is necessary to avoid receiver desensitization. Here we are describing a minimum separation between two receiving antennas to reduce the antenna pattern ripple effects. The two receiving antennas are used for a space-diversity receiver. Because of the near field disturbance due to the close spacing, ripples will form in the antenna patterns (Fig.8). The difference in power reception between two antennas at different angles of arrival is shown in Fig. 8. If the antennas are located closer; the difference in power between two antennas at a given pointing angle increases. Although the power difference is confined to a small sector, it affects a large section of the street as shown in Fig. 8. If the power difference is excessive, use of space diversity will have no effect reducing fading. At 850 MHz, the separation of eight wavelengths between two receiving antennas creates a power difference of ±2 dB, which is tolerable for the advantageous use of a diversity scheme.

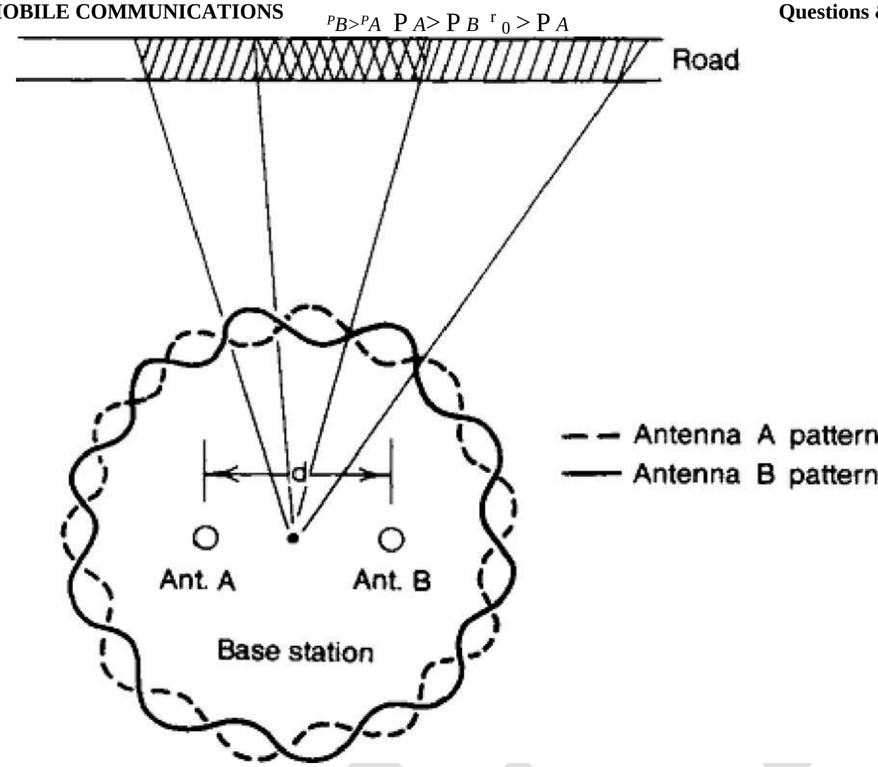


Fig.8. Antenna pattern ripple effect

9. Explain the following,

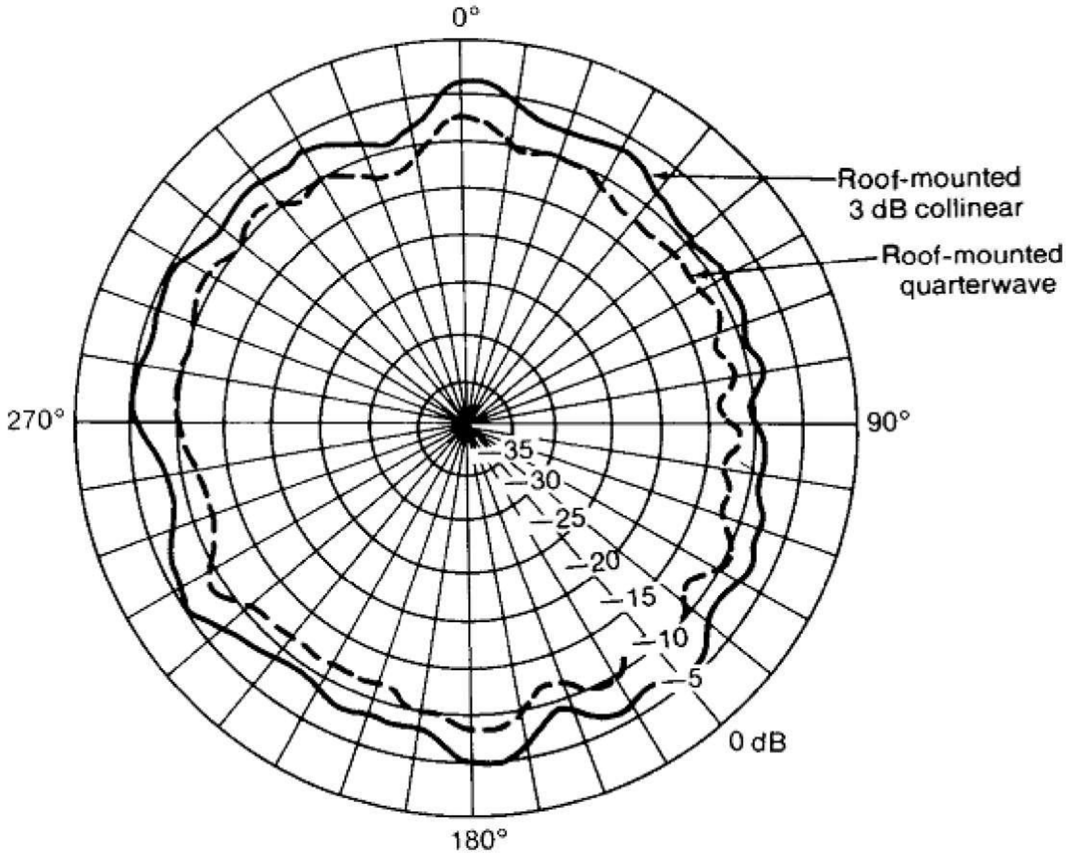
(a) Roof mounted antennas

(b) Glass mounted antennas

(c) Mobile high gain antennas.

Mobile Antennas:

The requirement of a mobile (motor-vehicle-mounted) antenna is an omnidirectional antenna that can be located as high as possible from the point of reception. However, the physical limitation of antenna height on the vehicle restricts this requirement. Generally, the antenna should at least clear the top of the vehicle. Patterns for two types of mobile antenna are shown in Fig. 9.1.

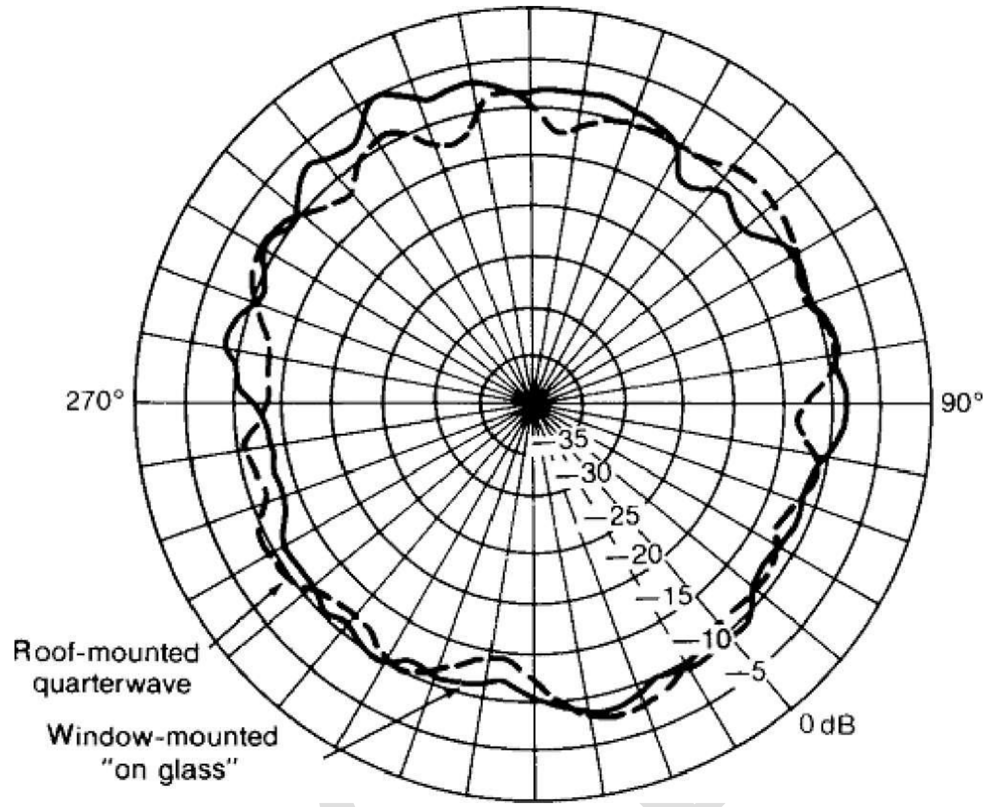


(a)

0°

Roof-Mounted Antenna:

The antenna pattern of a roof-mounted antenna is more or less uniformly distributed around the mobile unit



1S0°

Fig.9.1. Mobile antenna patterns (a) Roof mounted 3-dB-gain collinear antenna versus roof-mounted quarter-wave antenna, (b) Window- mourned "on-glass" gain antenna versus roof-mounted quarter-wave antenna.

when measured at an antenna range in free space as shown in Fig.9.2. The 3-dBhigh- gain antenna shows a 3-dBgain over the quarter-wave antenna. However, the gain of the antenna used at the mobile unit must be limited to 3 dB because the cell-site antenna is rarely as high as the broadcasting antenna and out-of-sight conditions often prevail. The mobile antenna with a gain of more than 3 dB can receive only a limited portion of the total multipath signal in the elevation as measured under the out-of-sight condition.

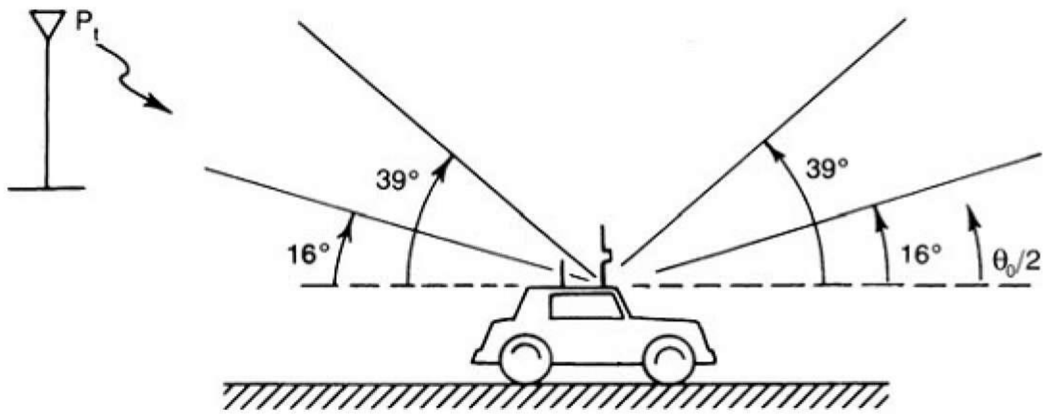


Fig.9.2. Vertical angle of signal arrival

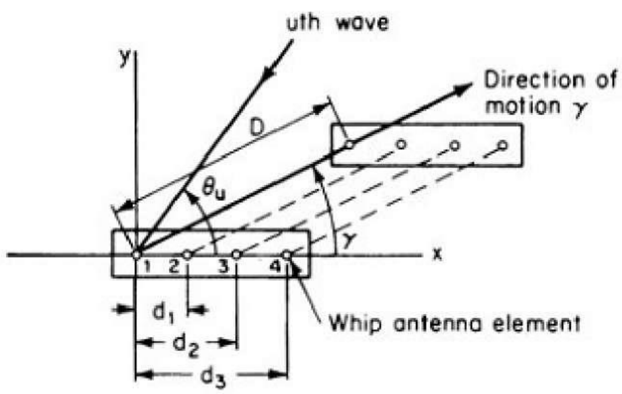
Glass-Mounted Antennas:

There are many kinds of glass-mounted antennas. Energy is coupled through the glass; therefore, there is no need to drill a hole. However, some energy is dissipated on passage through the glass. The antenna gain range is 1 to 3 dB depending on the operating frequency. The position of the glass-mounted antenna is always lower than that of the roof-mounted antenna; generally there is a 3-dBdifference between these two types of antenna. Also, glass mounted antennas cannot be installed on the shaded glass found in some motor vehicles because this type of glass has a high metal content.

Mobile High-Gain Antennas:

A high-gain antenna used on a mobile unit has been studied. This type of high-gain antenna should be distinguished from the directional antenna. In the directional antenna, the antenna beam pattern is suppressed horizontally; in the high-gain antenna, the pattern is suppressed vertically. To apply either a directional antenna or a high-gain antenna for reception in a radio environment, we must know the origin of the signal. If we point the directional antenna opposite to the transmitter site, we would in theory receive nothing. In a mobile radio environment, the scattered signals arrive at the mobile unit from every direction with equal probability. That is why an omnidirectional antenna must be used. The scattered signals also arrive from different elevation angles. Lee and Brandt used two types of antenna, one A/4 whip antenna with an elevation coverage of 39° and one 4-dB-gain antenna (4-dB gain with respect to the gain of a dipole) with an elevation coverage of 16° and measured the angle of signal arrival in the suburban Keyport-Matawan area of New Jersey. There are two types of test: a line-of-sight condition and an out-of-sight condition. In Lee and Brandt's study, the transmitter was located at an elevation of approximately 100 m (300 ft) above sea level. The measured areas were about 12 m (40 ft) above sea level and the path length about 3 mi. The received signal from the 4-dB-gain antenna was 4 dB stronger than that from the whip antenna under line-of-sight conditions. This is what we would expect. However, the received signal from the 4-dB-gain antenna was only about 2 dB stronger than that from the whip antenna under out-of-sight conditions. This is surprising. The reason for the latter observation is that the scattered signals arriving under out-of- sight conditions are spread over a wide elevation angle. A large portion of the signals outside the elevation angle of 16° cannot be received by the high-gain antenna. We may calculate the portion being received by the high-gain antenna from the measured beamwidth. For instance, suppose that a 4:1 gain (6 dBi) is expected from the high-gain antenna, but only 2.5:1 is received. Therefore, 63 percent of the signal is received by the 4-dB-gain antenna (i.e., 6 dBi) and 37 percent is felt in the region between 16 and 39°

	Gain, dBi	Linear ratio	$\theta_0/2$, degrees
Whip antenna (2 dB above isotropic)	2	1.58:1	39
High-gain antenna	6	4:1	16
Low-gain antenna	4	2.5:1	24



Therefore, a 2- to 3-dB-gain antenna (4 to 5 dBi) should be adequate for general use. An antenna gain higher than 2 to 3 dB does not serve the purpose of enhancing reception level. Moreover, measurements reveal that the elevation angle for scattered signals received in urban areas is greater than that in suburban areas.

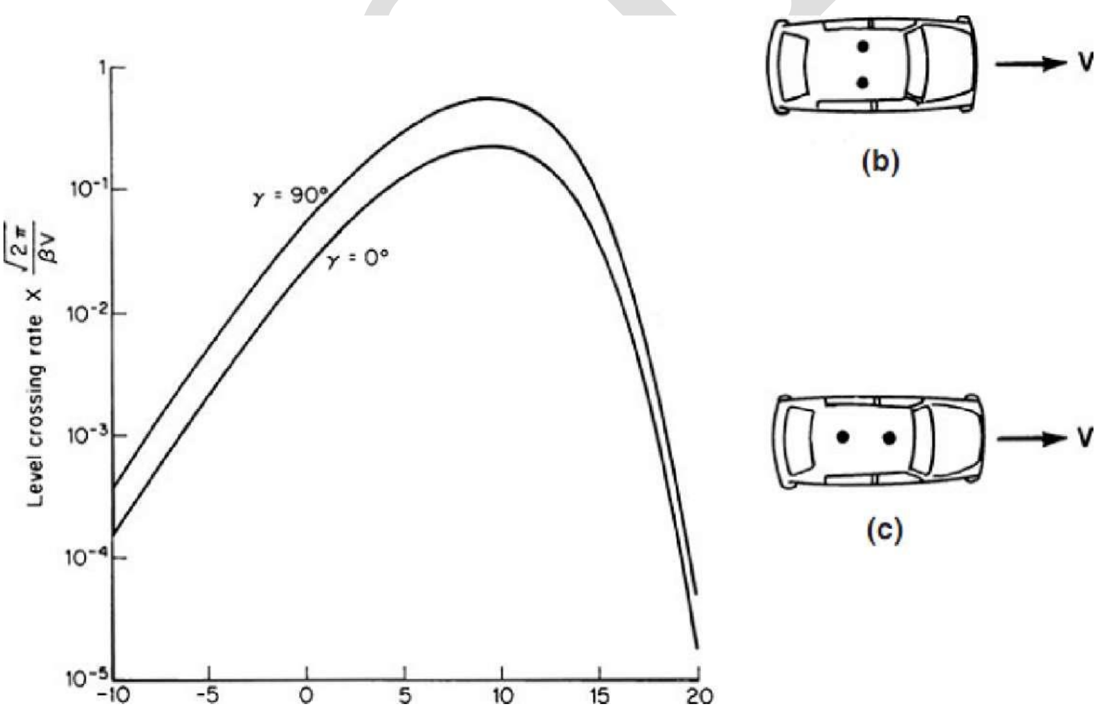
10. Explain the following,

(a) Horizontal oriented space diversity antenna

(b) Vertically Oriented space diversity antenna.

(a)Horizontally Oriented Space-Diversity Antennas:

A two-branch space-diversity receiver mounted on a motor vehicle has the advantage of reducing fading and thus can operate at a lower reception level. The advantage of using a space-diversity receiver to reduce interference. The discussion here concerns a space-diversity scheme in which two vehicle-mounted antennas separated horizontally by 0.5A wavelength (15 cm or 6 in) can achieve the advantage of diversity. We must consider the following factor. The two antennas can be mounted either in line with or perpendicular to the motion of the vehicle. Theoretical analyses and measured data indicate that the inline arrangement of the two antennas produces fewer level crossings, that is, less fading, than the perpendicular arrangement does. The level crossing rates of two signals received from different horizontally oriented space-diversity antennas are shown in Fig.10.1.



dB.wiih respect roihe rms voJue of a îingie channel

(a)

Fig.10.1. Horizontally spaced antennas. (a) Maximum difference in lcr of a four-branch equal-gain signal between a = 0 and a = 90 with antenna spacing 0.15X,; (b) Not recommended. (c) Recommended.

(b) Vertically Oriented Space-Diversity Antennas:

The vertical separation between two space-diversity antennas can be determined from the correlation between their received signals. The positions of two antennas X1 and X2 are shown in Fig.10.2. The theoretical derivation of correlation is

$$\rho\left(\frac{d}{\lambda},\theta\right) = \frac{\sin[(\pi d/\lambda)\sin\theta]}{(\pi d/\lambda)\sin\theta}$$

Equation is plotted in Fig.10.3. A set of measured data was obtained by using two antennas vertically separated by 1.5 A, wavelengths. The mean values of three groups of measured data are also shown in Fig. 10.3. In one group, in New York City, low correlation coefficients were observed. In two other groups, both in New Jersey, the average correlation coefficient for perpendicular streets was 0.35 and for radial streets, 0.225. The following table summarizes the correlation coefficients in different areas and different street orientations.

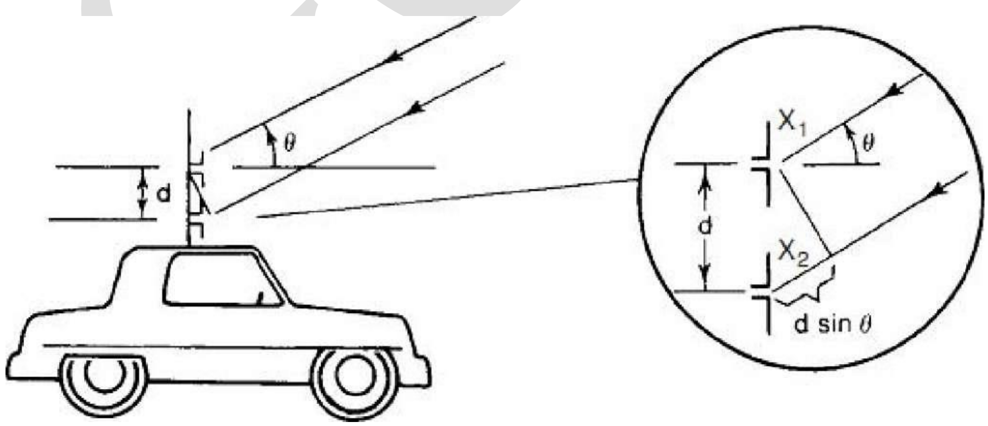


Fig.10.2. Vertical separation between two mobile antennas

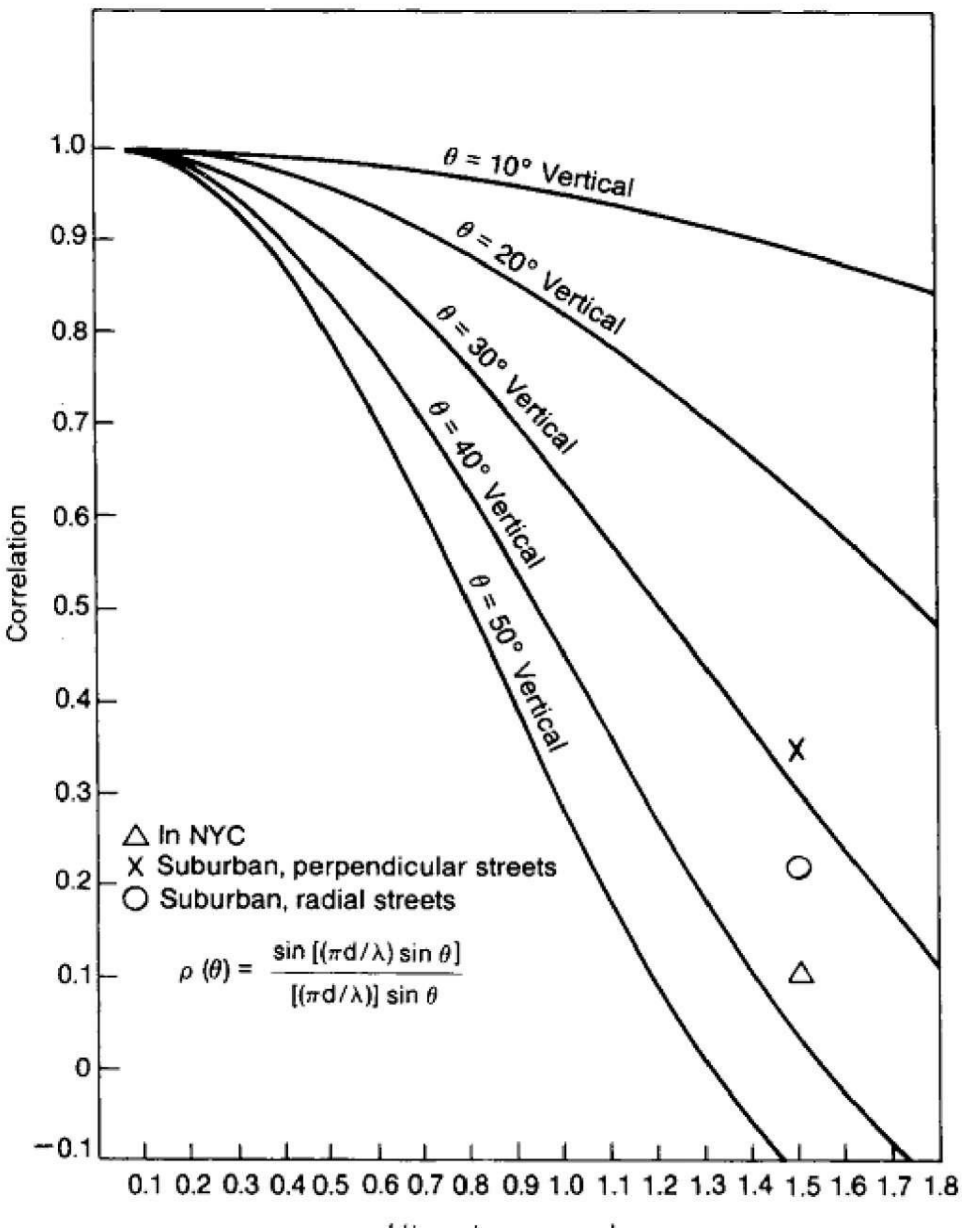


Fig.10.3. Two vertically spaced antennas mounted on a mobile unit

Area	Correlation Coefficient	
	Average	Standard Deviation
New York City	0.1	0.06
Suburban Neu Jersev		
Radial streets	0.226	0.127
Perpendicular streets	0.35	0.182

From Fig.10.3 we can also see that the signal arrives at an elevation angle of 29° in the suburban radial streets and 33° in the suburban perpendicular streets. In New York City the angle of arrival approaches 40°

Tutorial Class Topics and related Information

Unit VI: Tutorial Class

- sectorization
- Overlaid cells on fixed Channels assignment.
- channel assignments

UNIT-VI

1.Discuss the concept of frequency management concern to the numbering the channels and grouping into the subset.

Frequency Management:

The function of frequency management is to divide the total number of available channels into subsets which can be assigned to each cell either in a fixed fashion or dynamically (i.e., in response to any channel among the available channels). The terms "frequency management" and "channel assignment" often create some confusion. Frequency management refers to designating setup channels and voice channels (done by the FCC), numbering the channels (done by the FCC), and grouping the voice channels into subsets (done by each system according to its preference). Channel assignment refers to the allocation of specific channels to cell sites and mobile units. A fixed channel set consisting of one more subsets is assigned to a cell site on a long-term basis. During a call, a particular channel is assigned to a mobile unit on a short-term basis. For a short-term assignment, one channel assignment per call is handled by the mobile telephone switching office (MTSO). Ideally channel assignment should be based on causing the least interference in the system. However, most cellular systems cannot perform this way.

Numbering the channels:

The total number of channels at present (January 1988) is 832. But most mobile units an systems are still operating on 666 channels. Therefore we describe the 666 channel numbering first. A channel consists of two frequency channel bandwidths, one in the low band and one in the high band. Two frequencies in channel 1 are 825.030 MHz (mobile transmit) 870.030 MHz (cell-site transmit). The two frequencies in channel 666 are 844.98 MHz (mobile transmit) and 898 MHz (cell-site transmit). The 666 channels are divided into two groups: block A system and block B system. Each market (i.e., each city) has two systems for a duopoly market policy. Each block has 333 channels, as shown in Fig. 1.1.

The 42 set-up channels are assigned as follows.

block A

block B

block A
block B

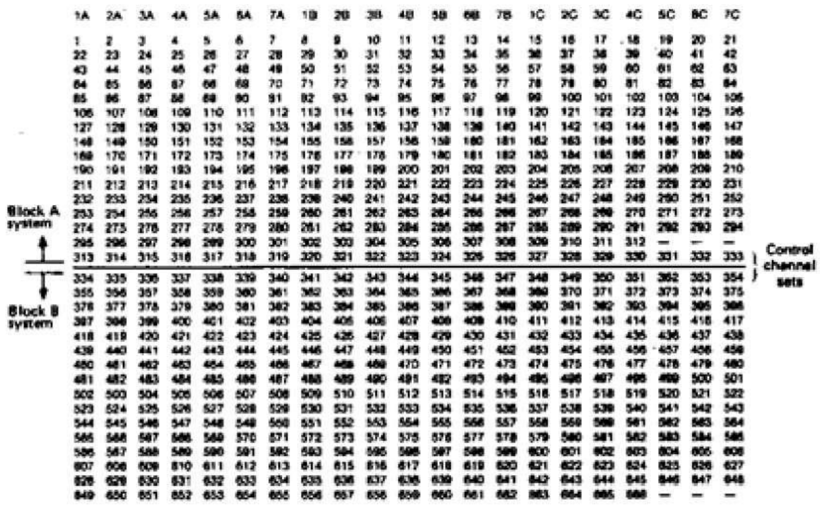
Channels 313-333

Channels 334-354

The voice channels are assigned as follows.

Channels 1-312 (312 voice channels)

Channels 355-666 (312 voice channels)



	1A	2A	3A	4A	5A	6A	7A	1B	2B	3B	4B	5B	6B	7B	1C	2C	3C	4C	5C	6C	7C	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	
	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	
	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	
	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	
	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	
	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	
	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	
	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	
	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	
Block A system	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	
	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	—	—	—	
	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	Control channel sets
	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	
	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	
Block B system	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	
	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	
	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	
	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	
	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	
	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	
	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	
	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	
	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	
	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	
	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	
	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	
	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	
	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	—	—	—	

Fig. 1.1. Frequency management chart

These 42 set-up channels are assigned in the middle of all the assigned channels to facilitate scanning of those channels by frequency synthesizers. In the new additional spectrum allocation of 10 MHz (sec Fig. 1.2.), an additional 166 channels are assigned. Since a 1 MHz is assigned below 825 MHz (or 870 MHz) in the future, additional channels will be numbered up to 849 MHz (or 894 MHz) and will then circle back.

M DEM T*
fiwt 935 BIS a-si mi Big Sii MHI

A	ft	B	A	8	ft

OMIT** 991 1 333 Ö« Ìli 799
10Ï3

The last channel number is 1023. There are no Channels between channels 799 and 991.

C»:l »it* Tj
free 369 $.7$ 69C 3» Siti ££4 «98 M Hi

A	A	0	A	S	Ft

Chini» t 991 1 333 66$ Tltì T&9
T039

Fig.1.2. New additional spectrum allocation

Grouping into subsets:

The number of voice channels for each system is 312. We can group these into any number of subsets. Since there are 21 set-up channels for each system, it is logical to group the 312 channels into 21 subsets. Each subset then consists of 16 channels. In each set, the closest adjacent channel is 21 channels away, as shown in Fig. 1.1. The 16 channels in each subset can be mounted on a frame and connected to a channel combiner. Wide separation between adjacent channels is required for meeting the requirement of minimum isolation. Each 16- channel subset is idealized for each 16-channel combiner. In a seven- cell frequency-reuse cell system each cell contains three subsets, iA+iB+iC, where i is an integer from 1 to 7. The total number of voice channels in a cell is about 45. The minimum separation between three subsets is 7 channels. If six subsets are equipped in an omnicell site, the minimum separation between two adjacent channels can be only three (21/6> 3) physical channel bandwidths.

For example,

1A+1B+1C+4A+4B +4C

or 1A+1B+1C+5A+5B+5C

2. What are the different techniques to utilize the frequency spectrum, give a brief explanation?

Frequency -Spectrum Utilization:

Since the radio-frequency spectrum is finite in mobile radio systems, the most significant challenge is to use the radio-frequency spectrum as efficiently as possible. Geographic location is an important factor in the application of the frequency-reuse concept in mobile cellular technology to increase spectrum efficiency. Frequency management involving the assignment of proper channels in different cells can increase spectrum efficiency. Thus, within a cell the channel assignment for each call is studied.

The techniques for increasing frequency spectrum can be classified as

5. Increasing the number of radio channel using narrow banding, spread spectrum, or time division.

6. Improving spatial frequency-spectrum reuse.

7. Frequency management and channel assignment.

8. Improving spectrum efficiency in time.

5. Reducing the load of invalid calls

    a. Off-air call setup—reducing the load of setup channels

b. Voice storage service for No-Answer calls
c. Call forwarding
d. Reducing the customers' Keep-Dialing cases
e. Call waiting for Busy-Call situations
f. Queuing

3. Explain in detail about grouping of Set-up channels.

Set-up channels also called control channels are the channels designated to setup calls. We should not be confused by fact that a call always needs a set-up channel. A system can be operated without set-up channels. If we are choosing such a system all the 333 channels in each cellular system (block A or block B) can be voice channels; however each mobile unit must then scan 333 channels continuously and detect the signaling for its call. A customer who wants to initiate a call must scan all the channels and find an idle (unoccupied) one to use.

In a cellular system, we are implementing frequency-reuse concepts. In this case the set-up channels are acting as control channels. The 21 set-up channels are taken out from the total number of channels. The number 21 is derived from a seven-cell frequency-reuse pattern with three 120° sectors per cell, or a total of 21 sectors, which require 21 set-up channels. However, now only a few of the 21 setup channels are being used in each system. Theoretically, when cell size decreases the use of set-up channels should increase. Set-up channels can be classified by usage into two types: access channels and paging channels. An access channel is used for the mobile-originating calls and paging channels for the land originating calls. For this reason, a set-up channel is sometimes called an 'access channel' and sometimes called a 'paging channel.' Every two- way channel contains two 30-kHz bandwidth.. Normally one set-up channel is also specified by two operations as a forward set-up channel (using the upper band) and a reverse set-up channel (using the lower band). In the most common types of cellular systems, one set-up channel is used for both access and paging. The forward setup channel functions as the paging channel for responding to the mobile-originating calls. The reverse set-up channel functions as the access channel for the responder to the paging call. The forward set-up channel is transmitted at the cell site, and the reverse set-up channel is transmitted at the mobile unit. All set-up channels carry data information only.

4. Explain in detail access channels and operational techniques. Access

channels:

In mobile-originating calls, the mobile unit scans its 21 set-up channels and chooses the strongest one. Because each set-up channel is associated with one cell, the strongest set-up channel indicates which cell is to serve the mobile-originating calls. Th. mobile unit detects the system information transmitted

from the cell site. Also, the mobile unit monitors the Busy/Idle status bits over the desired forward setup channel. When the idle bits are received, the mobile unit can use the corresponding reverse set-up channel to initiate a call.
Frequently only one system operates in a given city; for instance, block B system might be operating and the mobile unit could be set to "preferable A system." When the mobile unit first scans the 21 set-up channels in block A, two conditions can occur.

1. If no set-up channels of block A are operational, the mobile unit automatically switches to block B.

2. If a strong set-up signal strength is received but no message can be detected, then the scanner chooses the second strongest set-up channel. If the message still cannot be detected, the mobile unit switches to block B and scans to block B set-up channels.

The operational functions are described as follows:

1. **Power of a forward set-up channel [or forward control channel (FOCC)]:** The power of the set-up channel can be varied in order to control the number of incoming calls served by the cell. The number of mobile-originating calls is limited by the number of voice channels in each cell site, when the traffic is heavy, most voice channels are occupied and the power of the set-up channel should be reduced in order to reduce the coverage of the cell for the incoming calls originating from the mobile unit. This will force the mobile units to originate calls from other cell sites, assuming that all cells are adequately overlapped.

2. **The set-up channel received level:** The setup channel threshold level is determined in order to control the reception at the reverse control channel (RECC). If the received power level is greater than the given set-up threshold level, the call request will be taken.

3. **Change power at the mobile unit:** When the mobile unit monitors the strongest signal strength from all Set-up channels and selects that channel to receive the messages, there are three types of message.
    a. **Mobile station control message.** This message is used for paging and consists of one, two, or four words -DCC, MIN, SCC and VMAX.
    b. **System parameter overhead message.** This message contains two words, including DCC, SID, CMAX, or CPA.
    c. **Control-filler message.** This message may be sent with a system parameter overhead message, CMAC—a control mobile attenuation code (seven levels).

4. **Direct call retry.** When a cell site has no available voice channels, it can send a direct call- retry message through the set-up channel. The

mobile unit will initiate, the call from a neighboring cell which is on the list of neighboring cells in the direct call-retry message.

5. Explain about paging channels.

Paging channels:

Each cell site has been allocated its own setup channel (control channel). The assigned forward set-up channel (FOCC) of each cell site is used to page the mobile unit with the same mobile station control message.

Because the same message is transmitted by the different set-up channels, no simulcast interference occurs in the system. The algorithm for paging & mobile unit can be performed in different ways. The simplest way is to page from all the cell sites. This can occupy a large amount of the traffic load. The other way is to page in an area corresponding to the mobile unit phone number. If there is no answer, the system tries to page in other areas. The drawback is that response time is sometimes too long. When the mobile unit responds to the page on the reverse set-up channel, the cell site which receives the response checks the signal reception level and makes a decision regarding the voice channel assignment based on least interference in the selected sector or underlay-overlay region.

6. Write the concept of the self location scheme at the mobile unit and the autonomous registration.

Self -location scheme at the mobile unit:

In the cellular system, 80 percent of calls originate from the mobile unit but only 20 percent originate, from the land line. Thus, it is necessary to keep the reverse set-up channels as open as possible. For this reason, the self-location scheme at the mobile unit is adapted. The mobile unit selects a set-up channel of one cell site and makes a mobile-originating call. It is called a self- location scheme.

However, the self-location scheme at the mobile unit prevents the mobile unit from sending the necessary information regarding its location to the cell site. Therefore, the MTSO does not know where the mobile is. When a land-line call is originated, the MTSO must page all the cell sates In order to search for the mobile unit. Fortunately, land-line calls constitute only 20 percent of land-line originating calls, so the cellular system has no problem in handling them. Besides, more than 50 percent of land-line originating calls are no response.

Autonomous registration:

If a mobile station is equipped for autonomous registration, then the mobile station stores the value of the last registration number (REGID) received on a forward control channel. Also, a REGINCR (the increment in time between registrations) is received by the mobile station. The next registration ID should be

$$NXTREG = REGID + REGINCR$$

This tells the mobile unit how long the registration should be repeatedly sent to the cell site, so that the MTSO can track the location of the mobile. This feature is not used in cellular systems at present. However when the volume of land-line calls begins to increase or the number of cell sites increases, this feature would facilitate paging of the mobile units with less occupancy time on all set-up channels.

7. Write about fixed channel assignment schemes in detail.

Fixed Channel Assignment Schemes: Adjacent-Channel Assignment:

Adjacent-channel assignment includes neighboring-channel assignment and next-channel assignment. The near-end-far-end (ratio) interference, can occur among the neighboring channels (four channels on each side of the desired channel). Therefore, within a cell we have to be sure to assign neighboring channels in an omnidirectional-cell system and in a directional- antenna-cell system properly. In an omnidirectional-cell system, if one channel is assigned to the middle cell of seven cells, next channels cannot be assigned in the same cell. Also, no next channel (preferably including neighboring channels) should be assigned in the six neighboring sites in the same cell system area (Fig. 7.1a). In a directional-antenna-cell system, if one channel is assigned to a face, next channels cannot be assigned to the same face or to the other two faces in the same cell. Also, next channels cannot be assigned to the other two faces at the same cell site (Fig. 7.1b). Sometimes the next channels are assigned in the next sector of the same cell in order to increase capacity. Then performance can still be in the tolerance range if the design is proper.

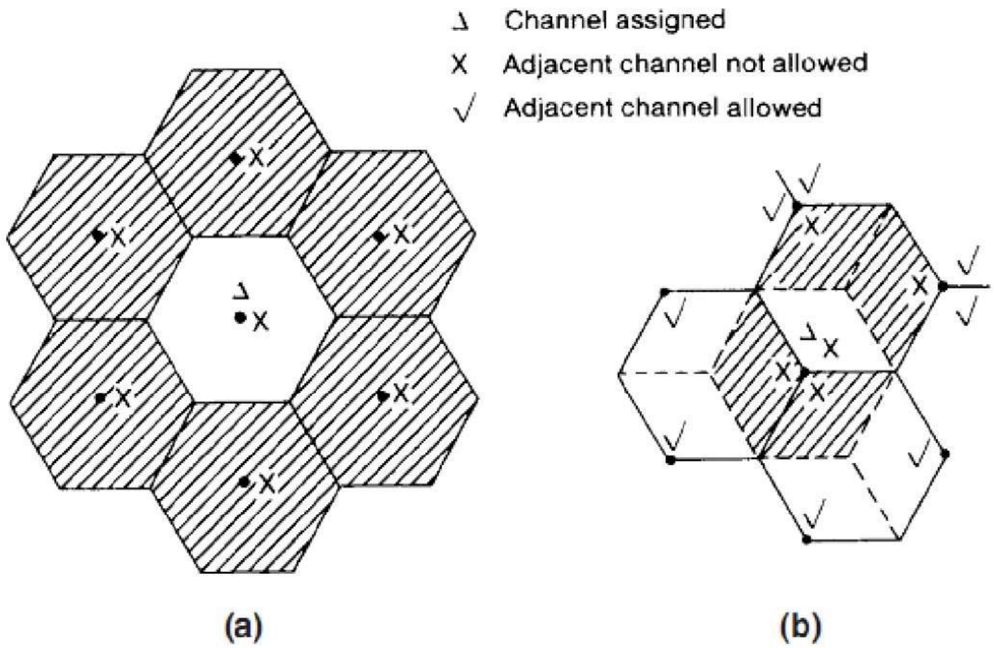


Fig.7.1 Adjacent channel assignment (a) Omni direction antenna cells; (b) Directional antenna cells

Channel Sharing:

Channel sharing is a short-term traffic-relief scheme. A scheme used for a seven-cell three-face system is shown in Fig. 7.2. There are 21 channel sets, with each set consisting of about 16 channels. Figure7.2 shows the channel set numbers. When a cell needs more channels, the channels of another face at the same cell site can be shared to handle the short-term overload. To obey the adjacent-channel assignment algorithm, the sharing is always cyclic. Sharing always increases the trunking efficiency of channels. Since we cannot allow adjacent channels to share with the nominal channels in the same cell, channel sets 4 and 5 cannot both be shared with channel sets 12 and 18, a indicated by the grid mark. Many grid marks are indicated in Fig.7.2 for the same reason. However, the upper subset of set 4 can be shared with the lower subset of set 5 with no interference. In channel-sharing systems, the channel combiner should be flexible in order to combine up to 32 channels in one face in real time. An alternative method is to install a standby antenna.

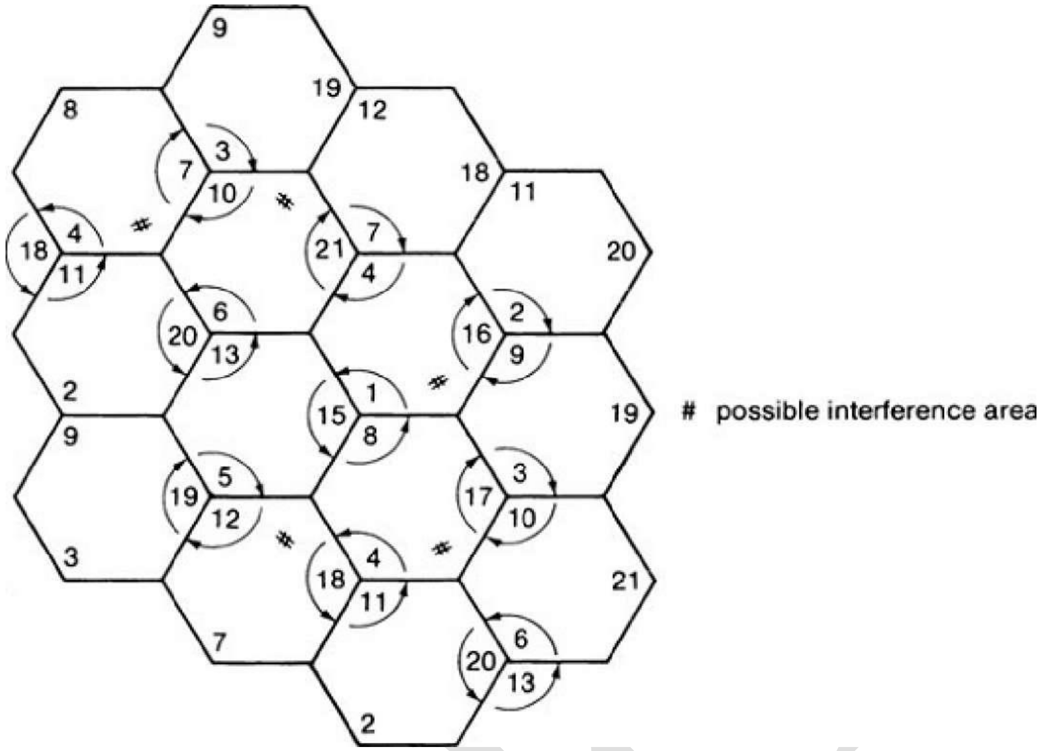


Fig.7.2. Channel sharing algorithm

Channel Borrowing:

Channel borrowing is usually handled on a long-term basis. The extent of borrowing more available channels from other cells depends on the traffic density in the area. Channel borrowing can be implemented from one cell-site face to another face at the same cell site. In addition, the central cell site can borrow channels from neighboring cells. The channel-borrowing scheme is used primarily for slowly-growing systems. It is often helpful in delaying cell splitting in peak traffic areas. Since cell splitting is costly, it should be implemented only as a last resort.

8. What are the advantages of sectorized cells?

Advantage of Sectorization:

The total number of available channels can be divided into sets (subgroups) depending on the sectorization of the cell configuration: the 120°-sector system, the 60°-sector system, and the 45°-sector system. A seven-cell system usually uses three 120°sectors per cell, with the total number of channel sets being 21. In certain locations and special situations, the sector angle can be reduced (narrowed) in order to assign more channels in one sector without increasing neighboring-channel interference. Sectorization serves the same purpose as the channel- borrowing scheme in delaying cell splitting. In addition, channel coordination to avoid cochannel interference is much easier in sectorization than in cell splitting. Given the same number of channels, trunking efficiency decreases in sectorization.

9. Compare the omni cells and sectorized cells.

Comparison of Omni cells (Non sectorized Cells) and Sectorized Cells: Omni cells:

If a K = 7 frequency-reuse pattern is used, the frequency sets assigned in each cell can be followed by the frequency-management chart. However, terrain is seldom flat; therefore, K = 12 is sometimes needed for reducing cochannel interference. For K = 12, the channel-reuse distance is D = 6R, or the cochannel reduction factor q = 6.

Sectorized Cells: There are three basic types.

4. The 120°-sector cell is used for both transmitting and receiving sectorization. Each sector has an assigned a number of frequencies. Changing sectors during a call requires handoffs.
5. The 60°-sector cell is used for both transmitting and receiving sectorization. Changing sectors during a call requires handoffs. More handoffs are expected for a 60° sector than a 120° sector in areas close to cell sites (close-in areas).
6. The 120° or 60°-sector cell is used for receiving sectorization only. In this case, the transmitting antenna is omnidirectional. The number of channels in this cell is not sub- divided for each sector. Therefore, no handoffs are required when changing sectors. This receiving-sectorization-only configuration does not decrease interference or increase the D/R ratio; it only allows for a more accurate decision regarding handing off the calls to neighboring cells.

10. Explain about the Underlay-Overlay Arrangement.

Underlay-Overlay Arrangement:

In actual cellular systems cell grids are seldom uniform because of varying traffic conditions in different areas and cell-site locations.

Overlaid Cells: To permit the two groups to reuse the channels in two different cell-reuse patterns of the same size, an "underlaid" small cell is sometimes established at the same cell site as the large cell (see Fig. 10a). The "doughnut" (large) and "hole" (small) cells are treated as two different cells. They are usually considered as "neighboring cells."

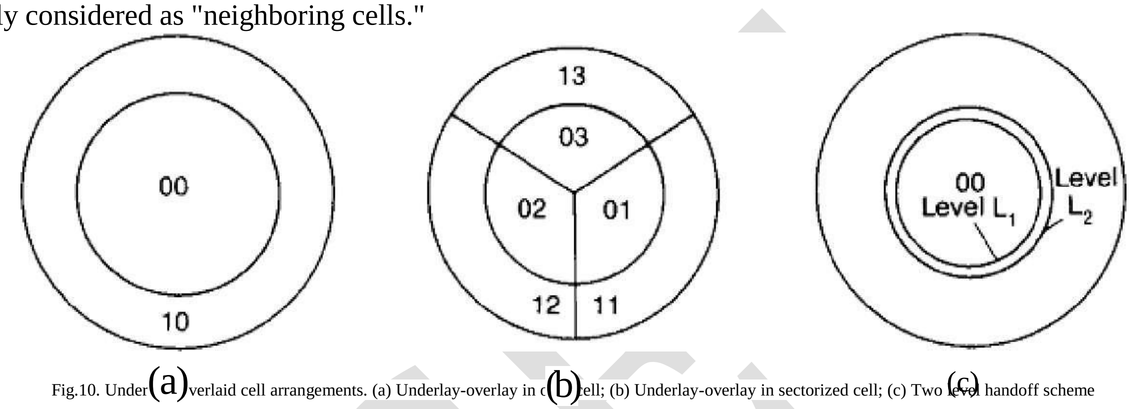


Fig.10. Underlaid-overlaid cell arrangements. (a) Underlay-overlay in omni cell; (b) Underlay-overlay in sectorized cell; (c) Two level handoff scheme

The use of either an omnidirectional antenna at one site to create two sub ring areas or three directional antennas to create six subareas is illustrated in Fig. 10b. As seen in Fig.10, a set of frequencies used in an overlay area will differ from a set of frequencies used in an underlay area in order to avoid adjacent-channel and cochannel interference.

The channels assigned to one combiner—say, 16 channels—can be used for overlay, and another combiner can be used for underlay.

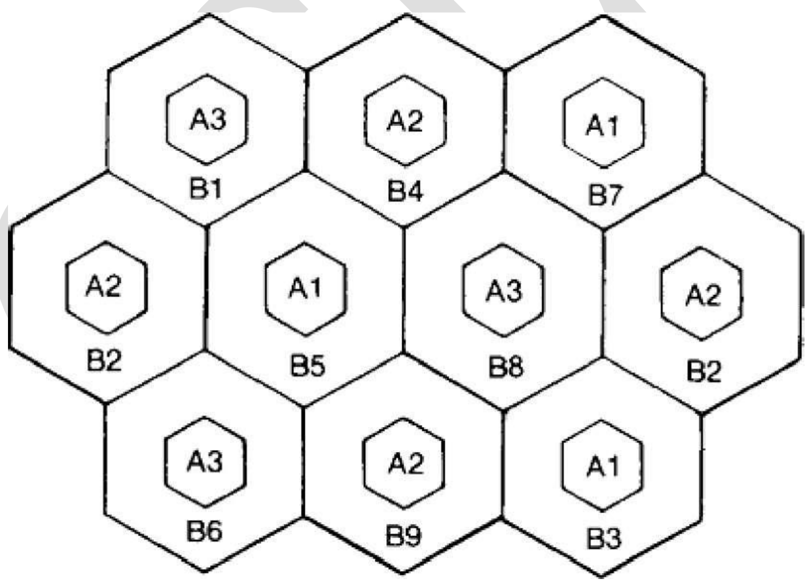
Implementation:

The antenna of a set-up channel is usually omnidirectional. When an incoming call is received by the set-up channel and its signal strength is higher than a level L, the underlaid cell is assigned; otherwise, the overlaid cell is assigned. The handoffs are implemented between the underlaid and overlaid cells. In order to avoid the unnecessary handoffs, we may choose two levels L1 and L2 and L1 > L2 as shown in Fig. 10(c). When a mobile signal is higher than a level L1 the call is handed off to the underlaid cell. When a signal is lower than a level L2 the call is handed off to the overlaid cell. The channels assigned in the underlaid cell have more protection against cochannel interference.

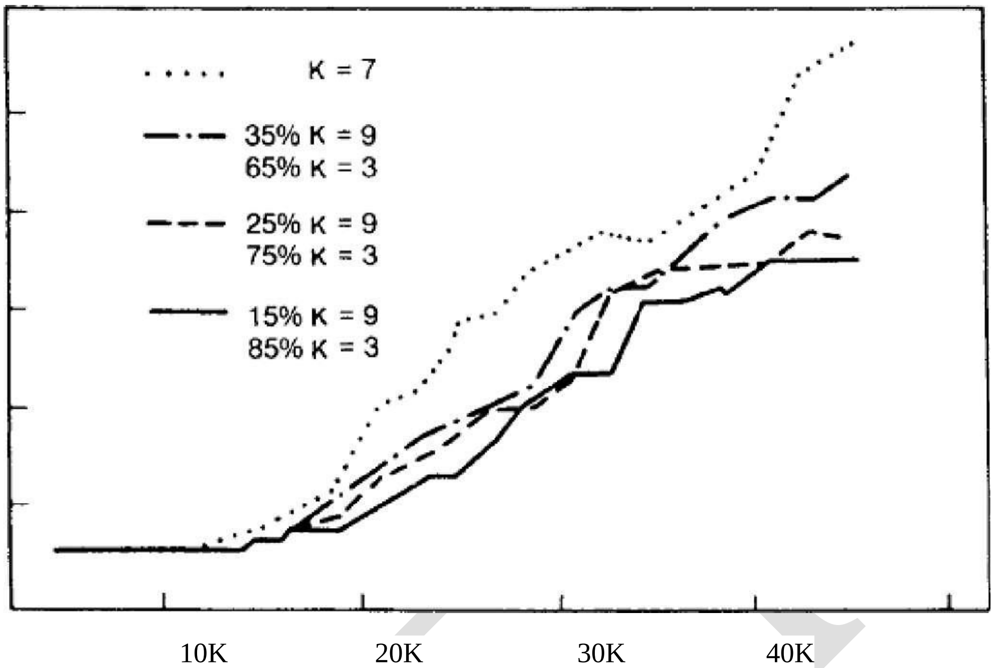
11. Present the reuse partition scheme in overlaid cell system, mention the advantages associated with it.

Reuse Partition:

Through implementation of the overlaid-cell concept, one possible operation is to apply a multiple-K system operation, where K is the number of frequency-reuse cells. The conventional system uses K = 7. But if one K is used for the underlaid cells, then this multiple-K system can have an additional 20 percent more spectrum efficiency than the single K system with an equivalent voice quality. In Fig. 11(a), the K = 9 pattern is assigned to overlaid cells and the K = 3 pattern is assigned to underlaid cells. Based on this arrangement the number of cell sites can be reduced, while maintaining the same traffic capacity. The decrease in the number of cell sites which results from implementation of the multiple K systems is shown in Fig. 11(b). The advantages of using this partition based on the range of K are



(a)



Customers (b)

120 **100 80**

Cell sites go 40

20

0

Fig.11. Reuse partition scheme (a) Reuse partition Ka=3; Kb=9; (b) Reuse partitioning performance

4. The K range is 3 to 9; the operational call quality can be adjusted and more reuse patterns are available if needed.

5. Each channel set of old K = 9 systems is the subset of new K = 3 systems. Therefore the amount of radio retuning in each cell in this arrangement is minimal.

6. When cell splitting is implemented, all present channel assignments can be retained.

12. What do you understand by non-fixed channel assignment? Describe the corresponding algorithms.

Non Fixed Channel Assignment Algorithms:

1. Fixed Channel Algorithm: The fixed channel assignment (FCA) algorithm is the most common algorithm adopted in many cellular systems. In this algorithm, each cell assigns its own radio channels to the vehicles within its cell.

2. Dynamic Channel Assignment: In dynamic channel assignment (DCA), no fixed channels are assigned to each cell. Therefore, any channel in a composite of N radio channels can be assigned to the mobile unit. This means that a channel is assigned directly to a mobile unit. On the basis of overall system performance, DCA can also be used during a call.

3. Hybrid Channel Assignment: Hybrid channel assignment (HCA) is a combination of FCA and DCA. A portion of the total frequency channels will use FCA and the rest will use DCA.

4. Borrowing Channel Assignment: Borrowing channel assignment (BCA) uses FCA as a normal assignment condition. When all the fixed channels are occupied, then the cell borrows channels from the neighboring cells.

5. Forcible-Borrowing Channel Assignment: In forcible-borrowing channel assignment (FBCA), if a channel is in operation and the situation warrants it, channels must be borrowed from the neighboring cells and at the same time, another voice channel will be assigned to continue the call in the neighboring cell. There are many different ways of implementing FBCA. In a general sense, FBCA can also be applied while accounting for the forcible borrowing of the channels within a fixed channel set to reduce the chance of cochannel assignment in a reuse cell pattern. The FBCA algorithms based on assigning a channel dynamically but obeying the rule of reuse distance. The distance between the two cells is reuse distance, which is the minimum distance at which no cochannel interference would occur. Very infrequently, no channel can be borrowed in the neighboring cells. Even those channels currently in operation can be forcibly borrowed and will be replaced by a new channel in the neighboring cell or the neighboring cell of the neighboring cell. If all the channels in the neighboring cells cannot be borrowed because of interference problems, the FBCA stops.

13. Compare the average blocking in spatially uniform and non uniform traffic distribution for FCA, BCA and FBCA.

On the basis of the FBCA, FCA, and BCA algorithms, a seven-cell reuse pattern with an average blocking of 3 percent is assumed and the total traffic service in an area in 250 Erlangs. The traffic distributions are

(1) Uniform traffic distribution—11 channels per cell;

(2) A non uniform traffic distribution—the number of channels in each cell is dependent on the vehicle distribution (Fig.13.1).

The simulation model is described as follows:

1. Randomly select the cell (among 41 cells).

2. Determine the state of the vehicle in the cell (idle, off-hook, on-hook, and handoff)

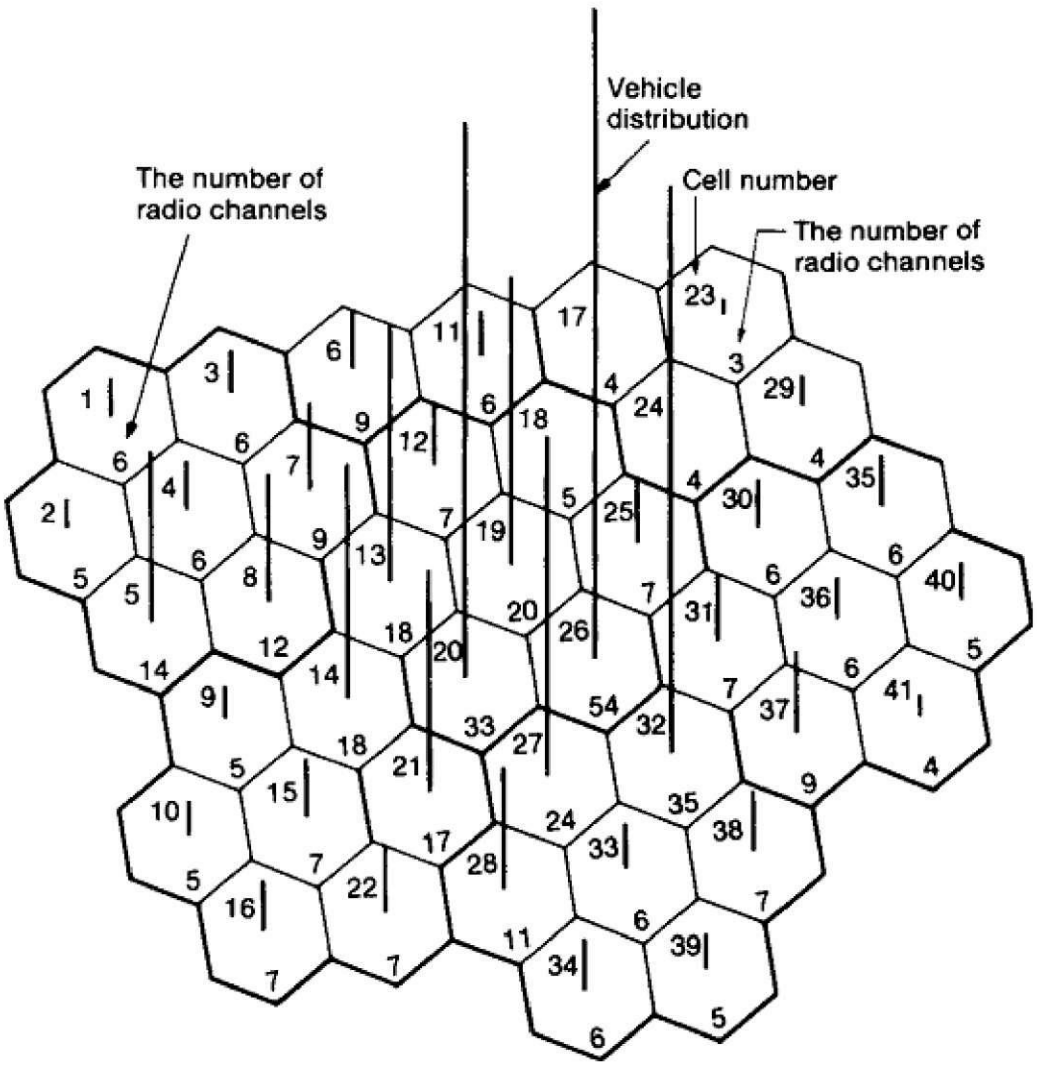
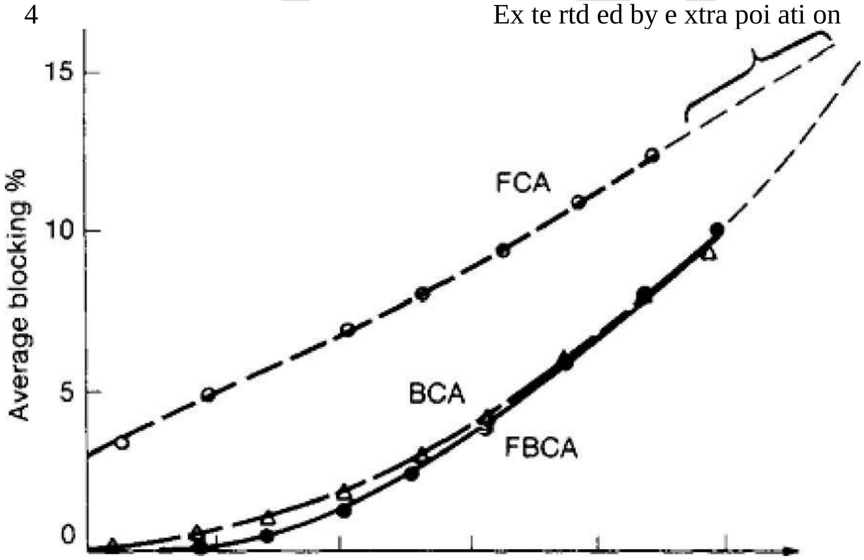


Fig. 13.1 Cellular system Vehicle and radio-channel distribution in the busy rush hour

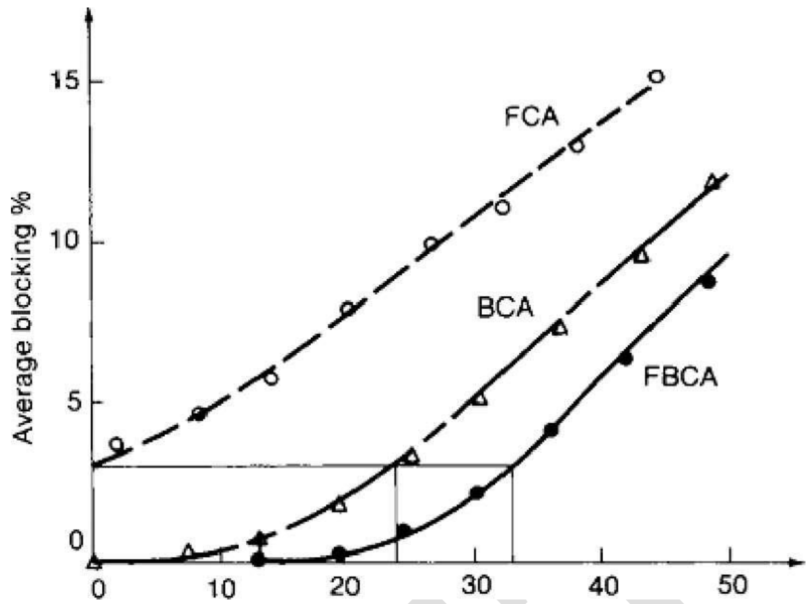
3. In off-hook or handoff state, search for an idle channel. The average number of handoffs is assumed to be 0.2 times per call. However, FBCA will increase the number of handoffs.

Average Blocking: Two average blocking cases illustrating this simulation are shown in Fig. 13.2. In a uniform traffic condition (Fig. 13.2a), the 3 percent blocking of both BCA and FBCA will result in a load increase of 28 percent, compared to 3 percent blocking of FCA. There is no difference between BCA and FBCA when a uniform traffic condition exists.

In a non uniform traffic distribution (Fig. 13.2b), the load increase in BCA drops to 23 percent and that of FBCA increases to 33 percent, as at an average blocking of 3 percent. The load increase can be utilized in another way by reducing the number of channels. The percent increase in load is the same as the percent reduction in the number of channels.



(a)



Load increase. % **(b)**

Fig.13.2. Comparison of average blockings from three different schemes (a) Average blocking in spatially uniform traffic distribution; (b) average blocking in spatially non uniform traffic distribution.

Handoff Blocking: Blocking calls from all handoff calls occurring in all cells is shown in Fig. 13.3. Handoff blocking is not considered as the regular cell blocking which can only occur at the call setup stage. In both BCA and FBCA, load is increased almost equally to 30 percent, as compared to FCA at 3 percent handoff blocking in uniform traffic (Fig. 13.3a). For a non uniform traffic distribution, the load increase of both BCA and FBCA at 4 percent blocking is about 50 percent (Fig. 13.3b), which is a big improvement, considering the reduction in interference and blocking. Otherwise, there would be multiple effects from interference in several neighboring cells.

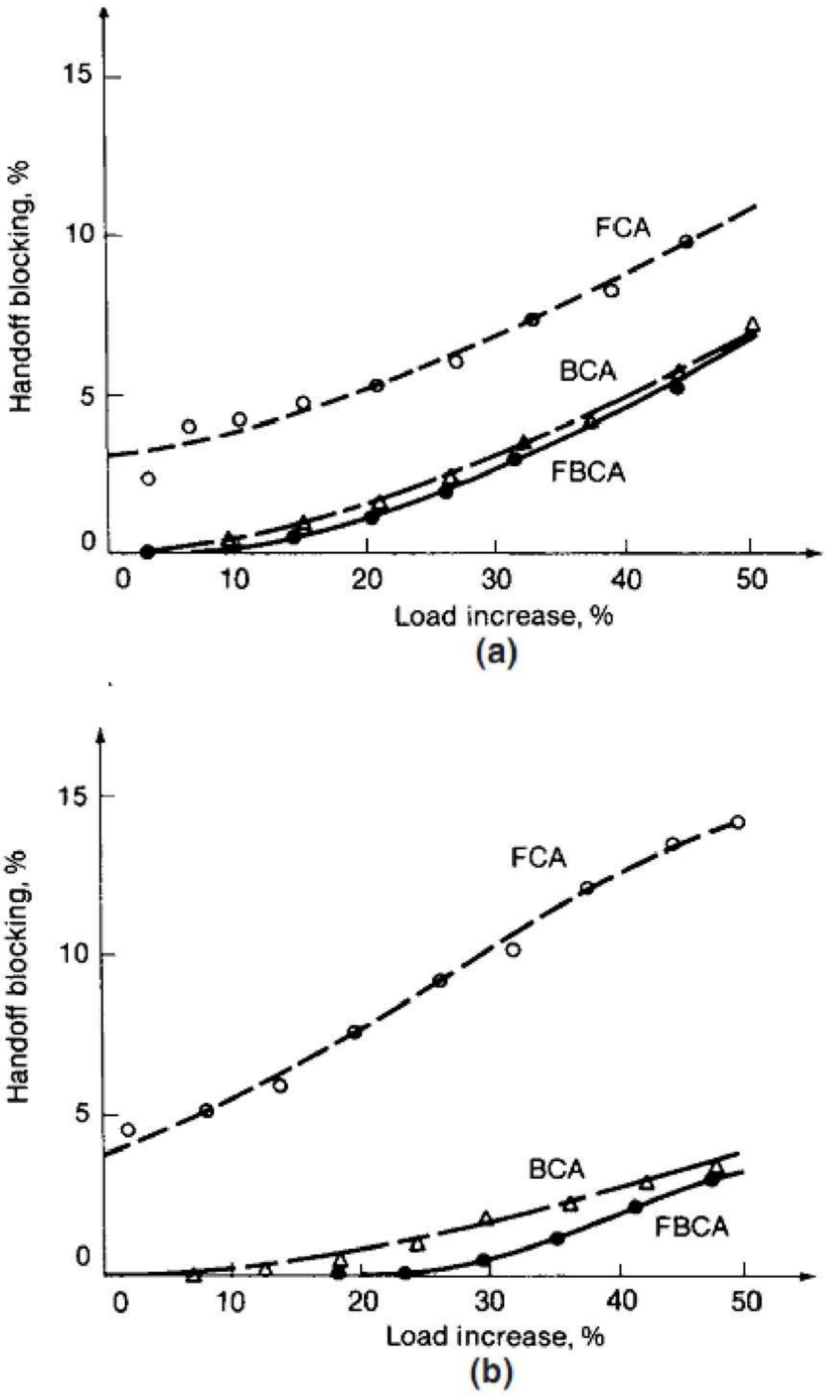


Fig.13.3. Comparison of handoff blocking from three different schemes (a) Handoff blocking in spatially uniform traffic distribution; (b) handoff blocking in spatially non uniform traffic distribution.

Tutorial Class Topics and related Information

Unit VII: Tutorial Class

- handoff invitation
- Mobile assigned handoff
- vehicle locating methods

UNIT-VII

1.Why hand off is necessary ?

In an analog system, once a call is established, the set-up channel is not used again during the call period. Therefore, handoff is always implemented on the voice channel. In the digital systems, the handoff is carried out through paging or common control channel. The value of implementing handoffs is dependent on the size of the cell. For example, if the radius of the cell is 32 km (20 mi), the area is 3217 km^{A}2(1256 mi^{A}2). After a call is initiated in this area, there is little chance that it will be dropped before the call is terminated as a result of a weak signal at the coverage boundary. Then why bother to implement the handoff feature? Even for a 16-km radius, cell handoff may not be needed. If a call is dropped in a fringe area, the customer simply redials and reconnects the call. Today the size of cells becomes smaller in order to increase capacity. Also people talk longer. The handoffs are very essential. Handoff is needed in two situations where the cell site receives weak signals from the mobile unit: (1) at the cell boundary, say, -100 dBm, which is the level for requesting a handoff in a noise-limited environment; and (2) when the mobile unit is reaching the signal-strength holes (gaps) within the cell site as shown in Fig.1.

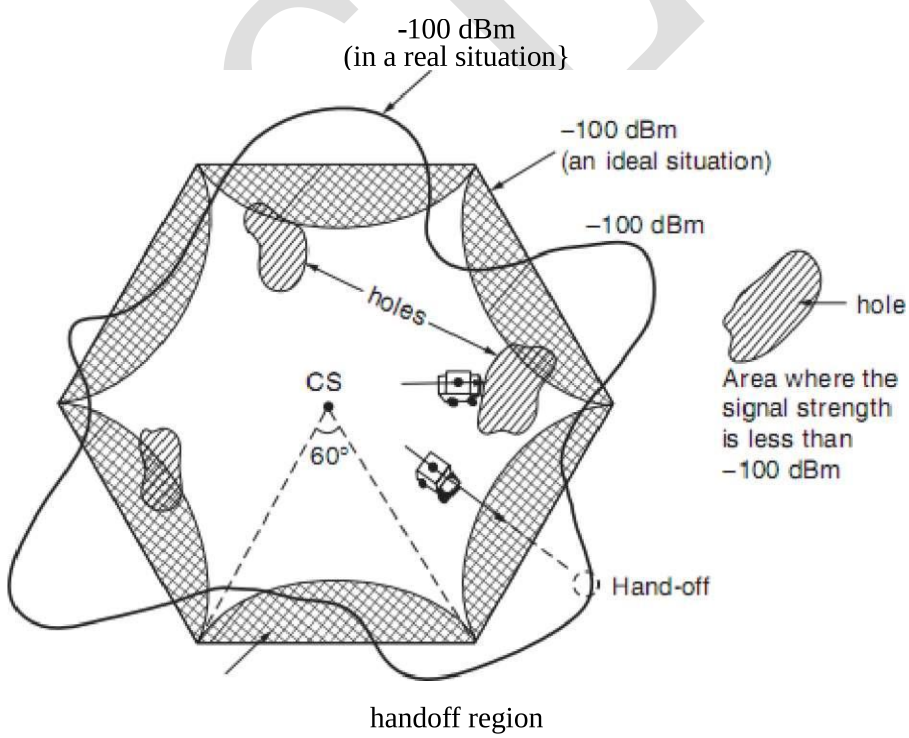


Fig.1. Occurrence of handoffs

2. What are the two decision making parameters of handoff explain.

There are two decision-making parameters of handoff: (1) that based on signal strength and (2) that based on carrier-to-interference ratio. The handoff criteria are different for these two types. In type 1, the signal-strength threshold level for handoff is -100 dBm in noise-limited systems and -95 dBm in interference-limited systems. In type 2, the value of C/I at the cell boundary for handoff should be at a level, 18 dB for AMPS in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

Type 1: It is easy to implement. The location receiver at each cell site measures all the signal strengths of all receivers at the cell site. However, the received signal strength (RSS) itself includes interference.

$$RSS = C + I$$

where C is the carrier signal power and I is the interference. Suppose that we set up a threshold level for RSS; then, because of the I , which is sometimes very strong, the RSS level is higher and far above the handoff threshold level. In this situation handoff should theoretically take place but does not. Another situation is when I is very low but RSS is also low. In this situation, the voice quality usually is good even though the RSS level is low, but since RSS is low, unnecessary handoff takes place. Therefore, it is an easy but not very accurate method of determining handoffs. Some analog systems use SAT information together with the received signal level to determine handoffs. Some CDMA systems use pilot channel information.

Type 2: Handoffs can be controlled by using the carrier-to-interference ratio C/I

$$C+I/I = C/I$$

we can set a level based on C/I ,so C drops as a function of distance but I is dependent on the location. If the handoff is dependent on C/I , and if the C/I drops, it does so in response to increase in (1) propagation distance or (2) interference. In both cases, handoff should take place. In today's cellular systems, it is hard to measure C/I during a call because of analog modulation. Sometimes we measure the level I before the call is connected, and the level C + I during the call. Thus (C + I)/I can be obtained. Another method of measuring C/I is described in Sec. 9.3.

3. Concept of delaying a handoff

In many cases, a two-handoff-level algorithm is used. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available cell could take the call. A plot of signal strength with two request handoff levels and a threshold level is shown in Fig.3. The plot of average signal strength is recorded on the channel received

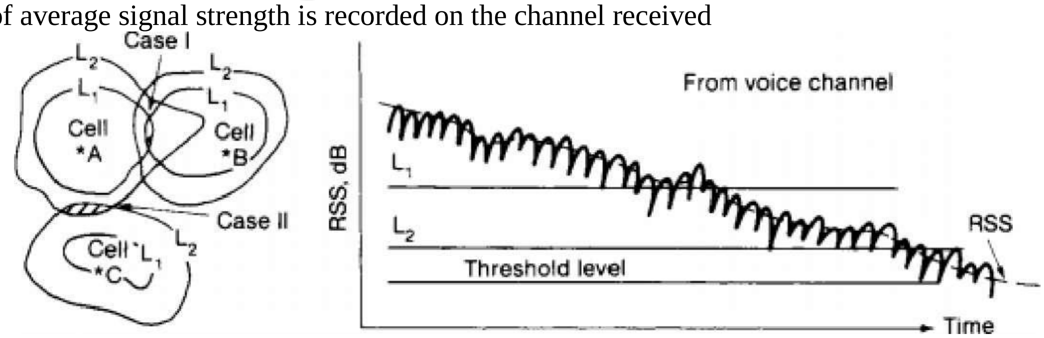


Fig.3. A two level handoff scheme

Signal strength indicator (RSSI), which is installed at each channel receiver at the cell site. When the signal strength drops below the first handoff level, a handoff request is initiated. If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighboring cell is busy, the handoff will be requested periodically every 5 s. At the first handoff level, the handoff takes place if the new signal is stronger. However, when the second handoff level is reached, the call will be handed off with no condition. The MSO always handles the handoff call first and the originating calls second. If no neighboring calls are available after the second handoff level is reached, the call continues until the signal strength drops below the threshold level; then the call is dropped. In AMPS systems if the supervisory audio tone (SAT) is not sent back to the cell site by the mobile unit within 5 s, the cell site turns off the transmitter.

4. What are the advantages of delayed handoff

Consider the following example. The mobile units are moving randomly and the terrain contour is uneven. The received signal strength at the mobile unit fluctuates up and down. If the mobile unit is in a hole for less than 5 s (a driven distance of 140 m for 5 s, assuming a vehicle speed of 100 km/h), the delay (in handoff) can even circumvent the need for a handoff. If the neighboring cells are busy, delayed handoff may take place. In principle, when call traffic is heavy, the switching processor is loaded, and thus a lower number of handoffs would help the processor handle call processing more adequately. Of course, it is very likely that after the second handoff level is reached, the call may be dropped with great probability. The other advantage of having a two-handoff-level algorithm is that it makes the handoff occur at the proper location and eliminates possible interference in the system. Figure 3, case I, shows the area where the firstlevel handoff occurs between cell A and cell B. If we only use the second-level handoff boundary of cell A, the area of handoff is too close to cell B. Figure 3, case II, also shows where the second-level handoff occurs between cell A and cell C. This is because the first-level handoff cannot be implemented.

5. Write about forced handoff

A forced handoff is defined as a handoff that would normally occur but is prevented from happening, or a handoff that should not occur but is forced to happen.

Controlling a Handoff:

The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer or assign a high handoff threshold level to request a handoff earlier. The MSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site.

Creating a Handoff:

In this case, the cell site does not request a handoff but the MSO finds that some cells are too congested while others are not. Then, the MSO can request call sites to create early handoffs for those congested cells. In other words, a cell site has to follow the MSO's order and increase the handoff threshold to push the mobile units at the new boundary and to handoff earlier.

Queuing of handoff:

Queuing of handoffs is more effective than two-threshold-level handoffs. The MSO will queue the requests of handoff calls instead of rejecting them if the new cell sites are busy. A queuing scheme becomes effective only when the requests for handoffs arrive at the MSO in batches or bundles. If handoff requests arrive at the MSO uniformly, then the queuing scheme is not needed. Before showing the equations, let us define the parameters as follows. 1/^ average calling time in seconds, including new calls and handoff calls in each cell

A,1 arrival rate (A,1 calls per second) for originating calls

12 arrival rate (A2 handoff calls per second) for handoff calls

M1 size of queue for originating calls

M2 size of queue for handoff calls

N number of voice channels

a (A1 + A2)/^ b1

b2 A2/p.

The following analysis can be used to see the improvement. We are analyzing three cases. **GRIET** -

1. No queuing on either the originating calls or the handoff calls. **The blocking for either an originating call or a handoff call is**

$$B_o = \frac{a^N}{N!} P(0)$$

Where

$$P(0) = \left(\sum_{n=0}^{N} \frac{a^N}{n!} \right)^{-1}$$

2. Queuing the originating calls but not the handoff calls. **The blocking probability for originating calls is**

$$B_{oq} = \left(\frac{b_1}{N} \right)^{M_1} P_q(0)$$

Where

$$P_q(0) = \left[N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)} \right]^{-1}$$

The blocking probability for handoff calls is

$$B_{oh} = \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)} P_q(0)$$

3. Queuing the handoff calls but not the originating calls. **The blocking probability for handoff calls is**

PJQ)

The blocking probability for originating calls is

$$B_{ho} = \frac{1-(b_2/N)^{M_2+1}}{1-(b_2/N)} P_q(0)$$

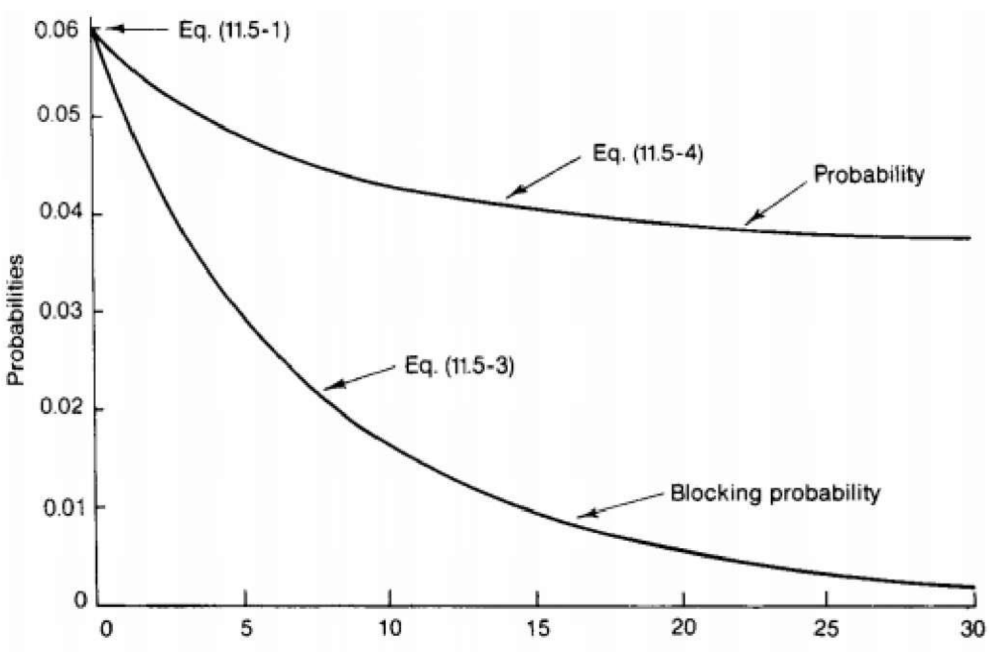


Fig.5. Originating queue size

We have seen (Fig.5.) with queuing of originating calls only, the probability of blocking is reduced. However, queuing of originating calls results in increased blocking probability on handoff calls, and this is a drawback. With queuing of handoff calls only, blocking probability is reduced from 5.9 to 0.1 percent by using one queue space. Therefore it is very worthwhile to implement a simple queue (one space) for handoff calls. Adding queues in handoff calls does not affect the blocking probability of originating calls. However, we should always be aware that queuing for the handoff is more important than queuing for those initiating calls on assigned voice channels because call drops upset customers more than call blockings.

6. Write about Power difference handoff

A better algorithm is based on the power difference (A) of a mobile signal received by two cell sites, home and handoff. A can be positive or negative. The handoff occurs depending on a preset value of A.

A = the mobile signal measured at the candidate handoff site

- the mobile signal measured at the home site For

example, the following cases can occur.

A> 3 dB request a handoff 1dB <A< 3 dB

prepare a handoff

-3dB <A< 0 dB monitoring the signal strength A< -3

dB no handoff

Those numbers can be changed to fit the switch processor capacity. This algorithm is not based on the received signal strength level, but on a relative (power difference) measurement. Therefore, when this algorithm is used, all the call handoffs for different vehicles can occur at the same general location in spite of different mobile antenna gains or heights.

7. What is Intersystem handoff?

Occasionally, a call may be initiated in one cellular system (controlled by one MSO) and enter another system (controlled by another MSO) before terminating. In some instances, intersystem handoff can take place; this means that a call handoff can be transferred from one system to a second system so that the call is continued while the mobile unit enters the second system. The software in the MSO must be modified to apply this situation. Consider the simple diagram shown in Fig.7. The car travels on a highway and the driver originates a call in system A. Then the car leaves cell site A of system A and enters cell site B of system B. Cell sites A and B are controlled by two different MSOs. When the mobile unit signal becomes weak in cell site A, MSO A searches for a candidate cell site in its system and cannot find one. Then MSO A sends the handoff request to MSO B through a dedicated line between MSO A and MSO B, and MSO B makes a complete handoff during the call conversation. This is just a one-point connection case. There are many ways of implementing intersystem handoffs, depending on the actual circumstances. For instance, if two MSOs are manufactured by different companies, then compatibility must be determined before implementation of intersystem handoff can be considered.

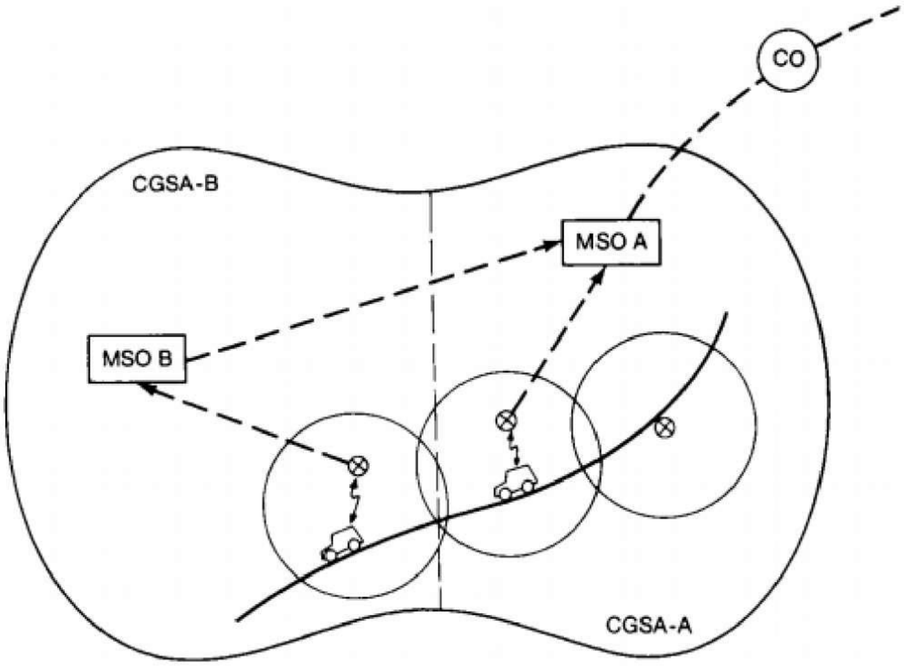


Fig.7. Intersystem handoffs

8. Definition of dropped call rate and consideration of dropped call rates

The definition of a dropped call is after the call is established but before it is properly terminated. The definition of "the call is established" means that the call is setup completely by the setup channel. If there is a possibility of a call drop due to no available voice channels, this is counted as a blocked call not a dropped call. If there is a possibility that a call will drop due to the poor signal of the assigned voice channel, this is considered a dropped call. This case can happen when the mobile or portable units are at a standstill and the radio carrier is changed from a strong setup channel to a weak voice channel due to the selective frequency fading phenomenon.

The perception of dropped call rate by the subscribers can be higher due to:

1. The subscriber unit not functioning properly (needs repair).

2. The user operating the portable unit in a vehicle (misused).
3. The user not knowing how to get the best reception from a portable unit (needs education).

In principle, dropped call rate can be set very low if we do not need to maintain the voice quality. The dropped call rate and the specified voice quality level are inversely proportional. In designing a commercial system, the specified voice quality level is given relating to how much C/I (or C/N) the speech coder can tolerate. By maintaining a certain voice quality level, the dropped call rate can be calculated by taking the following factors into consideration:

1. Provide signal coverage based on the percentage (say 90 percent) that the entire received signal will be above a given signal level.

2. Maintain the specified co-channel and adjacent channel interference levels in each cell during a busy hour (i.e., the worst interference case).

3. Because the performance of the call dropped rate is calculated as possible call dropping in every stage from the radio link to the PSTN connection, the response time of the handoff in the network will be a factor when the cell becomes small, the response time for a handoff request has to be shorter in order to reduce the call dropped rate.

9. Relation among capacity, voice quality, dropped call rate

Radio Capacity m is expressed as follows: BrfB/m

Where BT/Bc is the total number of voice channels. BT /Bc is a given number, and (C/I)s is a required C/I for designing a system. The above equation is obtained based on six cochannel interferers which occur in busy traffic (i.e., a worst case). In an interference limited system, the adjacent channel interference has only a secondary effect.

$$(C/I)_S = \frac{3}{2}\left(\frac{B_T/B_c}{m}\right)^2 = \frac{3}{2}\left(\frac{B_T}{B_c}\right)^2 \cdot \frac{1}{m^2}$$

Because the (C/I)s is a required C/I for designing a system, the voice quality is based on the (C/I)s .When the specified (C/I)S is reduced, the radio capacity is increased. When the measured (C/I) is less than the specified (C/I)S , both poor voice quality and dropped calls can occur.

10. What is the general formula of dropped call rate? Explain?

General formula of dropped call rate

. z1 and z2 are two events, z1 is the case of no traffic channel in the cell, z2 is the case of no- safe return to original cell. Assuming that z1 and z2 are independent events, then

P{Z2\Zl)P(zÔ=P(Z2)-P(Zl) = e - T

2. (1 - ß) is the probability of a call successfully connecting from the old BSC to the MSC. Also, (1 - ß) is the probability of a call successfully connecting from the MSC to the new BSC. Then the total probability of having a successful call connection is

BSC (old) MSC (1-/3) MSC —v BSC
(new) (1-/3)

3. The call dropped rate P expressed in above Eq can be specified in two cases:

1. In a noise limited system (startup system): there is no frequency reuse, the call dropped rate PA is based on the signal coverage. It can also be calculated under busy hour conditions.

2. In an interference-limited system (mature system): frequency reuse is applied, and the dropped rate PB is based on the interference level. It can be calculated under busy hour conditions.

11. Write about cell site handoff only scheme Cell site handoff

scheme:

This scheme can be used in a non cellular system. The mobile unit has been assigned a frequency and talks to its home cell site while it travels. When the mobile unit leaves its home cell and enters a new cell, its frequency does not change; rather, the new cell must tune into the frequency of the mobile unit (see Fig. 10.). In this case only the cell sites need the frequency information of the mobile unit. Then the aspects of mobile unit control can be greatly simplified, and there will be no need to provide handoff capability at the mobile unit. The cost will also be lower. This scheme can be recommended only in areas of very low traffic. When the traffic is dense, frequency coordination is necessary for the cellular system. Then if a mobile unit does not change frequency on travel from cell to cell, other mobile units then must change frequency to avoid interference. Therefore, if a system handles only low volumes of traffic, that is, if the channels assigned to one cell will not reuse frequency in other cells, then it is possible to implement the cell-site handoff feature as it is applied in military systems.

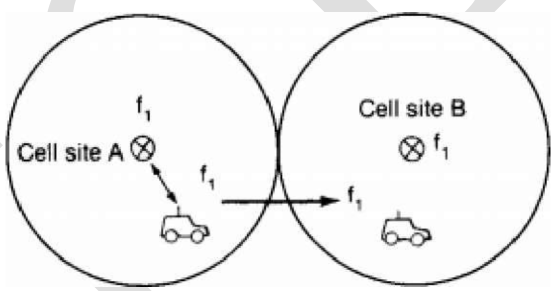


Fig.10. Cell site handoff only scheme

Tutorial Class Topics and related Information

Unit VIII: Tutorial Class

- TDMA
- Error corrections
- Questions of previous university papers to be reviewed with answers

UNIT-VIII

1.Explain in detail about GSM architecture

GLOBAL SYSTEM FOR MOBILE (GSM):

CEPT, a European group, began to develop the Global System for Mobile TDMA system in June 1982.GSM has two objectives: pan-European roaming, which offers compatibility throughout the European continent, and interaction with the integrated service digital network (ISDN), which offers the capability to extend the single-subscriber-line system to a multiservice system with various services currently offered only through diverse telecommunications networks. System capacity was not an issue in the initial development of GSM, but due to the unexpected, rapid growth of cellular service, 35 revisions have been made to GSM since the first issued specification. The first commercial GSM system, calledD2, was implemented in Germany in 1992.

GSM Architecture :

GSM consists of many subsystems, such as the mobile station (MS), the base station sub system (BSS), the network and switching subsystem (NSS), and the operation subsystem (OSS) in fig.1.1.

1. The Mobile Station: The MS may be a stand-alone piece of equipment for certain services or support the connection of external terminals, such as the interface for a personal computer or fax. The MS includes mobile equipment (ME) and a subscriber identity module (SIM). ME does not need to be personally assigned to one subscriber. The SIM is a subscriber module which stores all the subscriber-related information. When a subscriber's SIM is inserted into the ME of anMS, that MS belongs to the subscriber, and the call is delivered to that MS. The ME is not associated with a called number—it is linked to the SIM. In this case, any ME can be used by a subscriber when the SIM is inserted in the ME.

2. Base Station Subsystem: The BSS connects to the MS through a radio interface and also connects to the NSS. The BSS consists of a base transceiver station (BTS) located at the antenna site and a base station controller (BSC) that may control several BTSs. The BTS consists of radio transmission and reception equipment similar to the ME in an MS. A transcoder/rate adaption unit (TRAU) carries out encoding and speech decoding and rate adaptation for transmitting data. As a subpart of the BTS, the TRAU may be sited away from the BTS, usually at the MSC. In this case, the low transmission rate of speech code channels allows more compressed transmission between the BTS and the TRAU, which is sited at the MSC.

GSM uses the open system interconnection (OSI). There are three common interfaces based on OSI (Fig. 1.2.): a common radio interface, called air interface, between the MS and BTS, an interface A between the MSC and BSC, and an A-bis interface between the BTS and BSC. With these common interfaces, the system operator can purchase the product of manufacturing company A to interface with the product of manufacturing company B. The difference between interface and protocol is that an interface represents the point of contact between two adjacent entities (equipment or systems) and a protocol provides information flows through the interface. For example, the GSM radio interface is the transit point for information flow pertaining to several protocols.

Fig.1.1. The external environment of BSS

3. Work and Switching Subsystem: NSS (see Fig.1.3.) in GSM uses an intelligent network (IN). The IN's attributes will be described later. A signaling NSS includes the main switching functions of GSM. NSS manages the communication between GSM users and other telecommunications users. NSS management consists of:

Mobile service switching center (MSC): Coordinates call set-up to and from GSM users. An MSC controls several BSCs.

Interworking function (IWF): A gateway for MSC to interface with external networks for communication with users outside GSM, such as packet-switched public data network (PSPDN) or circuit-switched public data network (CSPDN).The role of the IWF depends on the type of user data and the network to which it interfaces.

Home location register (HLR): Consists of a stand-alone computer without switching capabilities, a database which contains subscriber information, and information related to the subscriber's current location, but not the actual location of the subscriber. A subdivision of HLR is the authentication center (AUC). The AUC manages the security data for subscriber authentication. Another sub-division of HLR is the equipment identity register (EIR) which stores the data of mobile equipment (ME) or ME-related data.

Visitor location register (VLR): Links to one or more MSCs, temporarily storing subscription data currently served by its corresponding MSC, and holding more detailed data than the HLR. For example, the VLR holds more current subscriber location information than the location information at the HLR.

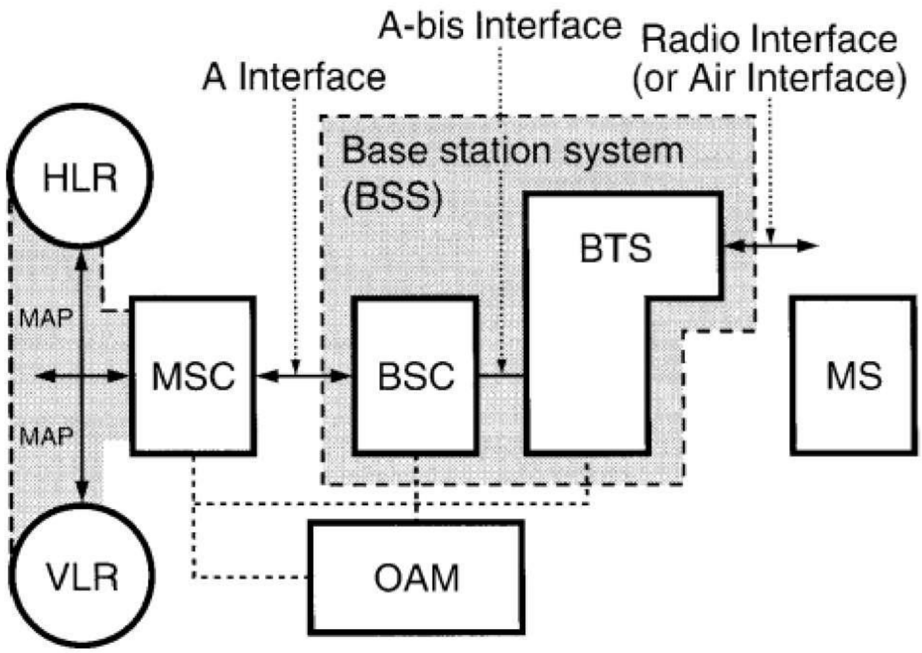


Fig.1.2. Functional architecture and principal interfaces

Gateway MSC (GMSC): In order to set up a requested call, the call is initially routed to a gateway MSC, which finds the correct HLR by knowing the directory number of the GSM subscriber. The GMSC has an interface with the external network for gatewaying, and the network also operates the full Signaling System 7 (SS7) signaling between NSS machines.

Signaling transfer point (STP): Is an aspect of the NSS function as a stand-alone node or in the same equipment as the MSC. STP optimizes the cost of the signaling transport among MSC/VLR, GMSC, and HLR.

As mentioned earlier, NSS uses an intelligent network. It separates the central data base (HLR) from the switches (MSC) and uses STP to transport signaling among MSC and HLR.

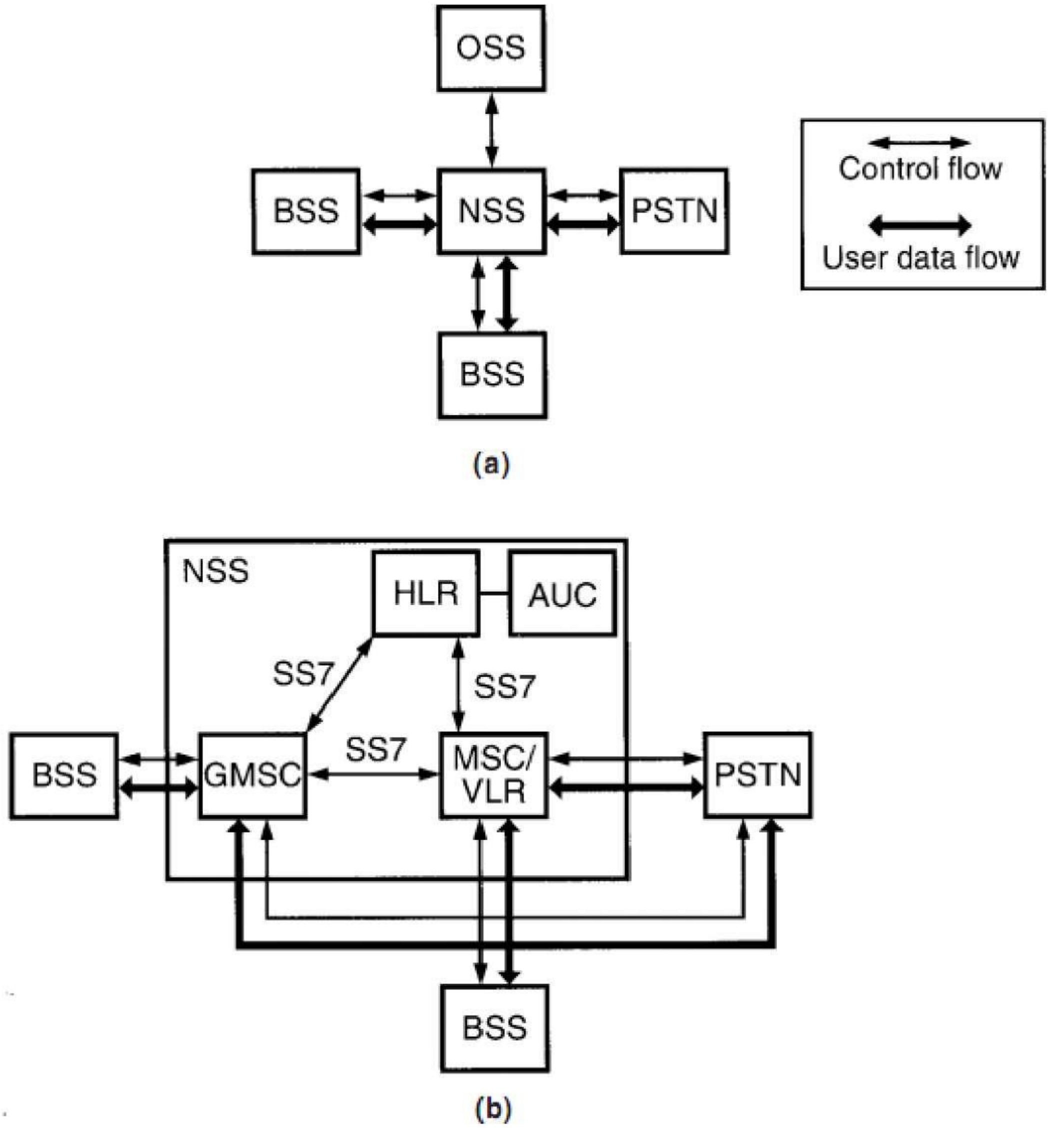


Fig.1.3. NSS and its environment (a) the external environment; (b) the internal structure

4. Operation Subsystem: There are three areas of OSS, as shown in Fig. 1.4. (1) network operation and maintenance functions, (2) subscription management, including charging and billing, and (3)mobile equipment management. These tasks require interaction between some or all of the infrastructure equipment. OSS is implemented in any existing network.

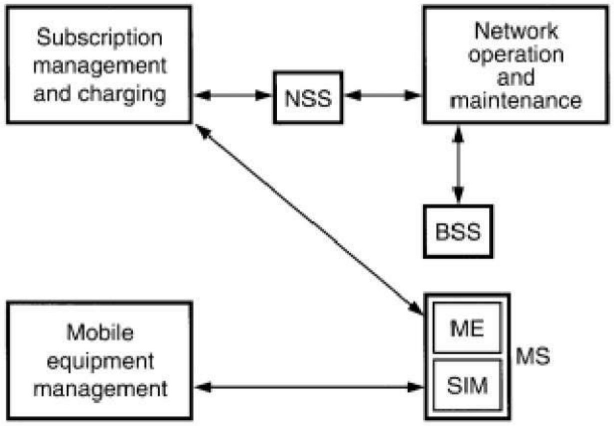


Fig.1.4. OSS organization

2. What are the services offered by GSM channels?

GSM Channel Structure: The services offered to users have four radio transmission modes, three data modes, and a speech mode. The radio transmission modes use the physical channels.

Physical Channels: There are three kinds of physical channels, also called traffic channels (TCHs):

1. TCH/F (full rate): Transmits a speech code of 13 kbps or three data-mode rates, 12, 6, and 3.6 kbps.

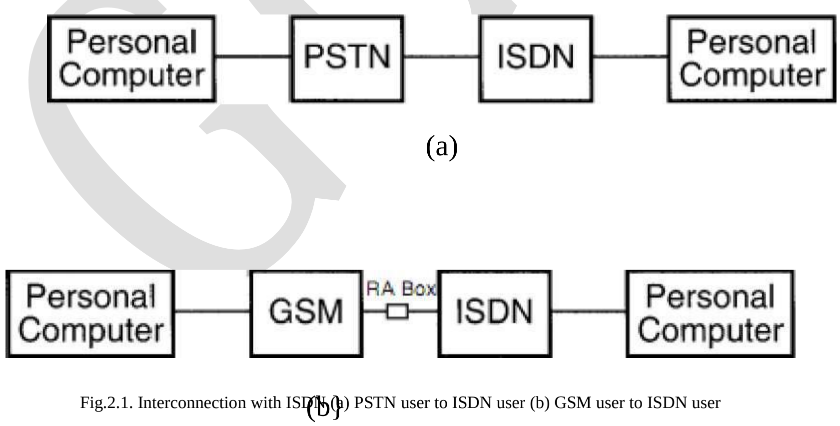


Fig.2.1. Interconnection with ISDN (a) PSTN user to ISDN user (b) GSM user to ISDN user

2. TCH/H (half rate): Transmits a speech code of 7 kbps or two data modes, 6 and 3.6 kbps.

3. TCH/8 (one-eighth rate): Used for low-rate signaling channels, common channels, and data channels.

Logic channels:

1. Common channels: All the common channels are embedded in different traffic channels. They are grouped by the same cycle (51 x 8 BP), where BP stands for burst period (i.e.,time slot), which is 577 (is.

2. Downlink common channels: There are five downlink unidirectional channels, shared or grouped by a TCH.

(i) Frequency correction channel (FCCH) repeats once every 51x8 BPs; used to identify a beacon frequency.

(ii) Synchronization channel (SCH) follows each FCCH slot by 8 BPs.

(iii) Broadcast control channel (BCCH) is broadcast regularly in each cell and received by all the mobile stations in the idle mode.

(iv) Paging and access grant channel (PAGCH) is used for the incoming call received at the mobile station. The access grant channel is answered from the base station and allocates a channel during the access procedure of setting up a call.

(v) Call broadcast channel (CBCH). Each cell broadcasts a short message for 2s from the network to the mobile station in idle mode. Half a downlink TCH/8 is used, and special CBCH design constraints exist because of the need for sending two channels (CBCH and BCCH) in parallel.

The mobile station (MS) finds the FCCH burst, then looks for an SCH burst on the same frequency to achieve synchronization. The MS then receives BCCH on several time slots and selects a proper cell, remaining for a period in the idle mode.

3. Uplink common channels: The random-access channel (RACH) is the only common uplink channel. RACH is the channel that the mobile station chooses to access the calls.

There are two rates: RACH/F (full rate, one time slot every 8 BP), and RACH/H (half rate, using 23 time slots in the 51 x 8 BP cycle, where 8 BP cycle [i.e. a frame] is 4.615ms).

4. Signaling channels: All the signaling channels have chosen one of the physical channels,and the logical channels names are based on their logical functions:

5. Slow Associated Control Channel (SACCH): A slow-rate TCH used for signaling transport and used for non urgent procedures, mainly handover decisions. It uses one-eighth rate. The TCH/F is always allocated with SACCH. This combined TCH and SACCH is denoted TACH/F.

6. Fast Associated Control Channel (FACCH): Indicates cell establishment, authenticates subscribers, or commands a handover.

7. Stand-alone Dedicated Control Channel (SDCCH): Occasionally the connection between a mobile station and the network is used solely for passing signaling information and not for calls. This connection may be at the user's demand or for other management operations such as updating the unit's location. It operates at a

8. SACCH occupies 1 time slot (0.577 ms) in every 26 frames (4.615ms x 26). The time organization of a TACH/F is shown in Fig.2.2.

very low rate and uses a TCH/8 channel. Radio slots are allocated to users only when call penetration is needed. There are two modes, dedicated and idle. The mode used depends on the uplink and the downlink. In GSM terminology, the downlink is the signal transmitted from the base station to the mobile station, and the uplink is the signal transmitted in the opposite direction.

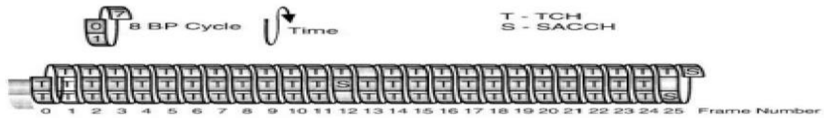


Fig.2.2. Time organization of TACH/F

9. Voice/data channels: Each time slot of a voice channel contains 260 bits per block. The entire block contains 316 bits. Each time slot of a data channel contains 120 or 240 bits per block.

3. Write short notes on modes in GSM channels.

The different modes of GSM channel are as follows

1. Channel mode

2. Dedicated mode

3. Idle mode

1. Channel modes: Because of the precious value of the radio spectrum, individual users cannot have their own TCH at all times.

2. Dedicated mode: Uses TCH during call establishment and uses SACCH to perform location updating in the dedicated mode. TCH and SACCH are dedicated channels for both uplink and downlink channels.

3. Idle mode: During non call activities, the five downlink channels are in the idle mode: FCCH; SCH; BCCH, which is broadcasting regularly; PAGCH and CBCH, which sends one message every 2 s. During idle mode, the mobile station listens to the common downlink channels, and also uses SDCCH (uplink channel) to register a mobile location associated with a particular base station to the network.

4. Explain in detail about multiple access scheme.

Multiple-Access Scheme: GSM is a combination of FDMA and TDMA. The total number of channels in FDMA is 124, and each channel is 200 kHz. Both the 935-960MHz uplink and 890916 MHz downlink have been allocated 25 MHz, for a total of 50 MHz Duplex separation is 45 MHz If TDMA is used within a 200-kHz channel, 8 time slots are required to form a frame, frame duration is 4.615 ms, and the time slot duration burst period is 0.577ms. There is a DCS- 1800 system, which has the same architecture as the GSM, but it is up converted to 1800MHz. The downlink is 1805-1880 MHz (base TX) and the uplink is 1700-1785 MHz (mobile Tx).

Constant Time Delay between Uplink and Downlink: The numbering of the uplink slots is derived from the downlink slots by a delay of 3 time slots. This allows the slots of one channel to bear the same time slot number in both directions. In this case, the mobile station will not transmit and receive simultaneously because the two time slots are physically separated. Propagation delay when the mobile station is far from the BTS is a major consideration. For example, the round trip propagation delay between an MS and BTS which are 35 km apart is 233 (is. As a result, the assigned time slot numbers of the uplink and downlink channels may not be the same (less than 3 time slots apart). The solution is to let BTS compute a time advance value. The key is to allow significant guard time by taking into account that BCCH is using only even time slots. This avoids the uncertainty of numbering the wrong time slot. Once a dedicated connection is established, the BTS continuously measures the time offset between its own burst schedule and the reception schedule of mobile station bursts on the bidirectional SACCH channel. The time compensation for the propagation delay (sending to the mobile station via SACCH) is 3 time slots minus the time advance.

Frequency Hopping: GSM has a slow frequency-hopping radio interface. The slow hopping is defined in bits per hop. Its regular rate is 217 hops/s, therefore, with a transmission rate of 270 kbps, the result is approximately 1200 bits/hop. If the PAGCH and the RACH were hopping channels, then hopping sequences could be broadcast on the BCCH. The common channel is forbidden from hopping and using the same frequency.

Different Types of Time Slots: Each cell provides a reference clock from which the time slots are defined. Each time slot is given a number (TN) which is known by the base station and the mobile station. The time slot numbering is cyclic. TN0 is a single set broadcast in any given call and repeated every 8 BPs for the confirmation of all common channels. The organization of TN0 (first of eight time slots) in sequence is as follows: FCCH(1), SCH (1), BCCH (4), PAGCH (4), FCCH (1), SCH (1), PAGCH (8), FCCH (1), SCH(1), PAGCH (8), FCCH (1), SCH (1), PAGCH (8), FCCH (1), SCH (1), PAGCH (8).

The symbol PAGCH (4) means that the PAGCH channel information appears in consecutive ones of every 8 BP cycle 4 times. Each of the remaining seven TNs (TN1 to TN7) is assigned to one TACH/F channel.

Bursts and Training Sequences: In TDMA, the signal transmits in bursts. The time interval of the burst brings the amplitude of a transmitted signal up from a starting value of 0 to its normal value. Then a packet of bits is transmitted by a modulated signal. Afterward, the amplitude decreases to zero. These bursts occur only at the mobile station transmission or at the base station if the adjacent burst is not transmitted. There are tail bits and training sequence bits within a burst. The tail bits are three 0 bits added at the beginning and at the end of each burst which provide the guard time. The training sequence is a sequence known by the receiver that trains an equalizer, a device that reduces inter symbol interference. The training sequence bits are inserted in the middle of a time slot sometimes called a midamble, for the same purpose as a preamble, so that the equalizer can minimize its maximum distance with any useful bit. There are eight different training sequences, with little correlation between any two sequences to distinguish the received signal from the interference signal.

There are several kinds of bursts:

1. The normal burst used in TCH:

Flag Flag

3	57	1	26	1	57	3

Tail Information Training Sequence Information Tail

The 1-bit binary information indicating data or signaling is called the stealing flag.

2. The access burst used on the RACH in the uplink direction:

Flag

7	41	1	35	3

Tail Training Sequence Information Tail

3. The F and S bursts. The F burst is used on the FCCH and has the simplest format. All of the 148 bits are zero, producing a pure sine wave. Five S bursts in each 51 x 8 BP cycle are used on the SCH. One S burst is shown below:

Flag Rag

3	38	1	64	1	33 3

Tail Information Training Sequence Information Tai!

5.Explain the architecture of TDMA?

The NA-TDMA architecture is similar to GSM architecture. The only difference is that in NA- TDMA, there is only one common interface, which is the radio interface as shown in Fig. 5. The NA-TDMA uses the intelligent network. All the components such as HLR, VLR, AUC, and EIR are the same as used in GSM. In developing the NA-TDMA system, there were two phases:

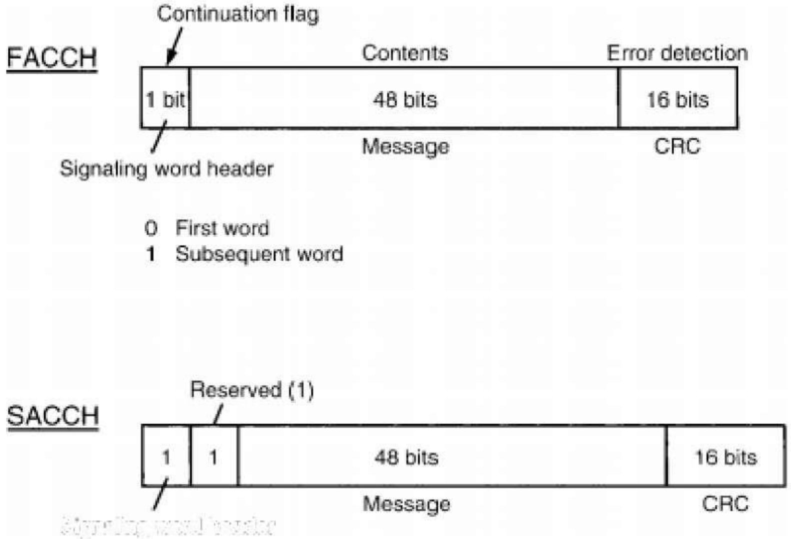
First phase: To commonly share the 21 set-up channels that are used for the analog system. The first-phase system is only for voice transmission. Both modes, AMPS and digital, are built in the same unit. The handoff procedure has to take care of the following four features:

1. AMPS cell to AMPS cell
2. TDMA cell to TDMA cell
3. AMPS cell to TDMA cell
4. TDMA cell to AMPS cell

Second phase: (1) generate new digital set-up channels (they were in the voice band) to access to TDMA voice channels so that a digital stand-alone unit can be provided and (2) specify a data-service signal protocol for transmitting data

6. Write about the signaling format and message structure in TDMA.

Signaling Format in Different Channels: A reverse digital traffic channel (RDTC) is used to transport user information and signaling. A forward digital traffic channel (FDTC) has same format as the RDTC (reverse digital traffic channel). Two control channels are used: the FACCH is a blank and burst channel, the SACCH is a continuous channel, and interleaving is on the SACCH. The signaling formats of these two channels are shown in Fig.6.



Signaìing word Header Fig.6.Signaling formats of FACCH and SACCH

Message Structure:

All messages contain:

1. An application message header
2. Mandatory fixed parameters
3. Mandatory variable parameters
4. Remaining length
5. Optional variable parameters

Purpose Which Protocol

Message	Protocol		Mandatory	Remaining	Optimum
Type	Discriminator	Mandatory Fixed	Variable	Length	Variable
(fi bili)	(2 bits)	Parameters	Parameters	& bits	Parameter

7. Write short notes on,

(a) TDMA structure

(b) Frame length

(c) Frame offset

(d) Modulation timing.

(a) TDMA Structure (Digital Channels):

In NA-TDMA, the set-up channels are analog channels shared with the AMPS system. One digital channel (a 30-kHz TDMA channel) contains 25 frames per second. Each frame is 40-ms long and has 6 time slots. Each time slot is 6.66-ms long. One frame contains 1944 bits (972 symbols), as shown in Fig. 7. Each slot contains 324 bits (162 symbols) and the duration between bits is 20.57 (is. Therefore, one radio channel is transmitted at 48.6 kbps but only 24,000 symbols per second over the radio path. Each frame consists of 6 time slots. The maximum effect on the signal for a forward time slot is one-half full symbol period and for a reverse time slot is 6 symbol periods (Fig. 7b).

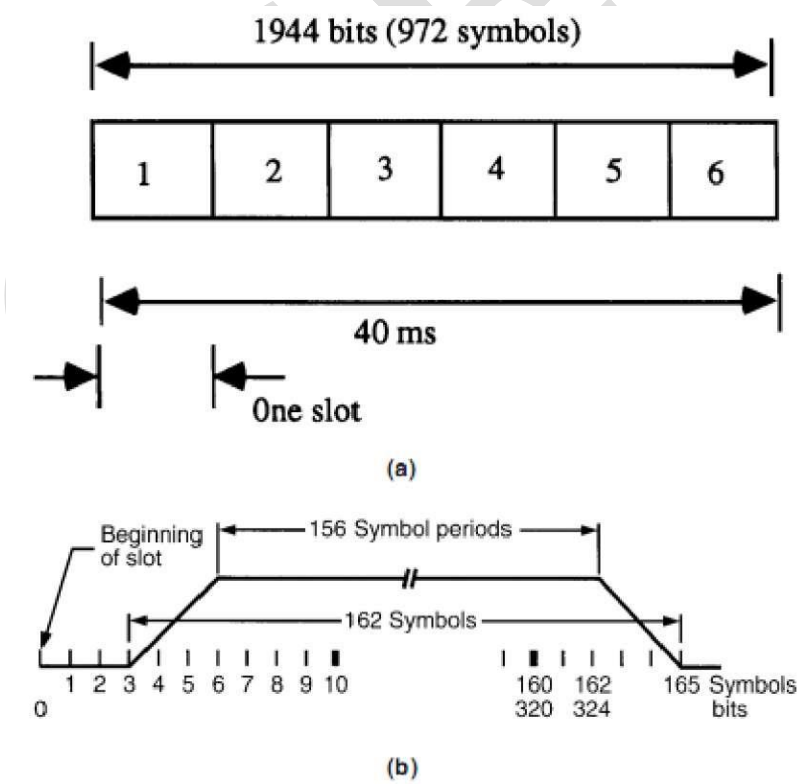


Fig.7. TDMA frame and slot (a) TDMA frame structure; (b) overall length in each slot

Frame Length: There are two frame lengths, full rate and half rate. Each full-rate traffic channel shall use two equally spaced time slots of the frame. The overall length in each slot is shown in Fig. 7b.

Channel 1 uses time slots 1 and 4

Channel 2 uses time slots 2 and 5

Channel 3 uses time slots 3 and 6

Each half-rate traffic channel shall use one time slot of the frame:

Channel 1 uses time slot 1

Channel 2 uses time slot 2

Channel 3 uses time slot 3

Channel 4 uses time slot 4

Channel 5 uses time slot 5

Channel 6 uses time slot 6

Frame Offset: At the mobile station, the offset between the reverse and forward frame timing (without time advanced applied), is

Forward frame = reverse frame + (1 time slot + 44 symbols)

= reverse frame + 206 symbols

The time slot (TS) 1 of frame N (in forward link) occurs 206 symbol periods after TS 1 of frame N in the reverse link.

Modulation Timing:

Modulation timing within a forward time slot: The first modulated symbol (the first symbol of the sync word) used by the mobile unit shall have maximum effect on the signal (156 symbols) transmitted from the base antenna, one-half symbol (1 bit) period after beginning the time slot.

Modulation timing within a reverse time slot: The first modulated symbol has a maximum effect on the signal transmitted at the mobile unit 6 symbol periods after the beginning of the reverse time slot.

8. Explain about TDMA channels. NA-TDMA

Channels:

In NA-TDMA, there are no common channels such as those used in GSM. The digital call set-up uses the 21 set-up channels which are shared with the analog system.

Supervision of the Digital Voice Channel: The supervision channels in NADC are similar to those in GSM:

(i) Fast Associated Control Channel FACCH is a blank and burst channel equivalent to a signaling channel for the transmission of control and supervision messages between the base station and the mobile station. It consists of 260 bits. Mostly FACCH is used for handoff messages.

(ii) Slot Associated Control Channel SACCH is a signaling channel including twelve code bits present in every time slot transmitted over the traffic channel whether these contain voice or FACCH information.

Mobile-Assisted Handoffs (MAHO): The mobile station performs signal quality measurements on two types of channels:

1. Measures the RSSI (received signal strength indicator) and the BER (bit error rate) information of the current forward traffic channel during a call.

2. Measures the RSSI of any RF channel which is identified from the measurement order message from the base station.

MAHO consists of three messages:

1. Start measurement order:

Measurement order message—sent from the base station to the mobile station.

Measurement order acknowledge message—sent from the mobile station to the base station.

2. Stop measurement order:

Stop measurement order—sent from the base station to the mobile station. Mobile

acknowledges—sent from the mobile station to the base station.

3. Channel quality message (mobile to base only)

The mobile transmits the signal quality information over either the SACCH or FACCH. In the

case of discontinuous transmission (DTX):

(a) Whenever the mobile is in the DTX high state, the mobile transmits channel quality information over the SACCH

(b) When the mobile is in the DTX low state, the mobile transmits the channel quality information over the FACCH

Handoff Action: When a handoff order is received, the mobile station is at DTX high state and stays at that state. If the mobile station is at DTX low state it must enter the DTX high state and wait for 200 ms before taking the handoff action. Handoff to a digital traffic channel is described as follows:

1. Turn on signaling tone for 50 ms, turn off signaling tone, turn off transmitter which was operating on the old frequency.

2. Adjust power, tune to new channel, set stored DVCCs to the DVCC field of the received message.

3. Set the transmitter and receiver to digital mode, set the transmit and receive rate based on the message-type field.

4. Set time slot based on the message-type field.

5. Set the time alignment offset to the value based on the TA field.
6. Once the transmitter is synchronized, enter the conversation task of the digital traffic channel.

9. Explain the some of the important terms of CDMA digital cellular systems.

CDMA development started in early 1989 after the NA-TDMA standard (IS-54) was established. A CDMA demonstration to test its feasibility for digital cellular systems was held in November 1989. The CDMA "Mobile Station-Base Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System" was issued as IS-95 (PN-3118, Dec. 9, 1992). CDMA uses the idea of tolerating interference by spread-spectrum modulation. 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. Before describing the structure of the system, we list the key terms of CDMA systems.

Terms of CDMA Systems:

Active set: The set of pilots associated with the CDMA channels containing forward traffic channels assigned to a particular mobile station (MS).

CDMA channel number: An 11-bit number corresponding to the center of the CDMA frequency assignment.

Code channel: A sub channel of a forward CDMA channel. A forward CDMA channel contains 64 code channels. Certain code channels are assigned to different logic channels.

Code channel zero: Pilot channel.

Code channels 1 through 7: Either paging channels or traffic channels. Code channel 32: A sync channel or a traffic channel. The remaining code channels are traffic channels. **Code symbol:** The output of an error-correcting encoder.

Dim-and-burst: A frame in which the primary traffic is multiplexed with either secondary traffic or signal traffic. It is equivalent to the blank-and-burst function in AMPS.

Forward CDMA channel: Contains one or more code channels.

Frame: A basic timing interval in the system. For the access channel, paging channel, and traffic channel, a frame is 20-ms long. For the sync channel, a frame is 26.666-ms long.

Frame offset: A time skewing of traffic channel frames from system time in integer multiples of 1.25ms. The maximum frame offset is 18.75ms.

GPS (Global Position System): System used for providing location and time information to the CDMA system.

Handoff (HO): The act of transferring communication with a mobile station from one base station to another.

Hard HO: Occurs when (1) the MS is transferred between disjoint active sets, (2) the CDMA frequency assignment changes, (3) the frame offset changes, and (4) the MS is directed from a CDMA traffic channel to an analog voice channel but not vice versa.

Soft HO: HO from CDMA cell to CDMA cell at the same CDMA frequency.

Idle HO: Occurs when the paging channel is transferred from one base station (BS) to another.

Layering: A method of organization for communication protocols. A layer is defined in terms of its communication protocol to a peer layer.

Layer 1: Physical layer presents a frame by the multiplex sub layer and transforms it an over-the-air waveform.

Layer 2: Provides for the correct transmission and reception of signaling messages.

Layer 3: Provides the control of the cellular telephone system. The signaling messages originate and terminate at layer 3.

Long code: A PN (pseudo noise) sequence with period - '''— - using a tapped n-bit shift register.

Modulation symbol: The output of the data modulator before spreading. There are 64 modulation symbols on the reverse traffic channel, 64-ary orthogonal modulation is used, and six code symbols are associated with one modulation symbol. On the forward traffic channel, each code symbol (data rate is 9600 bps) or each repeated code symbol (data rate is less than 9600 bps) is 1 modulation symbol.

Multiplex option: The ability of the multiplex sub layer and lower layers to be tailored to provide special capabilities. A multiplex option defines the frame format and the rate decision rules.

Multiplex sublayer: One of the conceptual layers of the system that multiplexes and demultiplexes primary traffic, secondary traffic, and signaling traffic.

Nonslotted mode: An operating mode of an MS in which the MS continuously monitors the paging channel.

Null traffic data: A frame of sixteen 1's followed by eight 0's sent at the 1200 bps rate. Null traffic channel data serve to maintain the connectivity between MS and BS when no service is active and no signaling message is being sent.

Paging channel: A code channel in a forward CDMA channel used for transmission of (1) control information and (2) pages from BS to MS. The paging channel slot has a 200-ms interval.

Power control bit: A bit sent in every 1.25 ms interval on the forward traffic channel to the MS that increases or decreases its transmit power.

Primary CDMA channel: A pre assigned frequency used by the mobile station for initial acquisition.

Primary paging channel: The default code channel (code channel 1) assigned for paging.

Primary traffic: The main traffic stream between MS and BS on the traffic channel.

Reverse traffic channel: Used to transport user and signaling traffic from a single MS to one or more BSs.

Shared Secret Data (SSD): A 128-bit pattern stored in the MS. SSD

is a concatenation of two 64-bit subsets. SSD-A is used to support

the authentication.

SSD-B serves as one of the inputs to generate the encryption mask and private long code.

Secondary CDMA channel: A pre assigned frequency (one of two) used by the mobile station for initial acquisition.

Secondary traffic: An additional traffic stream carried between the MS and the BS on the traffic channel.

Slotted mode: An operation mode of MS in which the MS monitors only selected slots on the paging channel.

Sync channel: Code channel 32 in the forward CDMA channel which transports the synchronization message to the MS.

Pilot channel: An un modulated, direct-sequence (DS) signal transmitted continuously by each CDMA BS. The pilot channel allows a mobile station to acquire the timing of the forward CDMA channel, provides a phase reference for coherent demodulation, and provides a means for signal strength comparisons between base stations for determining when to hand off.

System time: The time reference used by the system. System time is synchronous to universal time coordination (UTC) time and uses the same time origin as GPS time. All BSs use the same system time. MSs use the same system time, offset by the propagation delay from the BS to the MS.

Time reference: A reference established by the MS that is synchronous with the earliest arriving multipath component that is used for demodulation. The time reference establishes transmit time and the location of zero in PN space.

Walsh chip: The shortest identifiable component of a 64-walsh function. On the forward CDMA channel, one chip equals 1/1.2288 MHz or 813.802 ns. On the reverse CDMA channel, one chip equals 4/1.2288 MHz or 3255 ns.

Unit wise quiz questions with answers

Unit 1

1. Mobile unit is comprised of transceiver and

a) Control Unit b) **Antenna** c)Key Pad d) Timers

2. MTSO is
a) mobile transmitting office b) Mobile transmitting switching unit c)Multiple terminal switching office d)**Mobile telephone switching office**

3. To have more coverage cell shape should be
a)Hexagon b) Circular c) Square d) Hexagon & Square

4. The ability of base station to pick up the correct signal as mobile enters from cell 1 to cell 2 is
a) Cell splitting b) Cell sectoring c) **Soft hand of**f d) Coverage capacity.

5. Mobile unit is connected to PSTN through
a) BTS alone b) MSC alone c) Handoff Procedure d) **BTS & MSC**

6. No of channels possible with AMPS and ETACS are
a) 933, 1000 b) 849,1500 c) **832,1000** d) 1200,1500

7. AMPS standard uses
a) FM, FDD b) FM, AM c) AM, TDD d) FSK, MSK

8. Spectral Efficiency Of ETACS specification is

a) 0.43 bps /Hz b) 0.83 bps /Hz c) **0.33 bps /Hz** d) 0.93 bps /Hz

9. In GSM paging channel and access grant channel are known as

a) Dedicated control channel b) Broadcast channels c) **Common control channel** d)Dedicated broadcast channels

10. What are the process used in voice modulation and in Amps? Give in ascending order
1) Pre-emphasis 2) compander 3) post deviation limiter filter 4)deviation limiter
a) 1-2-3-4 **b) 2-1-4-3** c) 2-4-1-3 d) 1-4-2-3

11. The items required for service quality are

1) coverage 2) GOS 3) number of dropped calls 4) voice quality

a) **1-2-3** b) 2-3-4 c) 1-3-4 d) 1-2-4

12. The small geographical area in cellular communication is defined as,

a) N = 7 reuse pattern b) N = 4 reuse pattern c) cluster d) **cell**

Unit 2

1. The following are the elements of Cellular mobile radio system
a)Receiver and transmitter b) Mobile unit and control unit **c) C/I reduction factor and cell splitting** d) Handoff and receiver

2. The Concept of repeating same frequency is known as ________________ and the cell using same
frequencies is know__________________
a)Cell splitting , adjacent cells b) Frequency re use , adjacent channel cells
c)Frequency re use , co channel cells d) cell Sectoring , cells.

3. If D is the distance between two co channel cells and R is the cell radius then D/R is known as
a) Adjacent channel interference reduction factor b)co channel interference reduction factor c)Adjacent channel interference reduction factor d) **None of these.**

4. If N = 4 and N = 19 re use cellular patterns, the frequency re use distances are ___________ and __________-

a)3.6 R and 4.6 R b)3.46R and 6R c)6R and 7.55R d)**3.46R and 7.55R**

5. **For N = 7 cell reuse pattern, the co-channel interference reduction factor q is _____________________**

a) D/R = 5.6 b)) D/R = 7.6 c)) D/R = 6 d)) D/R = 4.6

6. When the mobile moves from an original cell to a new cell and the call in progress has to be continued smoothly ,it is known as _____________

a) Cell sectoring b) **Handoff techniques** c) Desectorization d)coverage

7. The cell splitting is done as per the traffic available in the cell is known as ______________

a) Permanent cell splitting b**) Dynamic cell splitting** c) Semi- permanent cell splitting d)static cell splitting

8. In general after cell splitting the new cell radius ______________

a) (old cell radius)^2 b) 2(old cell radius) c) (old cell radius)/π d) **old cell radius)/2**

9.MTSO does the following functions

a) **perform all internal switching of the calls.** b) does not perform internal switching
c) autonomously locates mobile d)manages data communication.

10. Interference in neighboring cells is reduced by _______________

a) **Antenna tilting** b) gain adjustment c) impedance d)Antenna height

11. Service life of switching equipment is not determined by
a) how long it takes to attain its full capacity b) temperature c) life cycle of the equipment d)**none**

12. To increase the capacity of the equipment in case of designing sswitching equipments as module is
a) Modules distribution b) modules can be reduced **c) more modules can be added**
d) modules need not be altered.

13. Data link ___
a) Cannot carry multiple data channels
b) Can carry multiple data channels
c) Is not affected by cellular system
d) Is affected by cellular system

14. The Macro and Micro cells are available in
a) handoff b)cell sectorization c)Co Channel cellular region d)**Umbrella pattern**

15.The cell using different carrier frequencies in a cluster is
a) Co channel cell b) Macro cell c) **Adjacent Cell** d)Micro cell

16.If the cluster size N=19 then the split parameters (I,j) are
a)2,3 b)1,3 c)3,3 **d)3,2**

17.If Q= 4000 T= 1.76 min the offered load will be _____________
a)119 **b)117** c)216 d)115

18. If Q=29000, calls per hour, B=2% & T 1.76 min then the offered load is ______________

a) 8620 b)7650 **c) 850** d)450

19. In a N cell re use pattern the equation of N is _______

a)$N=(i+j)^2$ b)$N=i^2+ixj+j^2$ c)N=i+j+2j d)N=j+2i

20. if average calling time =T, and maximum calls per hour per cell Q then the offered load is A in erlangs is ______

a)$A=Q^2T/360$ b) **A=QT/60** c) $A=Q^2T/30$ d) $A=Q^2T/60$

Unit 3

1. In cellular system if N> 7 it results in
a) reduce the no of channels in a cell b)Increase the No. of channels in the cell c)**Reduce the no. of channels but it also reduces spectrum efficiency** d) increase spectrum efficiency

2. The goal of frequency reuse technique in a cell is
a) To improve system gain b)To alter co channel interference factor c**) to increase spectrum efficiency** d) to provide synchronization

3. In a cellular system if 7 is the reuse pattern applied then the co channel interference reduction factor q will be cash
a)5.61 b)5.11 c)4.11 d)**4.6**

4. The value of q is 5.2 for N = 9 what Is q if N = 12
a)8 b)16 **c)6** d)12

5. An antenna used in wireless transmition radiate
a) Spot beam antenna b) yagi uda antenna c)**Omni directional antenna** d) none

6. If N=4 a better cell sectoring system will have ____________
a)120 degrees b)90 degrees c)**60 degrees** d)30 degrees

7. The __________ sector needs more antenna to be mounted and frequent handoffs.
a)120 degrees b)**60 degrees** c)90 degrees d)360 degrees

8. For narrow beam applications which celluar pattern given below is correct?
9. a)N = 7 with 120 degrees sector b) **N = 4 with 60 degrees sector** c) N = 4 with 90 degrees sector d) N = 7 with 90 degrees sector

10. In flat ground or in a valley interference can be effectively reduced by a)**Lowering the antenna height** b)reducing power level c)increasing antenna height d)lowering antenna sepration

11. If there is a notch available in antenna pattern it will have an effect
a)will not alter interference b**) reduce interference** c)increase interference d)none

12. The co channel and long distance interferences are reduced by

a) Yagi-uda antenna b) Umbrella pattern c)**Omni directional antenna** d)None

13. Techniques used for reducing interference is ______________

a) cell splitting b)Handoff c)**diversity** d)sectoring

14. Speech quality can be measured by ___________

a) S N R b)C/I c)**subjective and objective tests** d)either S N R or C/I

15. Adjacent channel and next channel interference are ___________

a)Different b)same c)Related by amplitude d)having more interference

16. If two service providers are available in one market then it is known as

a)Monopoly b)Duality c)**duopoly** d)duplex

17. In a celluar system if cross talk occurs it will be ___________as compared to telephone systems

a)less b)more c)**double** d)cannot define

18. Ring combiner can handle

a)16 channels b)8 channels c)**32 channels** d)18 channels

19. SAT is

a) Supervisory amplifier tuner b) Supervisory amplitude tone c) **Supervisory audio tone** d) Supervisory analog tone

20. The multiplexer used at cell site channel receiver ______________

a) Has no losses b)has more losses c)**has splic losses** d)has hystersis losses

21. SAT tones available are

a) **3** b)5 c)7 d)9

Unit 4

1. Cell coverage is based on _____ or on the ______________

a) Gain, power b) signal amplification, traffic coverage c) **signal coverage, traffic coverage** d)Human made structures, Natural terrains

2. Foliage areas are _______________

a) **Natural terrain** b) Human made structures c) open area d) urban area

3. At the mobile and base station antenna heights will be ____________ and ___________

a) 30m, 3m b) **3m, 30m** c) 40m, 3m d) 30m, 6m

4. Foliage loss is due to the following

a) tall building b) Indoor structures c**) Tall trees, leaves etc** d)outdoor structures

5.In a standard local mean spread, in the curve of signal strength versus distance from transmitting antenna measured standard deviation would be___________

a)18 db b)5 db c)**8 db** d)0.8 db

6. For base station and mobile antenna the antenna gain would be_____ and_____

a)**6 db/dipole, 0 db/dipole** b)4 db/dipole, 6 db/dipole c)2 db/dipole, 4 db/dipole d)5 db/dipole, 9 db/dipole

7.The cell site covers signal_________

a)smaller area b)**larger area** c)greater area d)long distance propogation

8.The gradual bending of rays due to changing effective dielectric constant of atmosphere is the following effect

a)Tropospheric reflection b)**Tropospheric refraction** c)moistness d)diffraction

9.Refractive index decreases with height, and the rays will be curved downward and known as following condition

a)**Duct propagation** b)Reflection c)Diffraction d)Refraction

10.Troposheperic wave propagation cause interferences and it can be controlled by, the following

a)Umbrella Antenna beam pattern b)directional antenna pattern c**)a & b** d)yagi uda antenna

11.The path unobstructed by terrain profile and man made structure is given below
a)non obstructive path b)indirect path c)**line of sight path** d)none of the above

12.Consider the following statements and mention whether it is true or false

1. In man-made structures, there is sparse structures
2. In man made structures there is dense man-made structures

a)1 is true b)2 is true c)**1 and 2 are true** d)both are false

13.The range for whichpoint to point model is very useful to provide predictions is ______________

a)**10 mi or less** b)100 mi or less c)more than 50 mi d)between 50-100 mi

14 .In double knife edge diffraction model the total diffraction loss is as the following
a)square of the sum of two diffraction loses b)differenece of the two diffraction losses c)**sum of the two diffraction losses** d)none of the above

15.the area-to area prediction model proides accuracy with8db σ which is the ________ of actual path loss data a)58% b)88% c)**68%** d)87%

16. in mobile-to-mobile the propogation channel acts as the following component
a)repeater b)attenuator c)**filter** d)amplifier

17.the path loss scope and 1 mi intercept are 2 parameters used in the following model
a)**area-to-area prediction** b)gain prediction c)power prediction d)antenna effective height prediction

18.when standard deviation σ is known confidence level can be applied to the following
a)prediction model b)area-to-area prediction c)**path loss curve** d)average noise power measurement

19.signal coverage is found by _____________ and generally applied to _________________
a)coverage prediction models, end system b)**coverage prediction model,start up system** c)point-to- point modelnend system d)point-to-point model,terrain contour

20.the parameters of foliage losses are ___________________
1.leaves
2.trunks
3.branches
4.density of distribution of trees
a)1,2 and 3 b)2,3 and 4 c)**1,2,3,4** d)1 and 2

Unit 5

1.the term EIRP refers to a)**effective isotropic radiated power** b)effective radiated poer c)effective isolated radiated power d)effective isolated radiated power

2.In a start-up system an omnicell transmitting antennas are ___________ a)directional b)**omnidirectional** c)yagi-uda antenna d)none of the above

3. In abnormal antenna configuration on omnicell site is equipped with 90 channels for which __________ transmitting antennas are used. a)16 b)9 c**)6** d)3

4. In abnormal antenna configuration on omnicell site is equipped with 45 channels for which __________ transmitting antennas are used a)13 b)5 c)**3** d)6

5. Which device can be used to reduce the number of transmitting antennas in mobile communication ? a)multiplexers b)**hybrid ring combiners** c)attenuators d)location antennas

6. One transmiting antenna for two receiving antennas is applied in directional antenna arrangement.
what will be type of cell sectoring ?
a)60^0 sector b)**120^0 sector** c)30^0 sector d)none of the above

7. several vertically stacked umbrella pattern antenna can form a
a)abnormal antenna b) **high-gain antenna** c)interference reduction antenna d)mobile antenna

8.minimum sepration of cell-site receiving antennas will have the following advantage a)**intermodulation can be avoided** b)reduces ISI c)reduces noise d)controls distortion

9.The motor vehicle mounted antenna is the following antena a)directional b)omnidirectional
c)smart d)micro strip antenna

10. what wil be the radiation patern of the rof mounted antenna ? a)**uniformly distributed** b)not uniformly distributed c)both a and b d)cannot be predicted

11.If a mobile antenna has gain more than 3 db what wil be its receiving capacity a)**Recives only limited portion of total multipath signals** b)suppressed horizontaly c)reduce gain d)coanot be drilled

12.Is it necessary to dril a hole in glass-mounted antenna for coupling a)yes b**)no** c)cannot be drilled d)b and c

13.Compare the positions of glas-mounted antenna with roof mounted antenna
a)**It should be lower than roof mounted antenna** b)it should be larger than roof mounted antenna c)they are at equal positions d)cannot be compared

14. comment an antenna beam pattern of directional antenna
a) elevated vertically b)suppressed vertically c) **suppressed horizontally** d)elevated horizontally

15. comment an antenna beam pattern of high-gain antenna
a) elevated vertically b) **suppressed vertically** c) elevated horizontally d) c suppressed horizontally

16. What is the difference in position between glass mounted and roof mounted antennas
a)6db b)7db c)0db d**)3db**

17. Find whether true or false
1. in mobile environment scattered signals arrive at mobile unit with equal probability
2. omnidirectional antennas must be used for 1
a**)both are true** b)both are false c)1 is true and 2 is false d)2 is false and 1 is true

18. The gain glass mounted antennas will be
a)1 to 10 db b)**1 to 3 db** c)5 db d)7db

19. The two branch space-diversity antennas can _ in mobile communication
a)**reduce fading** b)increase fading c)reduce gain d)increase ISI

20. How vertical separation between space-diversity antennas can be determined a)by their operating frequencies b)by their relative amplitudes c)by their gain values d)**by correlation between their received signal**

Unit 6

1.The main function of frequency management is given below
a)increasing gain b)increasing power c)**dividing total number of channels into subsets** d)adding the given number of channels

2. Numbering the channel is done by the following
a)RVC b)RCC c)FVC d)**FCC**

3. What basis in a fixed channel set that contains of one or more subsets is assigned to a cell site a)short term basis b)in dynamic basis c)**long term basis** d)temporary basis

4. What is the method of channel assignment to a mobile unit during cal in progress?
a) long term basis b)permanent basis c)short term basis d)in flexible mode

5. Allocation of specific channels to a cel site is known as _____
a)frequency management b)frequency allotment c)**channel assignment** d)channel modeling

6. what is the other name for set up channels ?
a) reverse chan nels b)forward channels c) **channels control** d)traffic channels

7. what are the types of setup channels ?
a)acces channel and forward channels b)paging channels and reverse channels c)**access and paging channels** d)forward and reverse channels

8. In set up channels every two way channel contains a _____ bandwidth
a)60 khz b)30khz c)**30Mhz** d)45khz
9.In normal case ______ set up channels can be used for paging and accessing a)two b)**one** c)three d)N
10.The forward set up channel is sent at the ____ and the reverse set up channel is sent at the ____
a) unit,cell unit mobile b)**cell site,mobile unit** c)BTS,PSTN d)BTS,MSC

11.All the set up channels carry only _____
a)header information b)**data information** c)addres s informationd)handoff information

12. if there are 90 voice radio channel what channel is required to co-ordinate for all call set up ?
a)**1 set up** b)2 set up c)1 voice d)1 voice and 2 set up

13.For a traffic load of 90 channels, if the blocking probability is 0.02 the holding time period is 100 sec. and the load offered is 78.3 then what will be the number of calls per hour ?
a)3218 b**)2818** c)1500 d)3300

14. In a cell how many set up channels are generally present a)32 b**)21** c)53 d)any

15. The access channel can be designated by ______ as a channel apart from set up channels in the cell site a)BSC b)PSTN c)**MTSO** d)control room

16.In selecting a voice channel process the voice channels are assigned from forward set up channel what antennas are used here ? a)one of the three 60^0 b)**one of the 2 120^0** c)One of the 3 120^0 d)none

17. For keeping the reverse set up channels open as far as possible what is adapted in a mobile unit ? a)handoff scheme b)self generation c)**self location** d)none

18. For searching a mobile unit is cell site what the MTSO has to do ?
a)waiting is awaited b)receiving ACK signal c)**sending page** d)receiving page

19. What is the main function of FOC in cell site
a)sending control signal b)**page to mobile unit** c)receives page d)controls page

20. When there is no voice channels the cell site could send a ____ message using set up channels a)page b)**acknowledgement** c)direct call retry d)ready signal

CHAPTER -7

1. SET-UP channel will not be in the following case.
   A. before the call is esteblished
   B. During the call period
   C. When call communication is over
   D. **after the call established**

2. Find weather true or false

i. The handoff is implemented on voice channel.

ii. After a call is established in a cell with cell area 3127 km^2 there is a chance of call drop before call termination

A. 1 is true

B .2 is false

C .**1 and 2 are true**

D . both are false

3. Find whether true or false

Handsoff is required in situation such as

1) Cell site receives weak signals from mobile at the cell boundary (- 100dBm)
2) When mobile unit reaches the signal strength holes with in the cell site

A. 1 is true

B .2 is true

C. Both are false

D. 1 and 2 are true

4. The received signal strength can be expressed as

A. C+1

B. C^2+1

C. CI

D . CI^2

5. The MTSO will handle the ___________ first and ____second

A. Origination calls, handoff calls.

B .**Handsoff calls, origination calls**

C. Dropped calls, handsoff calls

D. Dropped calls, originating calls

6. If a handoff that should not occur but if it is forced to happen then it is called as below

A . Soft handoff

B. Hard handoff

C. **Forced handoff**

D. None of the above

7. One of the methods to make handoff to occur in proper location and with less interference is known as below

A. Forced handoff

B. **two - handoff level**

C. Hard handoff

D. Soft handoff

8. Handoff controlling is done by

A. PSTN

B. **MTSO**

C. BSC

D. cell site

9. Creating handoff is required by

A. cell site

B . **MTSO**

C. BSC

D. PSTN

10. The queueing of handoffs is ____________when compared to two – threshold – level handoffs

A . More effective

B. less effective

C. equal

D. very negligible

11. Consider the statement and find weather it is true or false.

1) MTSO will queue the handoff requests

2) It is effective only when request arrived in bundles or batches at MTSO

A . 1 is true

B. 2 is false

C. **1 and 2 are true**

D. 1 is true , but 2 is false

12. If Δ power difference between received signal at 2 cellsite when a request for handoff and no handoff cases takes place?

A. **$\Delta > 3$ dB and $\Delta > -3$dB**

B. $\Delta > -3$ dB and $\Delta > 3$dB

C. $\Delta > 6$ dB

D. $\Delta < 6$dB

13. For the Q 12 prepare a handoff would take place when Δ value is ___________

A. **1dB< Δ < 3dB**

B. 1 dB < Δ < 2 dB

C. 1 dB < Δ < 8 dB

D. 3 dB < Δ < 6dB

14. In normal handoff procedure the handoff request is based on the following

A. **Power level**

B. Signal strength

C. Peak current

D. None of the above

15. If call handoff is transferred from one system to another system _________is known as _________-

A. **Intersystem**

B . Intrasystem

C. soft

D. Hard

16. The dropped call is __________-but __________-it is terminated prpperly

A . **After the call is established, before**

B. After the call is established, after

C. Before the call is established, after

D. Call in progress, before

17A good frequency management chart and frequency assignments will lead to _________

A Reducing Power

B Reducing time period

C reducing handoffs

D Reducing interference

18. The model used for selection cell site location is given below

A. Propagation prediction

B . Path loss

C. Durkin's

D. **Knife edge**

19 The purpose of tilting - antenna or using an umbrella pattern omnidirectional antenna is given below

A. To confine time slots

B. To confine energy in small area

C. to increase coverage area

D. To decrease path loss

20 . Dynamic channel assignment is mainly done for the following reason

A. **Increase traffic capacity**

B . Decrease traffic intensity

C. Increase gain intensity

D. Decrease transmit power

CHAPTER -8

1. GSM Is referred as below.

a. **global system for mobile**

b. general systems for mobile.

c. general scheme for mobile phones.

d. global scheme for mobile phones

2. Some of the digital cellular systems are ,

a. GS, AMPS

b. CDMA, GSM, AMPS

c. **GSM, CDMA**

D. GSM , AMPS, TDMA

3. The first commercial GSM system was called as

A. E3

B**. D2**

C. D1

D. A1

4. The first commercial system was implemented in Germany in ---------------

A. 1918

B. 1992

C. 1996

D. 1962

5. In GSM the base transceiver station is contained in the following

A. Mobile station (MS)

B. Network switching system (NSS)

C. Operating subsystem (OSS)

D. Base station subsystem (BSS)

6. The MS of GSM consists of ------------------ and ----------------

A. Mobile equipment, control register

B. control equipment, mobile unit

C. mobile equipment, Subscriber Identity Module

D. Mobile Equipment, control equipment

7. An intelligent network is used in ---------------------- in GSM

A. BSS

B. NSS

C. OSS

D. MS

8. In GSM a waterway for MSC for interfacing with external network s outside GSM is related to the following terms

A. Transcoder rate adaptation unit

B. Mobile equipment

C. Interworking function

D. Intelligent network

9. What is the number of common interfaces that is based on OSI in GSM?

A. 3

B. 5

C. 4

D. 1

10. The cost of signalling transport among the MSC /VLR , GMSC and HLR is done by

A. Signalling enabling points

B. Signalling transfer points

C. signalling transfer prediction

D. system transfer points

11. A -------------- can connect many GSM networks

A. SMS service points

B. SMS service center

C. SMS supplementary services

D. SMS service management

12. What is the function of RPE?

A. Generates impulse noise to simulate nature of speech

B. Generates signalling

C. Controls impulse noise

D. Filters impulse noise in the speech

13. In GSM OSS is an integral part of the following layer.

A. physical layer

B. OAM layer

C. MS layer

D. IN layer

14. What is the type of coding used for digital speech?

A.LPC

B. RLP

C. Binary coding

D. Speech coding

15. Which device defects the discontinuous transmission mode?

A. Voice activity device

B. control device

C. Filtering device

D. Mobility management device

16. The services offered to users in GSM how many radio and data modes are as given below.

A. 4,3

B. 3,4

C. 3,3

D. 2,1

17. Give two logical channels available in GSM

A. TCH/F,TCH/H

B. TCH/F,FCCH

C. Common channels, signalling channels

D.Common channels, TCH/S

18. In GSM there are –---------- kinds of physical channels and they are called as------------

A. 3, control channels

B. 13, traffic channels

C. 3, traffic channels

D. 4, control channels

19. Capacity of cellular CDMA and SDMA

A. **Capacity α interference**

B. Capacity α(1 / interference)

C. Capacity α (interference)^2

D. Capacity α 1 / (interference)^2

20. DAMA stands for

A. **Demand Assignment multiple Access**

B. Design Assignment multiple Access

C. Defined Assignment multiple Access

D. Dominate Assignment multiple Access

Previous question papers

CELLULAR AND MOBILE COMMUNICATIONS
JNTU previous years question papers

Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks

1. (a) Explain the terms GSM & GPRS.
   (b) Write notes on Digital cellular systems. [8+8]

2. (a) For a cellular system, If blocking probability is 40% and assuming each subscriber generates 0.1 Erlangs traffic load, find the no. of. subscribers if no. of channels are
   i. 1
   ii. 5
   iii. 10
   iv. 20
   v. 100. Use Erlang B model charts.

   (b) In a total 33MHz of BW allocated to a particular FDD system which uses two 25kHZ simplex channels to provide full duplex voice & control channels. Compute the no. of channels available per cell if a system uses:
   i. four cell reuse
   ii. seven cell reuse
   iii. 12 cell reuse.
   1 MHz of allocated spectrum is dedicated to control channels. Determine a equitable distribution of control & Voice channels in each cell for each of three systems. [8+8]

3. Explain the designing of the directional antenna, for k=4, k=12 and k=7 with all suitable values explaining each of them, consider a noise margin of 6dB. [16]

4. (a) From the free space propagation model derive the equation for received power.
(b) Discuss Lee model of point to point propagation. [6+10]

5. (a) What are the different synthesis of sum pattern? Explain them briefly.
(b) What are the antennas used at cellsite? Explain them. [8+8]

6. (a) What type of messages are received to the set up channels when the mobile unit monitors strongest signal strength?
(b) What are the advantages of Reuse-partition scheme?
(c) What is channel sharing and channel borrowing?

7. (a) What are the different types of handoffs? Explain how to implement them?
(b) Define a dropped call rate and explain how it differ from blocked call? [10+6]

8. (a) Explain the significance of SIM in Mobile station.
(b) What is the function of transcoder rate adoption unit in BSS?
(c) What are the different kinds of downlink common channels?

Code No: 411701

IV B.Tech I–Semester Regular Examinations, November-2004

CELLULAR AND MOBILE COMMUNICATION

(Electronics and Telematics)

Time: 3 hours **Max. Marks: 80**

Answer any Five questions

All questions carry equal marks

1.a) Explain the limitations of conventional mobile system? How are they overcome by cellular system?

b) Briefly explain the cell shape and handoff?

2.a) With help of neat diagrams, explain the N cell reuse pattern for four and seven cell reuse?

b) Derive the co- channel interference factor for 7 cell reuse pattern?

3.a) Compare the co-channel interference performance of a directional antenna system for K=7 and K = 4?

b) What is tilting antenna? How can these antenna patterns reduce the co-channel interference?

4.a) Derive the equation for the Feher's delay spread in mobile environment?

b) What is the delay spread bound T_{max} of a 220 MHz public land line mobile radio system.

If P_t = 1W (+30dBm) and P_{rmin} = - 90 dBm, How much T_{max} if the sensitivity of the receiver is improved to P_{rmin} = - 100_{dBm} Why does increased sensitivity of increased system gain $G_s = P_t P_{rmin}$ lead to a higher delay spread bound?

5.a) Classify the mobile unit antennas?

b) Explain about the sectorised cells?

6. Present the frequency management of cellular systems. for efficient spectrum utilization and increases the number of channels?

7.a) Explain clearly how to calculate δ and μ for single cell?

b) Why hand off is necessary for cellular systems. Determine the two types of handoffs based on signal strength and C/I ratio?

8. Present the concept of the narrow beam sector. How does it increase the traffic capacity? Consider K = 7.

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Set No. 2

Code No: 411701

IV B. Tech I – Semester Regular Examinations, November/2004

CELLULAR AND MOBILE COMMUNICATION

(Electronics and Telematics)

Time: 3 hours **Max. Marks: 80**

Answer any Five questions

All questions carry equal marks

1.a) Explain the direct wave path, line of sight path, out of sight path, and obstructive path?

b) What are the different types of noises in cellular frequency ranges. Explain in detail?

c) Explain about the marketing of hexagonal cells?

2.a) Derive the maximum number calls per hour per cell and the maximum number frequency channels per cell . How are they related?

b) Find the desire co-channel interference phenomena in a reuse cellular system that employs omni directional antenna system?

3.a) Explain about the co-channel and adjacent channel interference?

b) How many users can be supported for 0.3% blocking probability for the following number of trunked channels in a blocked calls clear system?

i) 2 ii) 5 iii) 25. Assume each user generates a 0.2% E of traffic

4.a) Explain about the small scale multi path propagation?

b) Consider a transmitter which radiates a sinusoidal carrier frequency of 1850MHz for a vehicle moving 60mph. Compute the received carrier frequency if the mobile is moving a) Direction towards the transmitter b) directly away from the transmitter c) in a direction which is perpendicular to the direction of the arrival of the transmitting signal?

5.a) Classify the cell site antennas and describe these in detail?

b) What do you understand by an engineering antenna pattern? Explain the corresponding pattern?

6.a) Describe the grouping of the voice, setup and paging channels?

b) Present the reuse partition scheme in overlaid cell system. Mention the advantages associated with it?

7.a) Explain the queuing handoff mechanism?

b) If the number channels at the cell site N=70, the call holding time is 101S. The number of originated calls per hour expressed as λ is 2270. The number of handoff calls attempted per hour is expressed as λ_2 is 80. Find the probability of the queuing handoff calls but not the originated calls . Also find the probability of the queuing the originated calls but not the handoff calls?

8. What do you mean by operational techniques? Why are these needed in cellular systems? Explain briefly different operational techniques.

@&@&@

Set No. 3

Code No: 411701

IV B. Tech I – Semester Regular Examinations, November/2004

CELLULAR AND MOBILE COMMUNICATION

(Electronics and Telematics)

Time: 3 hours **Max. Marks: 80**

Answer any Five questions

All questions carry equal marks

1.a) Distinguish between the landline telephone network and cellular telephone network?

b) Explain the phenomena of severe fading?

2.a) Explain the general description of the in mobile environment?

b) If the maximum calls per hour Qi in one cell be 3000 and an average calling time T be 1.76min. The blocking probability is 2%. Find out the offered load A. For the above Qi is 28000 what is the offered load and find the required channels to the above. Finally compare the two systems (use Erlang B model).

3.a) Explain the concept of the delay time Δt concern to the real time co-channel interference?

b) Give the idea about the directional antenna system?

4.a) Determine the maximum and minimum spectral frequency received from a stationary transmitter has a central frequency of exactly 1950MHz. Assume that the receiver is traveling at speeds of a)1Km b) 5Km c) 10Km d)100Km?

b) Describe all physical circumstances that relate to a stationary transmitter and a moving receiver such that the Doppler shift at the receiver is equal to

a) 0Hz b) f_{dmax} c) $-f_{dmax}$ d) $f_{dmax}/2$.

5.a) Write short notes on roof mounted antennas?

b) Explain about the necessity of diversity reception in mobile antennas?

6.a) What do you understand by non fixed channel assignment? Describe the corresponding algorithms?

b) Explain in detail access channels and operational techniques?

7.a) How do you find the values of δ and μ related to the cell?

b) How do you reduce the dropped call rate and explain?

8.a) As a mobile unit in a communication with base station moves, what factors determine the need for power control and the amount of power adjustment?

b) Explain the difference between the open loop and closed loop power control.

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Set No. 4

Code No: 411701

IV B. Tech I – Semester Regular Examinations, November/2004

CELLULAR AND MOBILE COMMUNICATION

(Electronics and Telematics)

Time: 3 hours **Max. Marks: 80**

Answer any Five questions

All questions carry equal marks

1.a) What do you mean by Mean Opinion Score and explain in detail?

b) Explain the history of 800MHz spectrum allocation to cellular systems?

2.a) What do you mean by desired C/I and Explain?

b) Compare interference from first tier of six interferes with that from twelve interferes of second tier (including first and second tiers).

3.a) Explain the importance of the notch in the tilted antenna pattern to reduce the co-channel interference?

b) What are the conditions on tilting antennas?

4.a) From the free space propagation model derive the equation for received power?

b) If a transmitter produces 50W of power express the transmitter power in units of (i) dBm (ii) dBW, if 50W is applied to a unity gain antenna with a 900MHz carrier frequency find the received power in dBm at a free space distance of 100m from the antenna. What is Pr (10Km)? Assume unity for the receiver antenna?

5.a) Explain the important effects of cell site antenna height?

b) Explain top mounted antennas in mobile systems?

6.a) Distinguish clearly the channel assignment to cell sites and the mobile units?

b) Explain the concept of the setup channels?

7.a) How hand offs are prioritized? Explain.

b) Discuss the practical hand off considerations. What is meant by cell dragging?

8. Explain the following special features in detail.

i) SMS ii) MMS iii) EMS iv) Call waiting

v) Call forwarding vi) Call diverting vii) Voice storage box

viii) Call re routing.

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IV B.Tech I Semester Supplementary Examinations, April/May 2005
CELLULAR & MOBILE COMMUNICATIONS

Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks

1. (a) How spectrum is utilized efficiently in mobile system explain each in detail with the suitable example?
(b) What do you mean by in efficient spectrum utilization?

2. (a) How do you find the difference between the simulation results and practical results in mobile environment?
(b) Explain the handoff mechanisms in cellular systems?

3. Explain the designing of the omni directional antenna under the practical case conditions for K = 7, K = 12 and K = 19 with all the suitable values and explaining each of them?

4. (a) Briefly explain the factors considered for prediction of path loss for a particular mobile radio environment.
(b) Explain how antenna spacing and height are done at base station.

5. Describe the directional antenna patterns and the respective antenna arrangement.
(a) At the cell site
(b) Explain the diversity receiver.

6. Explain the terms in detail
(a) Adjacent channel assignment
(b) Channel sharing and borrowing
(c) Sectorisation
(d) Overlaid cells.

7. (a) What is meant by soft hand off? Give example.
(b) What is meant by hard hand off?

8. Present the concept of the narrow beam sector. How does it increase the traffic capacity? Consider K = 7.

IV B.Tech I Semester Supplementary Examinations, November 2006

CELLULAR & MOBILE COMMUNICATIONS

(Electronics & Telematics)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

1. (a) Explain about the importance of the amplifier noise in cellular system?

(b) Explain the operation of the cellular system? [8+8]

2. (a) How do you find the difference between the simulation results and practical results in mobile environment?

(b) Explain the handoff mechanisms in cellular systems? [8+8]

3. (a) Briefly explain the interference of antenna height in co-channel interference reduction.

(b) Write a brief note on the interference of antenna parameters for reducing cochannel interference. [8+8]

4. (a) Explain the propagation concept in near in distance model in detail?

(b) Explain the propagation concept in long distance model in detail? [8+8]

5. (a) Discuss the characteristics of cell site antennas?

(b) If the antenna heights are varying what are the effects you are getting at the time of operation of mobile system? [8+8]

6. Explain the following

(a) Channel sharing

(b) Channel borrowing

(c) Underlay and overlay cells

(d) Setup channel

(e) Paging channel

(f) Voice channel. [16]

7. How hand offs are made in the first generation analog cellular system and how they are made in the second generation systems. Explain. [16]

8. What is leaky feeder? How does it provide adequate coverage and reduce the interference in mobile radio communication? [16]

IV B.Tech II Semester Supplementary Examinations, June 2006
CELLULAR & MOBILE COMMUNICATIONS
(Common to Electronics & Communication Engineering, Information Technology and Electronics & Computer Engineering)
Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks

1. (a) Differentiate the analog and digital cellular systems with their operating capacities?
(b) Explain the relation between the received power and the range of the system in detail? [8+8]

2. (a) Draw the general view of telecommunication and explain the function of the each unit?
(c) Distinguish between the permanent splitting and dynamic splitting? [8+8]

3. Briefly explain the interference of cellular mobile transmitter by UHF TV receiver. [16

4. (a) Briefly explain the factors considered for prediction of path loss for a particular mobile radio environment.
(c) Explain how antenna spacing and height are done at base station. [8+8]

5. (a) Write short notes on roof mounted antennas?
(b) Explain about the necessity of diversity reception in mobile antennas? [8+8]

6. (a) Write the procedure to allot the channels for the traveling mobile units?
(b) Explain the channel assignment to the cell sites based on the adjacent channels? [8+8]

7. (a) Discuss the advantages of delayed hand offs.
(b) Distinguish between forced hand off and soft hand offs. [8+8]

8. Explain the following special features in detail.

(a) SMS

(b) MMS

(c) EMS

(d) Call waiting

(e) Call forwarding

(f) Call diverting

(g) Voice storage box

(h) Call re routing. [16]

Code No: 410455

IV B. Tech I – Semester Supplementary Examinations, November/2004

CELLULAR AND MOBILE COMMUNICATION

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 70**

Answer any Five questions

All questions carry equal marks

1.a) What do you mean by Mean Opinion Score and explain in detail?

b) Explain the history of 800MHz spectrum allocation to cellular systems?

2.a) What do you mean by desired C/I and Explain?

b) Compare interference from first tier of six interferes with that from twelve interferes of second tier (including first and second tiers).

3.a) Explain the importance of the notch in the tilted antenna pattern to reduce the co-channel interference?

b) What are the conditions on tilting antennas?

4.a) From the free space propagation model derive the equation for received power?

b) If a transmitter produces 50W of power express the transmitter power in units of (i) dBm (ii) dBW, if 50W is applied to a unity gain antenna with a 900MHz carrier frequency find the received power in dBm at a free space distance of 100m from the antenna. What is Pr (10Km)? Assume unity for the receiver antenna?

5.a) Explain the important effects of cell site antenna height?

b) Explain top mounted antennas in mobile systems?

6.a) Distinguish clearly the channel assignment to cell sites and the mobile units?

b) Explain the concept of the setup channels?

7.a) How hand offs are prioritized? Explain.

b) Discuss the practical hand off considerations. What is meant by cell dragging?

8. Explain the following special features in detail.

i) SMS ii) MMS iii) EMS iv) Call waiting

v) Call forwarding vi) Call diverting vii) Voice storage box

viii) Call re routing.

IV B.Tech I Semester Supplementary Examinations, April/May 2005

CELLULAR & MOBILE COMMUNICATIONS
(Electronics & Communication Engineering)
Time: 3 hours Max Marks: 70
Answer any FIVE Questions
All Questions carry equal marks

1. (a) Explain the inefficient spectrum utilization based on the existing mobile systems MTS and IMTS
(b) Describe the special features in amps and compare these with now a days systems?

2. (a) What do you mean by desired C/I and Explain?
(b) Compare interference from first tier of Six interferes with that from twelve interferes of second tier (including first and second tiers).

3. (a) Prove that for hexagonal geometry the co channel reuse radio is given by Q =p3N Where $N = i_2+ij + j_2$.
(b) Explain the co channel interference are from the mobile receivers based on test?

4. (a) Consider a transmitter which radiates a sinusoidal carrier frequency of 1859 MHz. For a vehicle moving 60 miles/hr compute the received carrier frequency if the mobile is moving.
i. Directly towards the transmitter
ii. Directly away from the transmitter
iii. In a direction perpendicular to the direction of arrival of the transmitted signal.
(b) Derive the expression for the power received in ground reflected model.

5. (a) Derive the relation between the received power and electrical field of the antenna?
(b) Assume a receiver is located 10km from a 50W transmitter. The carrier frequency is 900MHz , assume free space propagation Gt = 1 and Gr = 2W
i. Find the power at the receiver
ii. The magnitude of the electric field at the receiving antenna
iii. The rms voltage applied to the receiver input assuming that the receiving antenna has purely real importance of 50 ohms and is matched to the receiver.

6. (a) What do you understood by non fixed channel assignment ? Describe the corresponding algorithms?
(b) Explain in detail access channels and operational techniques?

7. (a) Explain the initiation of the handoff mechanism?

(b) What is the delayed handoff and explain the advantages of this?

8. (a) Derive the expression for transmitted power after cell splitting for improving capacity.

(b) Discuss the splitting size limitations and traffic handling.

IV B.Tech I Semester Regular Examinations, November 2007
CELLULAR AND MOBILE COMMUNICATIONS
(Electronics & Telematics)
Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks

1. (a) Explain the importance of the data links in cellular system and explain the concept with basic cellular system?
(b) Explain about mobile originated and network originated calls? [10+6]

2. What do you mean by cell splitting? How area is divided, and explain the different cell splitting techniques? [16]

3. Briefly explain the design of a directional antenna system in co-channel interference reduction.

4. (a) If Pr = 10W, Gt = 0dB , Gr = 0dB and fc = 900MHz. Find Pr in watts at a frequency space distance of 1Km.
(b) Prove that in the two ray ground model_ = d? - d? _ $2h_t h_r$ /d when this holds as a good approximation [6+10]

5. (a) Classify the mobile unit antennas?
(b) Explain about the sectorised cells? [6+10]

6. Explain the following
(a) Channel sharing
(b) Channel borrowing
(c) Underlay and overlay cells
(d) Setup channel
(e) Paging channel
(f) Voice channel. [16]

7. (a) Discuss the methods of queuing of hand offs.
(b) Derive the blocking probability for hand off calls and the blocking probability of originating calls. [8+8]

8. Present the concept of the narrow beam sector. How does it increase the traffic capacity? Consider K = 7. [16]

IV B.Tech I Semester Regular Examinations, November 2007
CELLULAR AND MOBILE COMMUNICATIONS
(Electronics & Telematics)
Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks

1. (a) Explain the direct wave path, line of sight path, out of sight path, and obstructive path?
(b) What are the different types of noises in cellular frequency ranges Explain in detail?
(c) Explain about the marketing of hexagonal cells? [6+5+5]

2. (a) With help of neat diagrams, explain the N cell reuse pattern for four and seven cell reuse?
(b) Derive the co channel interference factor for 7 cell reuse pattern? [9+7]

3. (a) Derive the expression for co-channel interference reduction factor from basic principles
(b) Discuss the significances of directional antennas and omni-directional antennas. [8+8]

4. (a) Discuss about the multi path propagation present the associated losses and place the problem?
(b) Discuss about the point to point and area to area prediction model for cell coverage? [10+6]

5. (a) Explain in detail importance of consideration of cell site antennas?
(b) Assume a receiver is located 10Km from a 50W transmitter. The carrier frequency is 6GHz and free space propagation is assumed Gt =1 and Gr =1W.
i. Find the power at the receiver
ii. The magnitude of the electric field at the receiving antenna
iii. The rms voltage applied to the receiver input assuming that the receiving antenna has purely real importance of 50 ohms and is matched to the receiver. [8+8]

6. Explain the terms in detail
(a) Adjacent channel assignment
(b) Channel sharing and borrowing
(c) Sectorisation
(d) Overlaid cells. [16]

7. (a) List and briefly define different performance metrics that may be used to make the handoff decision?

(b) If the number channels at the cell site N=45 the call holding time is 1.76minutes The number of originated calls per hour expressed as λ is 2270. The number of handoff calls attempted per hour is expressed asλ_2 is 80 Find the probability of the queuing handoff. calls but not the originated calls . Also find the probability of the queuing the originated calls but not the handoff calls?
[10+6]

8. Present the concept of the narrow beam sector. How does it increase the traffic capacity? Consider K = 7. [16]

Code No: RR411701

IV B.Tech I Semester Regular Examinations, November 2007
CELLULAR AND MOBILE COMMUNICATIONS
(Electronics & Telematics)
Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks
⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Discuss analog cellular system (AMPS) in detail?
(b) Discuss the mobile radio transmission medium? [8+8]

2. (a) What do you mean by desired C/I and Explain?
(b) Compare interference from first tier of Six interferes with that from twelve interferes of second tier (including first and second tiers). [10+6]

3. (a) Explain about the SAT to reduce the non co channel interference?
(b) What is the effect of interference on systems performance? [8+8]

4. Explain the terms: delay spread, Coherence bandwidth and confidence interval with a neat figure. [16]

5. (a) Concern to the cell site directional antennas explain start up configuration and abnormal antenna configuration of start up system?
(b) Describe the sectorised antennas with all aspects? [8+8]

6. The U.S AMPS system is allocated 50MHz of spectrum in the 800 Mhz range and provides 832 channels. 42 of those channels are control channels. The forward channel frequency is exactly 45MHz greater then the reverse channel frequency.
(a) If the AMPS system is simplex, half duplex or full duplex? What is the band width for each channel and how is it distributed between the base station and subscriber?
(b) Assume a base station transmits control information on channel 352, operating at 880.560MHz What is the transmission frequency of the subscriber unit on

transmitting on channel 352?

(c) The A- side and B - Side cellular carriers evenly split the AMPS channels. Find the number of voice channels and the number of control channels for each carrier?

(d) let suppose you are chief engineer of a cellular system using seven cell reuse purpose a channel assignment strategy for a uniform distribution of user through out your cellular system specifically , assume that each cell has three control channels (1200 sector is employed)and specify the number of voice channels you would assign to each control in your system?

(e) For an ideal hexagonal cellular layout which has an identical cell coverage, what is the distance between the centers of two nearest co channel cells for seven cell reuse? For four cell reuse? [16]

1 of 2

7. (a) Discuss the reasons why hand offs are needed in cellular communication.

(b) Determine the probability of requirement for hand offs. [8+8]

8. (a) Prove that sectoring decreases trunking efficiency with an example.

(b) Explain how lowering the threshold level of a received signal increases the coverage area. [8+8]

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Code No: RR411701 **Set No. 4**

IV B.Tech I Semester Regular Examinations, November 2007

CELLULAR AND MOBILE COMMUNICATIONS

(Electronics & Telematics)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Explain the limitations of conventional mobile system? How are they overcome by cellular system?
(b) Briefly explain the cell shape and handoff? [8+8]

2. (a) Present the concept frequency reuse channels and frequency reuse distance?
(b) Why cell splitting and explain the cell splitting? [8+8]

3. Briefly explain the design of a directional antenna system in co-channel interference reduction.

4. (a) Explain about the small scale multi path propagation?
(b) Consider a transmitter which radiates a sinusoidal carrier frequency of 1850MHz For a vehicle moving 60mph. Compute the received carrier frequency if the mobile is moving
i. Direction towards the transmitter
ii. directly away from the transmitter
iii. in a direction which is perpendicular to the direction of the arrival of the transmitting signal? [10+6]

5. (a) Explain in detail importance of consideration of cell site antennas?
(b) Assume a receiver is located 10Km from a 50W transmitter. The carrier frequency is 6GHz and free space propagation is assumed Gt =1 and Gr =1W.

i. Find the power at the receiver

ii. The magnitude of the electric field at the receiving antenna

iii. The rms voltage applied to the receiver input assuming that the receiving antenna has purely real importance of 50 ohms and is matched to the receiver. [8+8]

6. (a) What are the different techniques to utilize the frequency spectrum with brief explanation?
(b) Write the concept of the self location scheme at the mobile unit and the autonomous registration? [8+8]

7. (a) List and briefly define different performance metrics that may be used to make the handoff decision?

(b) If the number channels at the cell site N=45 the call holding time is 1.76minutes The number of originated calls per hour expressed as λ is 2270. The number of handoff calls attempted per hour is expressed asλ_2 is 80 Find the probability of the queuing handoff. calls but not the originated calls . Also find the probability of the queuing the originated calls but not the handoff calls? [10+6]

8. Explain the different approaches to increase the coverage of a cellular system in a noisy environment. [16]

Code No: RR411701 **Set No. 1**

IV B.Tech I Semester Supplementary Examinations, February 2007
CELLULAR & MOBILE COMMUNICATION
(Electronics & Telematics)
Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks
⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Explain about the model of the transmission medium?
(b) Differentiate the call connecting procedure in mobile system and land line system? [8+8]

2. (a) With help of neat diagrams, explain the N cell reuse pattern for four and seven cell reuse?
(b) Derive the co channel interference factor for 7 cell reuse pattern? [9+7]
3. (a) Prove that for hexagonal geometry the co channel reuse radio is given byQ =p3N Where $N = i_2+ij + j_2$.
(b) Explain the co channel interference are from the mobile receivers based on test? [8+8]
4. (a) Discuss about the multi path propagation present the associated losses and place the problem?
(b) Discuss about the point to point and area to area prediction model for cell coverage? [10+6]
5. (a) Explain the important effects of cell site antenna height?
(b) Explain top mounted antennas in mobile systems? [10+6]
6. Explain the terms in detail
(a) Adjacent channel assignment
(b) Channel sharing and borrowing
(c) Sectorisation
(d) Overlaid cells. [16]
7. (a) Explain about the handoff and power control?
(b) Explain about the inter MSC handoff? [8+8]
8. Compare the capacity improvement in 120 degree and 60 degree sectoring. [16]
⋆ ⋆ ⋆ ⋆ ⋆

Code No: RR411701 **Set No. 2**

IV B.Tech I Semester Supplementary Examinations, February 2007

CELLULAR & MOBILE COMMUNICATION

(Electronics & Telematics)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

1. (a) Distinguish between the landline telephone network and cellular telephone network?
(b) Explain the phenomena of severe fading? [8+8]
2. (a) Present the concept frequency reuse channels and frequency reuse distance?
(b) Why cell splitting and explain the cell splitting? [8+8]
3. (a) Explain about the cross talk in voice channels?
(b) Explain about the nonlinear amplification in non co channel interference?[8+8]
4. (a) Derive the relation for the maximum coverage distance in mobile environment?
(b) Write the equation for the system gain? Write the importance of each parameter? [10+6]
5. (a) Discuss the characteristics of cell site antennas?
(b) If the antenna heights are varying what are the effects you are getting at the time of operation of mobile system? [8+8]
6. The U.S AMPS system is allocated 50MHz of spectrum in the 800 Mhz range and provides 832 channels. 42 of those channels are control channels. The forward channel frequency is exactly 45MHz greater then the reverse channel frequency.
(a) If the AMPS system is simplex, half duplex or full duplex? What is the band width for each channel and how is it distributed between the base station and subscriber?
(b) Assume a base station transmits control information on channel 352, operating at 880.560MHz What is the transmission frequency of the subscriber unit on transmitting on channel 352?
(c) The A- side and B - Side cellular carriers evenly split the AMPS channels. Find the number of voice channels and the number of control channels for each carrier?
(d) let suppose you are chief engineer of a cellular system using seven cell reuse purpose a channel assignment strategy for a uniform distribution of user through out your cellular system specifically , assume that each cell has three control channels (1200 sector is employed)and specify the number of voice channels you would assign to each control in your system?
(e) For an ideal hexagonal cellular layout which has an identical cell coverage, what is the distance between the centers of two nearest co channel cells for seven cell reuse? For four cell reuse? [16]
7. (a) Discuss the parameters for handling hand offs.
(b) How hand offs are initiated? Explain with examples. [8+8]
8. Explain the following under operational techniques:
(a) Separation between highway cell sites
(b) Low density small market design [16]

Code No: RR411701 **Set No. 3**

IV B.Tech I Semester Supplementary Examinations, February 2007

CELLULAR & MOBILE COMMUNICATION

(Electronics & Telematics)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Explain about the NMT and NTT systems?
(b) Explain the necessity of cellular concept? [8+8]
2. (a) Distinguish between the signal and co channel interference received by the mobile unit and cell site?
(b) Explain the hand off mechanism. How does one reduce the number of handoffs in a cellular system? [8+8]
3. (a) Define co channel interference How is it measured at the mobile unit?
(b) Describe the effect of antenna parameters on the cell interferes? [8+8]
4. (a) Derive the relation for path loss in land to mobile over water?
(b) Explain about the foliage losses? [8+8]
5. Explain the following terms concern to the antennas
(a) Location of the antenna
(b) Set up channel antennas
(c) Space diversity antennas used at the cell site
(d) Umbrella pattern antennas
(e) Interference reduction antennas. [16]
6. The U.S AMPS system is allocated 50MHz of spectrum in the 800 Mhz range and provides 832 channels. 42 of those channels are control channels. The forward channel frequency is exactly 45MHz greater then the reverse channel frequency.
(a) If the AMPS system is simplex, half duplex or full duplex? What is the band width for each channel and how is it distributed between the base station and subscriber?
(b) Assume a base station transmits control information on channel 352, operating at 880.560MHz What is the transmission frequency of the subscriber unit on transmitting on channel 352?
(c) The A- side and B - Side cellular carriers evenly split the AMPS channels. Find the number of voice channels and the number of control channels for each carrier?
(d) let suppose you are chief engineer of a cellular system using seven cell reuse purpose a channel assignment strategy for a uniform distribution of user through out your cellular system specifically , assume that each cell has three control channels (1200 sector is employed)and specify the number of voice channels you would assign to each control in your system?
(e) For an ideal hexagonal cellular layout which has an identical cell coverage, what is the distance between the centers of two nearest co channel cells for seven cell reuse? For four cell reuse? [16]
7. (a) Explain about the practical handoff considerations?

(b) How cell splitting effects on handover mechanisms and explain? [6+10]
8. What do you mean by operational techniques? Why are these needed in cellular systems? Explain briefly different operational techniques. [16]
⋆ ⋆ ⋆ ⋆ ⋆

Code No: RR411701 **Set No. 4**

IV B.Tech I Semester Supplementary Examinations, February 2007
CELLULAR & MOBILE COMMUNICATION
(Electronics & Telematics)
Time: 3 hours Max Marks: 80
Answer any FIVE Questions
All Questions carry equal marks
⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Explain the inefficient spectrum utilization based on the existing mobile systems MTS and IMTS
(b) Describe the special features in amps and compare these with now a days systems? [8+8]
2. (a) A seven cell reuse pattern is needed to achieve a C/I of 18 db. Prove this.
(b) Explain about the data links in a cellular systems? [8+8]
3. Explain the designing of the directional antenna under the worst case conditions for K=4, K=12 and K=7 with all the suitable values and explaining each of them? [16]
4. What are the causes of fading and how it is characterized in mobile environment Explain the effects of fading in detail? [16]
5. (a) Discuss the characteristics of cell site antennas?
(b) If the antenna heights are varying what are the effects you are getting at the time of operation of mobile system? [8+8]
6. Explain the following
(a) Channel sharing
(b) Channel borrowing
(c) Underlay and overlay cells
(d) Setup channel
(e) Paging channel
(f) Voice channel. [16]
7. (a) Explain intersystem handoff?
(b) Classify different handoff mechanisms and define each techniques? [6+10]

8. Explain the following special features in detail.
(a) SMS
(b) MMS
(c) EMS

(d) Call waiting
(e) Call forwarding
(f) Call diverting
(g) Voice storage box
(h) Call re routing. [16]

Code No: RR420401 **Set No. 1**

IV B.Tech II Semester Regular Examinations, Apr/May 2008

CELLULAR AND MOBILE COMMUNICATION

(Common to Electronics & Communication Engineering, Computer Science & Engineering, Information Technology, Computer Science & Systems Engineering and Electronics & Computer Engineering)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

1. (a) Explain the limitations of conventional mobile system? How are they overcome by cellular system?
(b) Briefly explain the cell shape and handoff? [8+8]
2. (a) Derive the C/I in an omni directional antenna system?
(b) What is cell splitting and explain the two kinds of cell splitting techniques? [10+6]
3. (a) A base station receiver capable of providing 80db of isolation between channels is receiving a signal from a mobile unit 2 Km away. What is the minimum distance that a second mobile unit can transmit the signal from the near end mobile unit.
(b) Write a brief note on designing directional antenna system considering the effect of interference. [8+8]
4. (a) Briefly explain the factors considered for prediction of path loss for a particular mobile radio environment.
(b) Explain how antenna spacing and height are done at base station. [8+8]
5. (a) Explain in detail importance of consideration of cell site antennas?
(b) Assume a receiver is located 10Km from a 50W transmitter. The carrier frequency is 6GHz and free space propagation is assumed Gt =1 and Gr =1W.
i. Find the power at the receiver
ii. The magnitude of the electric field at the receiving antenna
iii. The rms voltage applied to the receiver input assuming that the receiving antenna has purely real importance of 50 ohms and is matched to the receiver. [8+8]
6. The U.S AMPS system is allocated 50MHz of spectrum in the 800 Mhz range and provides 832 channels. 42 of those channels are control channels. The forward channel frequency is exactly 45MHz greater then the reverse channel frequency.
(a) If the AMPS system is simplex, half duplex or full duplex? What is the band width for each channel and how is it distributed between the base station and subscriber?
(b) Assume a base station transmits control information on channel 352, operating at 880.560MHz What is the transmission frequency of the subscriber unit on transmitting on channel 352?
(c) The A- side and B - Side cellular carriers evenly split the AMPS channels. Find the number of voice channels and the number of control channels for each carrier?
(d) let suppose you are chief engineer of a cellular system using seven cell reuse pur-

pose a channel assignment strategy for a uniform distribution of user through out your cellular system specifically , assume that each cell has three control channels (1200 sector is employed)and specify the number of voice channels you would assign to each control in your system?

(e) For an ideal hexagonal cellular layout which has an identical cell coverage, what is the distance between the centers of two nearest co channel cells for seven cell reuse? For four cell reuse? [16]

7. (a) How do you find the values of δ and μ related to the cell?

(b) How do you reduce the dropped call rate and explain? [8+8]

8. (a) Explain how by increasing the transmitted power, the coverage is increased.

(b) Discuss the methods for reducing the interference in cellular system. [8+8]

Code No: RR420401 **Set No. 2**

IV B.Tech II Semester Regular Examinations, Apr/May 2008

CELLULAR AND MOBILE COMMUNICATION

(Common to Electronics & Communication Engineering, Computer Science & Engineering, Information Technology, Computer Science & Systems Engineering and Electronics & Computer Engineering)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Differentiate the generations in the cordless phones and cellular phones?
(b) Explain about the dynamic channel assignment? [10+6]

2. (a) Draw the general view of telecommunication and explain the function of the each unit?
(b) Distinguish between the permanent splitting and dynamic splitting? [8+8]

3. (a) Define co channel interference How is it measured at the mobile unit?
(b) Describe the effect of antenna parameters on the cell interferes? [8+8]

4. (a) Discuss about the multi path propagation present the associated losses and place the problem?
(b) Discuss about the point to point and area to area prediction model for cell coverage? [10+6]

5. Describe the directional antenna patterns and the respective antenna arrangement.
(a) At the cell site
(b) Explain the diversity receiver. [16]

6. The U.S AMPS system is allocated 50MHz of spectrum in the 800 Mhz range and provides 832 channels. 42 of those channels are control channels. The forward channel frequency is exactly 45MHz greater then the reverse channel frequency.
(a) If the AMPS system is simplex, half duplex or full duplex? What is the band width for each channel and how is it distributed between the base station and subscriber?
(b) Assume a base station transmits control information on channel 352, operating at 880.560MHz What is the transmission frequency of the subscriber unit on transmitting on channel 352?
(c) The A- side and B - Side cellular carriers evenly split the AMPS channels. Find the number of voice channels and the number of control channels for each carrier?
(d) let suppose you are chief engineer of a cellular system using seven cell reuse purpose a channel assignment strategy for a uniform distribution of user through out your cellular system specifically , assume that each cell has three control channels (1200 sector is employed)and specify the number of voice channels you would assign to each control in your system?
(e) For an ideal hexagonal cellular layout which has an identical cell coverage, what is the distance between the centers of two nearest co channel cells for seven cell reuse? For four cell reuse? [16]

7. (a) How do you find the values of δ and μ related to the cell?

(b) How do you reduce the dropped call rate and explain? [8+8]

8. What do you mean by operational techniques? Why are these needed in cellular systems? Explain briefly different operational techniques. [16]

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IV B.Tech II Semester Regular Examinations, Apr/May 2008

CELLULAR AND MOBILE COMMUNICATION

(Common to Electronics & Communication Engineering, Computer Science & Engineering, Information Technology, Computer Science & Systems Engineering and Electronics & Computer Engineering)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Explain about the NMT and NTT systems?

(b) Explain the necessity of cellular concept? [8+8]

2. (a) Design the C/I formula from a normal case in omni directional antenna system?

(b) Explain two kinds of cell splitting techniques with neat sketches? [8+8]

3. Explain the designing of the directional antenna under the practical case conditions for K = 4 , K = 12 and K = 7 with all the suitable values and explaining each of them? [16]

4. (a) Write short notes on mobile to mobile propagation?

(b) State the merit of point to point model and give general formula of Lee point to point model? [8+8]

5. (a) Obtain the free space path loss formula from the transmitting antenna end?

(b) Obtain the free space path loss formula from the receiving antenna end?[8+8]

6. Present the frequency management of cellular systems for efficient spectrum utilization and increases the number of channels? [16]

7. (a) What are the advantages and disadvantages of CDMA for cellular network in system?

(b) Explain the difference between the soft handoff and hard handoff? [8+8]

8. Compare the capacity improvement in 120 degree and 60 degree sectoring. [16]

Code No: RR420401 **Set No. 4**

IV B.Tech II Semester Regular Examinations, Apr/May 2008

CELLULAR AND MOBILE COMMUNICATION

(Common to Electronics & Communication Engineering, Computer Science & Engineering, Information Technology, Computer Science & Systems Engineering and Electronics & Computer Engineering)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

⋆ ⋆ ⋆ ⋆ ⋆

1. (a) Explain about the Japanese mobile telephone service network configuration?
(b) Explain the Handoff mechanisms in mobile systems? [8+8]

2. (a) Differentiate the analytical situation and simulation?
(b) During a busy hour the number of calls per hour Qi for each of 10 cells is 2000,1500,3000,500,1000,1200,1800,2500,2800 and 900 Assume that 60% of the car phones will be used during the busy period and that one call is made per phone Find out the total number of customers in the system? [10+6]

3. (a) Prove that for hexagonal geometry the co channel reuse radio is given byQ =p3N Where $N = i^2+ij + j^2$.
(b) Explain the co channel interference are from the mobile receivers based on test? [8+8]

4. (a) From the signal coverage point of you explain ground incident angle, elevation angle, ground reflection and reflection point?
(b) If h_1 = 50mt, h_2 = 3mt, d = 5Km, H = 100m use approximate method find incident angle, elevation angle, ground reflection and reflection point? [8+8]

5. (a) Describe the effects of the cell site antenna heights and signal coverage cells?
(b) Define the following concern to the antennas
i. ERP
ii. Equivalent aperture
iii. Null free pattern
iv. 120^0 Sector cell. [6+10]

6. (a) What are the different techniques to utilize the frequency spectrum with brief explanation?
(b) Write the concept of the self location scheme at the mobile unit and the autonomous registration? [8+8]

7. (a) Explain intersystem handoff?
(b) Classify different handoff mechanisms and define each techniques? [6+10]

8. What do you mean by operational techniques? Why are these needed in cellular systems? Explain briefly different operational techniques. [16]

Students List

Discussion Topics

1. Evolution of Cellular systems from 1G to 4G.
2. Importance of hexagonal cell shape in cellular systems
3. Different performance methods: Frequency reuse, Cell splitting
4. Co-channel interference and reduction factor
5. Mobile Antennas
6. GSM
7. CDMA

Group-Wise students list for discussion topics (with reference to above)

Websites, Journals etc

Sources of Information

1. Text books

1. Mobile cellular Telecommunications-W.C.Y Lee, MC Graw Hill, 2nd Edn, 1989.

2. Wireless Communications-Theodore, S.Rapport, Pearson education, 2nd Edn,2002.

3. Cellular Communications by LAN Poole.

4. Mobile wireless communications by Mischa Schwartz.

5. Principle of Mobile Communication by Gordon L.Stuber.

2. Reference Text Books

1. Cellular &Mobile Communication.-Lee MC Graw Hill.

2. Wireless Communications Technology-R.Blake, Thompson Asia Pvt.Ltd, 2004.

3. Wireless Communications and Networking-Jon W.Mark and Weihua Zhqung, PHI, 2005.

4. Introduction to 3G Mobile Communications - by Juha Korhonen

5. Introduction to Mobile Communications ... - by Tony Wakefield, Dave McNally, David Bowler

3. Websites

1. *www.**mobile**in.com/**mobile**_basics.htm*
2. www.gsmfavorites.com
3. *www.tech-faq.com/gsm.shtml*
4. *www.comsoc.org/e-news/2002/aug/agrawal_book.pdf*
5. www.freepatentsonline.com/5875400.html

4 .Journals

1.'Switching plan for a cellular mobile telephone systems'-Z Fluhr & E.Nussbaun(1973)

2.'Data Signaling Functions for a cellular mobile telephone Systems 'V.Hachenburg,B.Holm& J.Smith.

3.'Cellular mobile communications & its impact on Metro Area 'by Quigely P.J.

4.'Multiple access protocols for mobile communication' by Alex brand, Hamid Aghvari 2002.

5.'Principles of digital communication System & Computer Network' by K.V.K.K Prasad 2004.

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4. www.tatamcgrawhill.com/html/9780070252202.html