NETWORK PLANNING IN CDMA MOBILE SYSTEM

By

SHAKTI SINGHAL-031043
VIVEK GUPTA-031054

JUNE-2007

Submitted in partial fulfillment of the Degree of Bachelor of Technology

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY-WAKNAGHAT

CERTIFICATE

This is to certify that the work entitled, **"NETWORK PLANNING IN CDMA MOBILE SYSTEM"** submitted by Shakti Singhal (031043) and Vivek Gupta (031054) in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering of Jaypee University of Information Technology has been carried out under my supervision. . This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

[Mr. D.S.Saini]
Sr. Lecturer
Dept. of ECE, JUIT

[Mr. Rajan Sood]
Asst. Manager (Networks)
Tata Teleservices Ltd., Shimla

ACKNOWLEDGMENT

This project is an outcome of our sincere effort to develop Network planning procedure during our four months training at Tata Teleservices Limited, Shimla, as part of our Bachelor's Degree Program.

Developing an optimized network plan, involving all the concepts of CDMA mobile technology, under the guidance of our esteemed mentor Mr. D.S.Saini not only cleared all our ambiguities but also generated a high level of interest and gusto in the subject. We are truly grateful to him.

We wish to express their sincere appreciation and gratitude for Mr. Rajan Sood, Assistant Manager, TTSL for his guidance and whose familiarity with the needs and ideas of this topic was helpful during this project.

The prospect of working in a group with a high level of accountability fostered a spirit of teamwork and created a feeling of oneness which thus, expanded our ken, motivated us to perform to the best of our ability and create a report of the highest quality.

To do only the best quality work, with utmost sincerity and precision has been our constant endeavor.

[Shakti Singhal]

[Vivek Gupta]

TABLE OF CONTENTS

Certificate........ 2
Acknowledgement..3
Table of contents...4
List of Figures..7
List of Abbreviations...8
Abstract..9

CHAPTER 1: Introduction **10-16**

1.1 CDMA definition 10
1.2 Basic principle behind the technoogy 11
1.3 Future scope 13
1.4 Network Elements 14

CHAPTER 2: Design philosophy **17-27**

2.1 Introduction 17
2.2 High level design objectives 18
2.3 CDMA System design 19
2.4 Implications of high level design 21
2.4.1 Coverage trade-off's 21
2.4.2 Site lay-out trade-off's 22
2.4.3 Trade-off's of designing with existing sites 23
2.5 Overview of system design proceedure 23
2.5.1 Phase - 1 24
2.5.2 Phase - 2 24
2.5.3 Phase - 3 25
2.6 Design entrance criteria 26
2.7 Design exit criteria 27

CHAPTER 3: Propagation Basics **28-34**

3.1 Free space propagation 28

3.1.1 Multipath 28

3.1.2 Cell 30

3.2 Urban Propagation 31

3.2.1 Building penetration 31

3.2.2 Propagation models 32

CHAPTER 4: Link Budget Analysis **35-50**

4.1 Overview 35

4.2 RF Path parameters 36

4.2.1 Assumptions 37

4.2.2 Example link budget 39

4.3 Determining RF design tools to estimate coverage 48

4.4 Impact of Trade-offs on link budget 49

CHAPTER 5: Clutter classifications and Antenna specifications **51-59**

5.1 Overview 51

5.2 Brief background of clutter codes 52

5.3 Clutter environment descriptions 55

5.4 Antenna specifications 56

5.4.1 Antenna considerations 57

5.4.2 Tackling multipath fading 58

5.5 Diversity antenna systems 59

CHAPTER 6: Model Tuning 60 -63

6.1 Introduction 60
6.2 Drive tests 61
6.3 Tuning process 63

CHAPTER 7: Preliminary RF design 64-80

7.1 Objective 64
7.2 Worked example 65
7.2.1 Introduction 65
7.2.2 Assumptions 66
7.2.3 Approach for preliminary RF design 69
7.2.4 Average cell radius calculations 72
7.2.5 Example case 74

Bibliography...81

LIST OF FIGURES

Fig 1.1: Principle of CDMA 12

Fig 1.2: Network elements 15

Fig 2.1: Balance: coverage, capacity & quality 20

Fig 2.2: Network Planning flow diagram 26

Fig 3.1: Free space propagation 29

Fig 3.2: Multipath Environment 30

Fig 3.3: Ideal and Practical cells 31

Fig 4.1: RF path 37

Fig 4.2: Gain and losses 39

Fig 4.3: Downlink budget 41

Fig 4.4: Uplink budget 41

Fig 4.5: CDMA link budget 47

Fig 4.6: ERP values 48

Fig 4.7: Pathloss limit 49

Fig 4.8: Percentage of cells based on Db changes to RF link budget 50

Fig 5.1: Clutter classifications 53

Fig 5.2: Building penetration loss 53

Fig 5.3: Hyderabad Digitizes map 54

Fig 5.4: Diversity systerms 58

Fig 5.5: Signal combiner 59

Fig 6.1: Drive test 62

Fig 7.1: Party enters Reference Number and Password 68

Fig 7.2: Application Status Page of Party, Party ID is retrieved 73

Fig 7.3: Administrator Login Page 74

Fig 7.4: Voter Database on Administrator Console 75

Fig 7.5: Voter Details 76

Fig 7.6: Party Database on Administrator Console 77

Fig 7.7: Party Details 79

Fig 7.8: Election Process is Held by Administrator 80

LIST OF ABBREVIATIONS

A/D	Analog to Digital
ACB	All Channels Busy
ADC	A/D Converter
AMPS	Advanced Mobile Phone System
BER	Bit Error Rate
BHCA	Busy hour call attempts
BSS	Base Station System
BTS	Base Transceiver (Sub) System
CCITT	International Consultative Committee for Telegraph and Telephony
CDMA	Code Division Multiple Access
dB	Decibel
EMI	Electromagnetic Interference
ERP	Effective Radiated Power
GPS	Global Positioning System
GSM	Global System for Mobile Communication
IMSI	International Mobile Station Identifier
PCM	Pulse code modulation
RSSI	Received Signal Strength indication
RX	Receive or receiver
TCH	Traffic Channel
TDMA	Time Division Multiple Access

ABSTRACT

In the present scenario, of wireless communications it has become inevitable for various operations and tasks to be performed with high degree of efficiency and reliability. need of better coverage, capacity and high data rate communications therefore tops the priority list. Equally important are the provisions for security, technological up-gradation and customization in present communication networks. Network planning forms the core function in any commercial wireless service provider company.

Network Planning is continuous process rather than a pre Network set-up event. It involves planning for expansion, cost reduction, continuous monitoring of various trade-offs among key parameters, customization and Optimization of network. There are various indicators for the testing the quality of planning of mobile network .

For the end uses, high data rates, call set-up time, call drop rate, security and service options are issues of prime importance. Lots of R&D has been done over the last decade to develop online Network Planning tools, refine the process according to the changing technology (2.5 G to 3 G), hence the increasing data rates and providing intelligence to the nodes in network thereby improving the efficiency of mobile networks.

CHAPTER-ONE

INTRODUCTION TO CDMA TECHNOLOGY

1.1 CDMA Definition

CDMA, Code Division Multiple Access, is a digital wireless air interface and networking standard based on the principle of spread-spectrum techniques, which allow multiple users to access the system simultaneously on the same carrier frequency.

CDMA is a method in which users occupy the same time and frequency allocations, and are channelized by unique assigned codes.The signals are separated at the receiver by using a correlator that accepts only signal energy from the desired channel. Undesired signals contribute only to noise. The technique of spreading the user waveform with code is called **spread spectrum**.

Two Types of spread spectrum techniques are there :

1. Direct Sequence(DS)
2. Frequency Hopping(FH)

In DS the information is spread over the transmit frequency. In FH information hops between multiple carriers in transmit spectrum in pseudo random manner. Commercially mainly DS spread spectrum technique is used .

1.2 Basic principle behind the technology

Designers and planners of the communication systems are often concerned with the efficiency with which the systems utilize the signal energy and bandwidth. In some cases, it is necessary for the system to resist external interference, to operate at low spectral energy, to provide multiple access capability without external control and secure channel not accessible to the outsiders. Thus, it is sometimes unavoidable to sacrifice some of the efficiency in order to enhance these features. Spread spectrum techniques allow accomplishing such objectives.

All of the spread-spectrum systems have to satisfy two criteria:

1. The bandwidth of the transmitted signal must be greater then the transmitted signal
2. Transmitted bandwidth must be determined by some function that is independent of the message and is known to the receiver.

Bandwidth expansion in spread spectrum systems is achieved by using a function that is independent of the message, thus it is more susceptible to white noise as opposed to other communication techniques, such as FM and PCM. Spread spectrum techniques have other applications that make it unique and useful. These applications include:

1. Anti-jam capability-particularly for narrow-band jamming.
2. Interference rejection.
3. Multiple-access capability.
4. Multi-path protection
5. Covert operation or low probability of intercept (LPI)
6. Secure communications.
7. Improved spectral efficiency-in special circumstances
8. Ranging

CDMA is a wireless communications technology that uses the principle of spread spectrum communication. The intent of CDMA technology is to provide increased bandwidth in a limited frequency system, but has also other advantages including extended range and more secure communications. In a CDMA system, a narrow-band message signal is multiplied by a spreading signal, which is a pseudo-noise code sequence that has a rate much greater than the data rate of the message. CDMA uses these code sequences as a means of distinguishing between individual conversations. All users in the CDMA system use the same carrier frequency and may transmit simultaneously.

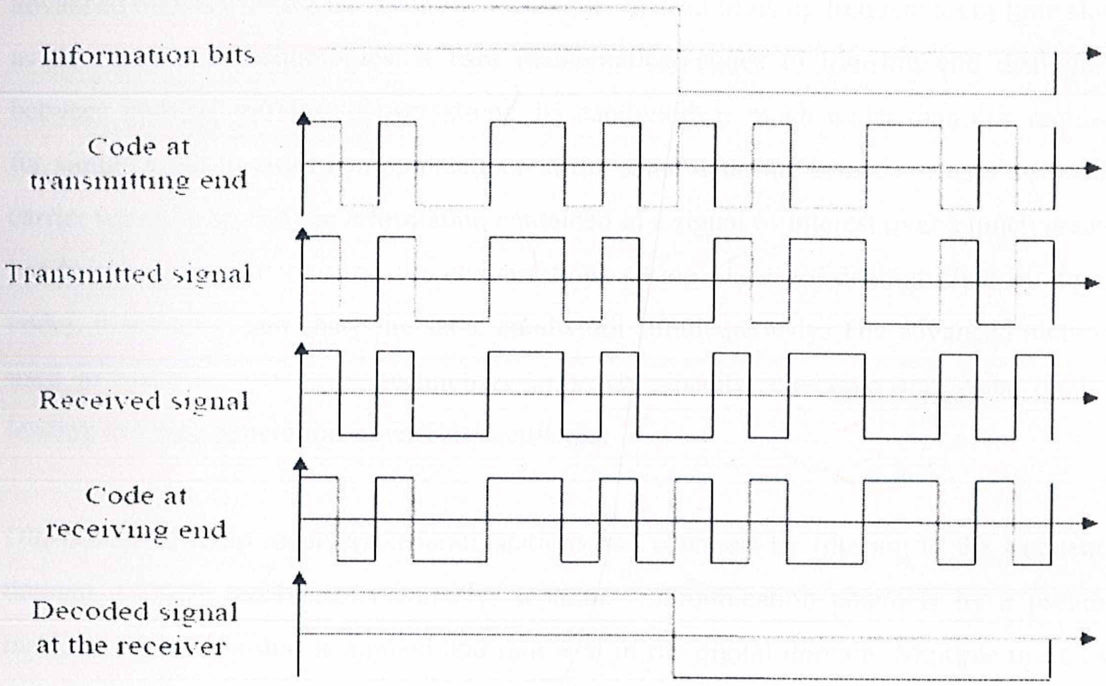

Fig 1.1 Principle of CDMA

1.3 Future scope

CDMA is a driving technology behind the rapidly advancing personal communications industry. Because of its greater bandwidth, efficiency, and multiple access capabilities, CDMA is becoming a leading technology for relieving the spectrum congestion caused by the explosion in popularity of cellular mobile phones, fixed wireless telephones, and wireless data terminals. Since becoming an officially recognized digital cellular protocol,

CDMA stands for "Code Division Multiple Access." It is a form of spread-spectrum, an advanced digital wireless transmission technique. Instead of using frequencies or time slots, as do traditional technologies, it uses mathematical codes to transmit and distinguish between multiple wireless conversations. Its bandwidth is much wider than that required for simple point-to-point communications at the same data rate because it uses noise-like carrier waves to spread the information contained in a signal of interest over a much greater bandwidth. However, because the conversations taking place are distinguished by digital codes, many users can share the same bandwidth simultaneously. The advanced methods used in commercial CDMA technology improve capacity, coverage and voice quality, leading to a new generation of wireless networks.

Old-fashioned radio receivers separate stations and channels by filtering in the frequency domain. CDMA receivers, conversely, separate communication channels by a pseudo-random modulation that is applied and removed in the digital domain. Multiple users can therefore occupy the same frequency band. This universal frequency reuse is crucial to CDMA's distinguishing high spectral efficiency. CDMA has gained international acceptance by cellular radio system operators as an upgrade because of its universal frequency reuse and noise-like characteristics. CDMA systems provide operators and subscribers with significant advantages over analog and conventional TDMA-based systems

1.4 Network elements

The Mobile Station

The Mobile Station (MS) is the user equipment in Wireless Networks.. Production of Mobile Stations is done by many different manufacturers, and there will almost always be a wide range of different Mobile Stations in a mobile network. Therefore the specifications specify the workings of the MS in great detail.

The Base Transceiver Station

The Base Transceiver Station (BTS) is the entity corresponding to one site communicating with the Mobile Stations. Usually, the BTS will have an antenna with several TRXs (radio transceivers) that each communicates on radio frequency. The link-level signaling on the radio-channels is interpreted in the BTS, whereas most of the higher-level signaling is forwarded to the BSC and MSC

The Base Station Controller

Each Base Station Controller (BSC) control the magnitude of several hundred BTSs. The BSC takes care of a number of different procedures regarding call setup, location update and handover for each MS. The handover control procedures will come especially into focus in this thesis. It is the BSC that decides when handover is necessary. This is accomplished by analyzing the measurement results that are sent from the MS during a call and ordering the MS to perform handover if this is necessary. The continuous analyzing of measurements from many MSs requires considerable computational power. This put strong constraints on the design of the BSC.

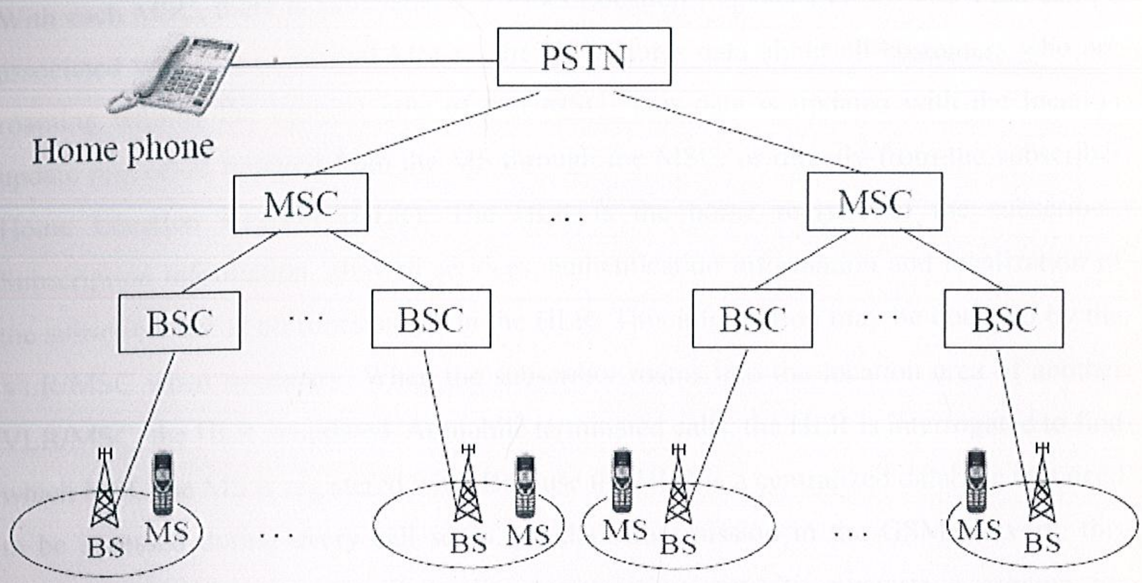

Fig 1.2 Network Elements

The Mobile Switching Center

The Mobile Switching Center is a normal ISDN-switch with extended functionality to handle mobile subscribers. The basic function of the MSC is to switch speech and data connections between BSCs, other MSCs, other Wireless networks and external non-mobile-networks. The MSC also handles a number of functions associated with mobile subscribers, among others registration, location updating and handover. There will normally exist only a few BSCs per MSC, due to the large number of BTSs connected to the BSC. The MSC and BSCs are connected via the highly standardized A-interface. However, due to the lack of standardization on Operation and Management protocols, network providers usually choose BSCs, MSCs and Location Registers from one manufacturer.

The Location Registers

With each MSC, there is associated a Visitors Location Register (VLR). The VLR can be associated with one or several MSCs. The VLR stores data about all customers who are roaming withing the location area of that MSC. This data is updated with the location update procedure initiated from the MS through the MSC, or directly from the subscriber Home Location Register (HLR). The HLR is the home register of the subscriber. Subscription information, allowed services, authentication information and localization of the subscriber are at all times stored in the HLR. This information may be obtained by the VLR/MSC when necessary. When the subscriber roams into the location area of another VLR/MSC, the HLR is updated. At mobile terminated calls, the HLR is interrogated to find which MSC the MS is registered with. Because the HLR is a centralized database that need to be accessed during every call setup and data transmission in the GSM network, this entity need to have a very large data transmission capacity suggests a scheme for distributing the data in the HLR in order to reduce the load.

CHAPTER-TWO

DESIGN PHILOSOPHY

2.1 Introduction

The overall Objective of the planning process is to design a cost-effective design of a good cellular network

A good plan should address the following issues

- Provision of required Capacity
- Optimum usage of the available carriers
- Minimum number of sites
- Provision for easy and smooth expansion of the network in future
- Provision of adequate coverage of the given area, for a minimum specified level of interference

In general the planning process starts with the inputs from the customer. The customer inputs include customer requirements, business plans, system characteristics and any other constraints.

After the planned system is implemented, the assumptions made during the planning process need to be validated and corrected whenever necessary through an OPTIMIZATION process.

We can summarize the whole planning process under four broad headings

- Capacity Planning
- Coverage Planning
- Parameter Planning
- Optimization

2.2 High Level Design Objectives

Before beginning a CDMA RF system design, the objectives of the design need to be clearly understood by all parties involved. For example, some common questions to ask include;

- Are the requirements coverage based?
  - To Maximum coverage
  - To Provide In-building Coverage
  - To Provide a Highway Coverage Design
  - To Provide coverage of specific areas i.e. Malls. Airports etc..
- Is the system maximized for capacity?
- What is the minimum requirement for the target FER
- Is the objective to design a demonstration system or field trial system?
- Is the objective to design a new system?
- Is the objective to design a growth plan for an existing network?
- Is the design to provide area coverage with low initial subscriber penetration to minimize deployment costs but provide rapid growth?
- Are there real estate or location constraints that the system designer should consider?
  - Re-Use of Existing Site Locations (such as 800 MHz AMPS locations)
  - Contractual Agreements with Real Estate Holders (such as power
  - companies, gas stations, etc.)
  - Government Regulations
  - City Ordinance/Zoning Restrictions

- Does the system designer need to consider RF overlap/interference Into a bordering system?
- Are there a fixed number of available site locations?
- Are there differing constraints between different regions of the system?
  - Example - Urban area design requirement is for maximum capacity while rural area design requirement is for maximum coverage.
  - Example - Requirements are not consistent over the entire system and also vary with time.
- What are the equipment requirements?
  - Available Space at Site (amount of real estate that is available to place the physical hardware)
  - PA Sizing
  - BTS Requirements
  - Site Configuration
  - Focus on Customer Requirements While Meeting Initial Objectives
  - Design Balance – Capacity, Coverage, Quality

2.3 CDMA System Design

A CDMA system design should focus on capacity, coverage and quality to determine a proper balance of each of these parameters in order to achieve the desired system requirements and system performance standards. The common factor between each of these parameters is the required Eb/No.

- **Capacity**
  - Reverse link capacity is inversely proportional to Eb/No (i.e. as the Eb/No requirement is lowered, the capacity is increased).
  - As the number of users increases in the system, the amount of noise generated by these users increases. The additional noise will increase the noise floor.

Capacity of a CDMA system = { (channel BW) / (Data Rate) } x { 1/(S/N)} x {1/(Vaf)} x {Fr}

where, **Vaf** is Voice Activity Factor & **Fr** is Frequecy reuse factor

- **Coverage**
  - ➢ Path loss is a function of receiver sensitivity which, in turn, is a function of Eb/No. As the Eb/No requirement is reduced, the receiver sensitivity value is also lowered and thus, the allowable path loss of the site is improved.
  - ➢ As mentioned under capacity, more users will increase the noise floor and thus reduce the maximum allowable path loss of the site. On the other hand, fewer users on the system will not generate as much noise and therefore the impact on the noise floor will be lessened
- **Quality**
  - ➢ The CDMA design accounts for quality by using FER (frame Erasure Rate). Standard recommended design procedures require the FER target criteria to be 1% and the FER outage criteria to be 3%. If this criteria is relaxed then a lower Eb/No is required.

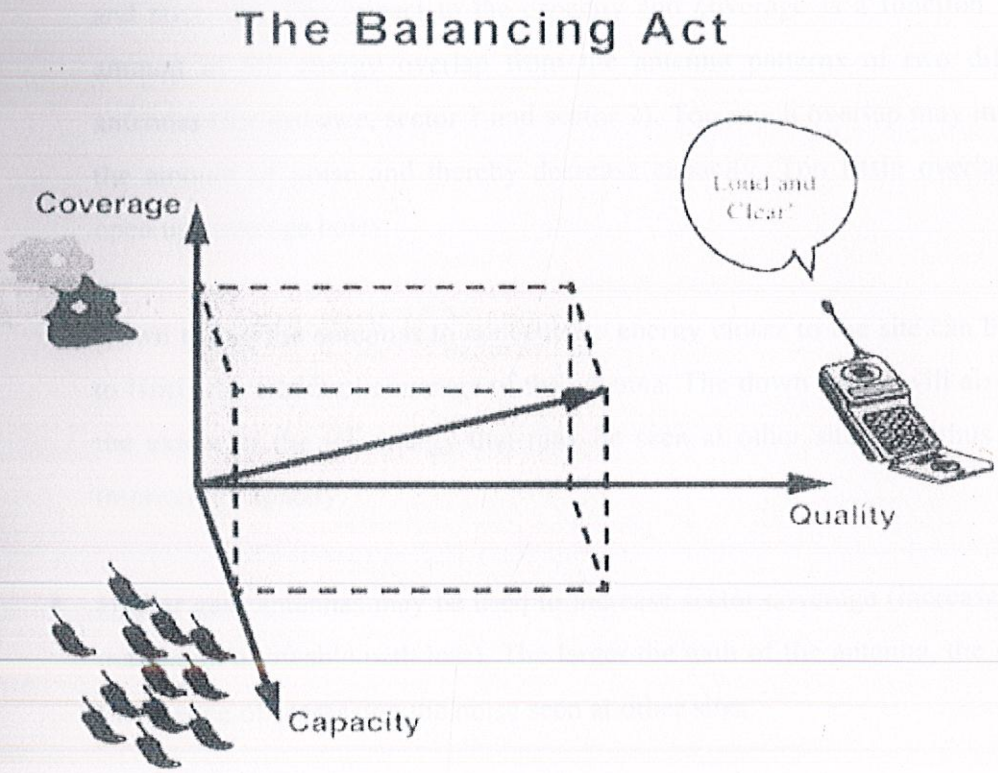

Fig 2.1 Balancing Coverage, Capacity & Quality

CDMA allows an operator to vary the relationship between Capacity, Coverage & Quality,trade-offs are involved in varying this relationship. If one of the axes is altered, then one or both of the remaining axes must also be altered to compensate for the change.

2.4 Implications of high level design

2.4.1 Coverage Trade-offs

- Site Configuration (omni. three-sector, six-sector):
  - Typically, the antenna gains available for directional antennas are greater than omni directional antennas.
  - Antenna Trade-offs
    - The horizontal/vertical patterns of the selected antenna will impact capacity and coverage. The impact to the capacity and coverage is a function of the amount of RF energy overlap from the antenna patterns of two different antennas (for instance, sector 1 and sector 2). Too much overlap may increase the amount of noise and thereby decrease capacity. Too little overlap may open up coverage holes.

    - Down tilting the antennas to concentrate energy closer to the site can be used to limit the extent of coverage of the antenna. The down tilting will also limit the extent of the RF energy that may be seen at other sites and thus aid in improving capacity.

    - Higher gain antennas may be used to increase sector coverage (increase of the maximum allowable path loss). The larger the gain of the antenna, the greater the chance of increasing the noise seen at other sites.

- A larger front-to-back ratio and faster roll off (attributes of the horizontal antenna pattern) will both aid in reducing the area where the RF energy is directed. In this case, capacity will be improved, however the trade off will be reduced coverage.

- Vocoder Rate:
  - The 13 kb vocoder provides for a high quality call but at the expense of capacity and coverage. The standard 8 kb vocoder will provide for better capacity and coverage over the 13 kb vocoder but at the sacrifice of sound quality. The 8 kb EVRC vocoder has capacity and coverage equivalent to the standard 8 kb but has better sound quality.
- Loading of the CDMA Carrier:
  - Lightly loaded (few users) sites will produce less interference/noise to the system than a system with sites that are heavily loaded. The highly loaded sites will produce more noise to the system, which increases the noise floor required for a call, thus reducing the path loss of the site
- Site Configuration (omni, three-sector, Six -Sector): The more sectors available at a site, the more capacity that can be supported at the site.

2.4.2 Site Layout trade-offs

If a system is designed for in-building penetration. sites will be placed closer together which can create a large amount of interference for on-street or in-vehicle subscribers in the same area. If the interference level for the system increases sufficiently, the system quality and capacity will degrade.

- To keep costs down, the system designer can limit the number of sectors for areas where the load is predicted to be light. Along highways and in rural areas, it is not unusual to use onmi or two-sector sites.

- As the system designer lays out a new system, attempts should be made to allow for ease of system growth. Growth can be measured either by coverage or capacity or both. For capacity growth, the system designer may space the sites closer together such that there are no coverage holes when the site meets its maximum capacity. Another option that the system designer has is to place the sites further apart to support a lighter load of users but also as a means to reduce the number of sites required. As the traffic demand increases, the designer can then cell split or add additional carriers (if additional frequency spectrum is available).

2.4.3 Trade-offs of Designing with Existing Sites

- Site Location Restrictions
- Antenna Bandwidth Restrictions
  - Antenna Down tilt Restrictions
- Equipment must always be part of the system designer's considerations.
  - Certain BTS types may be capacity or coverage limited for various reasons (i.e. micro versus macro sites, and omni versus sectored sites).
  - Power amplifiers (including tower top amplifiers) may be a limiting factor.

2.5 Overview of System Design Procedure

The purpose of this procedure is to provide CDMA system design engineers with a procedure to follow when designing CDMA RF systems. The procedure addresses those steps which should be taken to select CDMA cell sites and predict their performance.

A CDMA system is designed in three phases, each of which will require a thorough review before proceeding on to the next phase.

2.5.1 Phase I

The first step in a system design is setting up the link budget to model the path between the mobile and the base station, accounting for all of the gains and losses along the path. This link budget is used to establish system design assumptions which are used in RF Design Tool and the simulation portion of the design process, as well as to establish an estimate for maximum allowable path loss. The link budget parameters are then used in conjunction with the propagation model in Design Tool to estimate coverage.

Since the system design assumptions in the link budget are used in the CDMA Design tool, it is important that these assumptions be discussed and agreed upon. For this reason, it is recommended that the link budget and its assumptions be reviewed before proceeding to the next design step.

2.5.2 Phase II

The objective of Phase II of the system design is to produce, and review path loss prediction plots. These plots are generated using Design tool inputs based on the link budget enhanced clutter database, terrain database, antenna placement, antenna type, and all other parameters associated with propagation.

Analyzing plots that are based on maximum allowable path loss can help determine major issues such as coverage holes, cell site placement problems terrain obstruction issues, and sites which may present interference problems. By identifying these issues early in the design process, some of these issues can be resolved before going through the time and effort of simulations. This allows the simulation process to be used to concentrate on issues that can only be analyzed with the simulator rather than issues that can be addressed by coverage plots based on path loss only.

Once coverage estimates have been run and analyzed, it is suggested that the plots be carefully reviewed. This step is important to make sure that the system coverage from a "path loss only" perspective meets the design expectations

2.5.3 Phase III

Finally Phase III encompasses all of the remaining steps required to run a system simulation (as many iterations as is necessary) and to review each run. The system simulations analyze both the forward and reverse links and account for CDMA effects (such as mobile speed, soft handoff, voice activity, pilot settings, etc.). The steps in Phase- III include:

- Determining CDMA Simulation Inputs
  - A Traffic Distribution Map
  - A Speed Map (optional)
  - Path Loss Information
  - Simulation Input Parameters
  - Inter-System Interference input files (optional)
  - Neighbor List (optional)
- Running the Simulator
- Analyzing Simulator Outputs (Statistics and Images)

  - The simulator produces various images and statistical outputs. These outputs must be analyzed to determine if a given design is operating properly. It is important to understand that analyzing just statistics or images alone does not validate a good system design. Images and statistics must both be used to validate a system design.
  - While evaluating a system design, it is important to see if it meets the design requirements and minimum system performance standards. If it does not, then the design needs to be modified and simulations repeated until it meets the defined expectations.
- Comparison of Simulator Coverage vs. Path Loss Only Coverage
  - Comparing the coverage based on the simulator results with the coverage based on path loss only will highlight the areas where "CDMA" effects impact the coverage environment.

- Final Design Review
  - ➢ Verification that system design meets the defined performance expectations.
  - ➢ A formalized report, complete with plots, graphs and data, should be prepared.

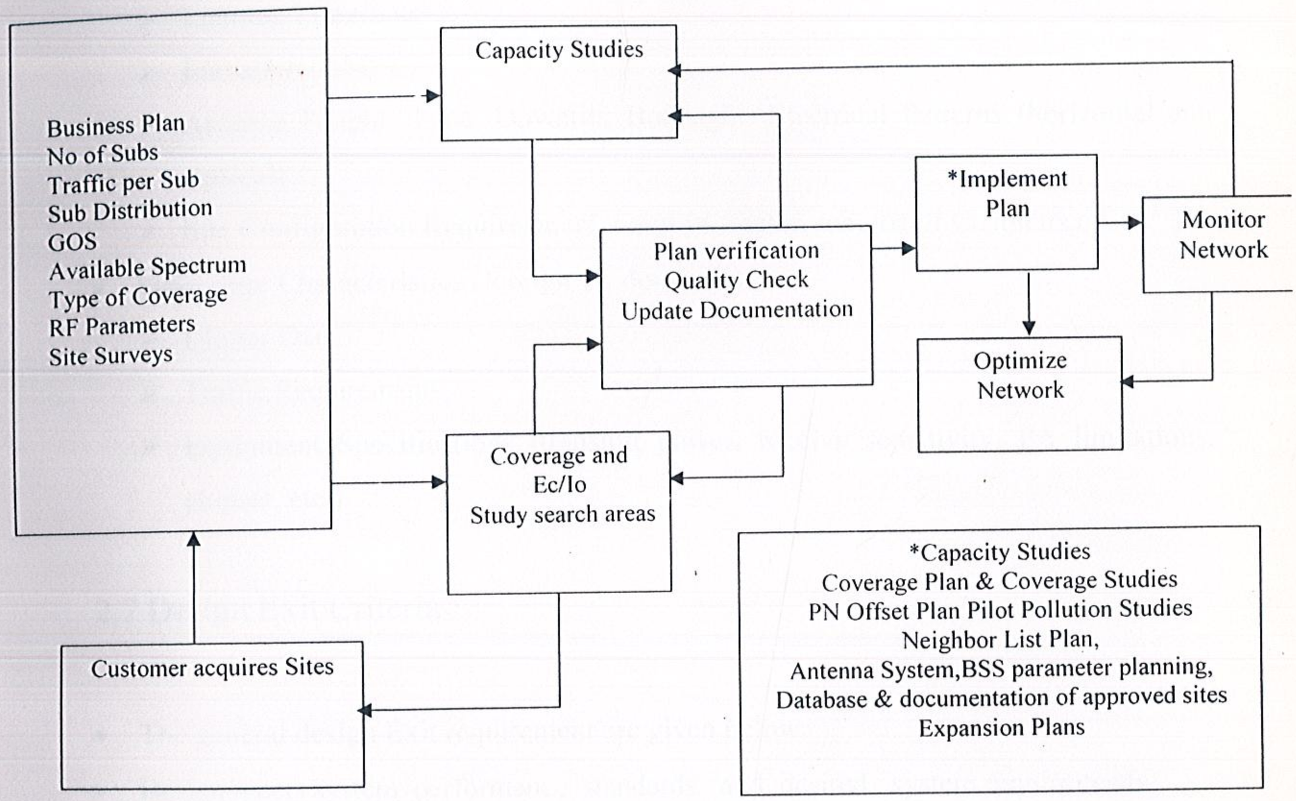

Fig 2.2 Network planning flow diagram

2.6 Design entrance Criteria

- General Design Entrance Requirements are given below:
- Desired RF Coverage Area
- Frequency Spectrum to be Utilized
- Desired vocoder Rate
- RF Link Budget
- Clutter Data

- Terrain Data
- Design Objectives
- Warranty and Performance Requirements
- Site Information
  - Latitude/Longitude
  - Elevation (AMSL)
  - Antenna Height, Type, Downtilt, Boresight, Electrical Patterns (horizontal and vertical)
  - Site Configuration Requirements (omni vs. sector, macrocell vs. microcell, etc..)
- Subscriber Characteristics (foreign vs. domestic)
  - Clutter Data
  - Traffic Requirements
  - Equipment Specifications (transmit power, receive sensitivity. PA limitations, chipset, etc.)

2.7 Design Exit Criteria

- The general design Exit requirement are given below:
- Design meets system performance standards and desired system requirements.
- Quantity of Sites
- Channel Quantities per Site
- Site Locations
- Site Configurations
- Antenna Information (height, orientation, tilts, etc.)
- Simulator Images (including coverage plots)
- Statistics
- Neighbor Lists
- Parameter Settings
- Channel Power Settings

CHAPTER-THREE

PROPAGATION BASICS

3.1 Free Space Propagation

The ability of Electro Magnetic waves to propagate depends a lot on the propagation environment. In vacuum, i.e. free space, they propagate (radiate) without any obstruction. Such a radiation according to Maxwell's theory, occurs uniformly in all directions, at the speed of light.

This may be viewed as a set of concentric SPHERES expanding both in time and space. We can visualize the radiation as shown in the diagram given in page opposite.At the speed of light the signal takes 3.3 microsec to travel at a distance of 1Km. Thus the signal at point d3 (3 KMs) arrives 9.9 microsec with uniform signal strength at all points on the sphere S3. In cellular communications, this sphere is called the CELL.

The signal is attenuated as it travels to the receiver. The Extent of attenuation is called the FREE SPACE LOSS. Free Space Loss is expressed in dBs and is given by the equation given below:

$$\mathbf{L_{FS} = 32.44 + 20 \log (f) + + 20 \log (d)}$$

Where the frequency 'f' is in MHz and distance 'd' is in KMs.

3.1.1 Multipath

In a mobile environment, there is seldom a direct line of sight between the mobile and the BTS. Hence, the pure free space path loss calculated as per the formula given above is not directly applicable.

The multipath is due to reflection, diffraction and scattering of radio waves. The extent of these effects depends on the type and the total area of the obstruction. For instance a plain surface will cause maximum reflection while a sharp edge like the corner of a building will cause scattering of signals known as the *knife edge effect.*

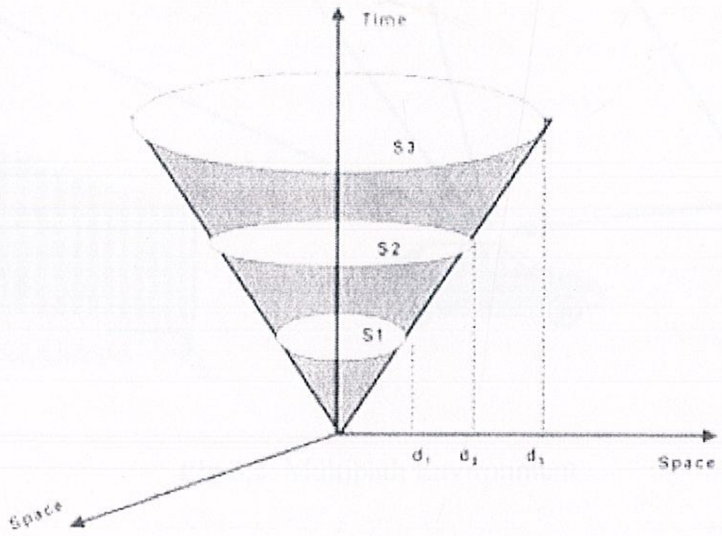

Fig 3.1 Free space propagation

Multipath

A typical Multi Path Environment:

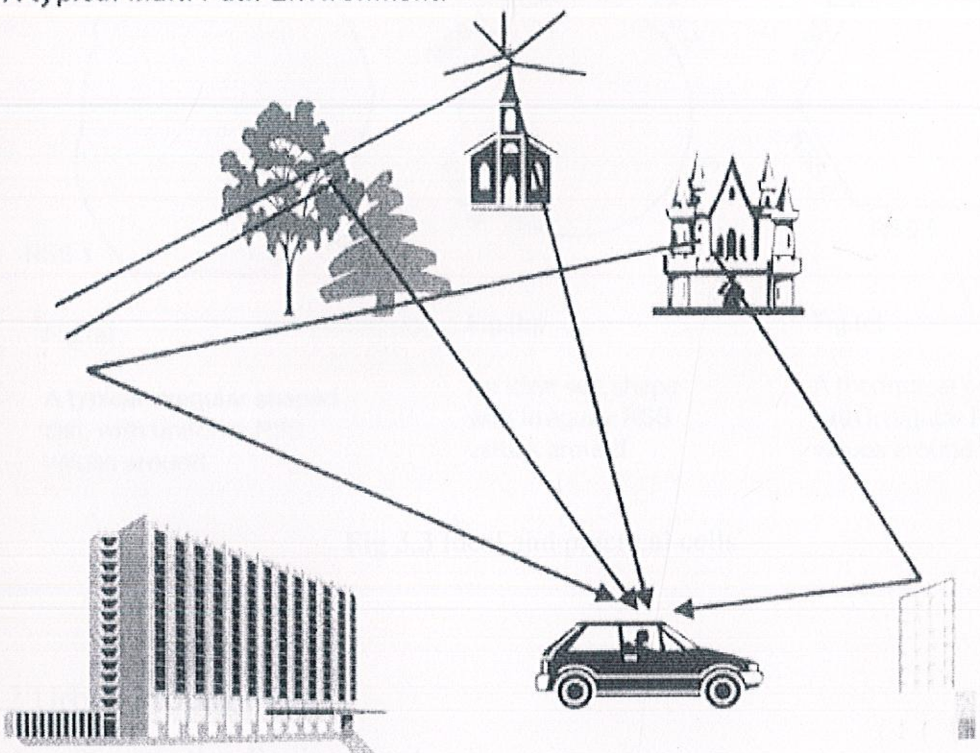

Fig 3.2 Multipath Environment

3.1.2 Cell

A cell is a geographical area, which is covered by radio signals. Conventionally, a practical cell is considered to have an irregular shape, with uniform Receive Signal Strength (RSS) all around.

However, it is convenient to assume a regular shape for analytical and planning purposes. Ideally a cell should be circular in shape with varying signal strengths all around. From geometrical point of view this can be approximated by a hexagon, with different RSS values on the sides.

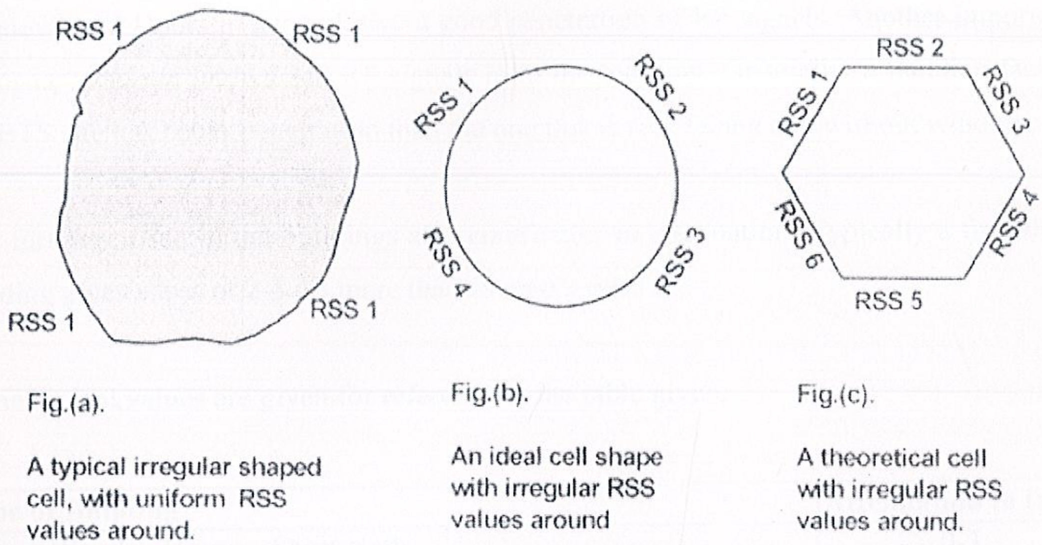

Fig 3.3 Ideal and practical cells

3.2 Urban Propagation

Urban Propagation Environment

This is the most common and yet unpredictable propagation environment for a mobile system.

3.2.1 Building Penetration

Buildings are responsible for reflection and shadowing of signals. Trees and foliage also contribute to shadowing as well as scattering of radio signals. Typically, the attenuation values may cause the signal levels to vary by - 40 to +80 dB. The negative value implies that signal is attenuated and the positive "values mean that the signal level increases as we move up inside the building.

Windows and Doors in general give a good penetration of RF signals. Another important factor is *"angle of arrival"* of RF signals in to the building. Generally, a building facing the BTS site has better penetration than the one that is side facing and without windows.

The furniture used in the buildings also contributes to attenuation. Typically a furnished building gives a loss of 2-3 dB more than an empty one.

Some typical values are given for reference in the table given.

Type of Building	**Attenuation in (dBs)**
Farms, Wooden Houses, Sport Halls	0-3
Small offices, Parking lots, Independent houses, Small apartment blocks	4-7
Row houses, Offices in containers, Offices, Apartment blocks	8-11
Offices with large areas	12-15
Medium Factories, workshops without rooftop windows	16-19
Halls of metal, without windows	20-23
Shopping malls, ware houses, buildings with metal/glass	24-27

Table 3.1 Attenuation values

3.2.2 Propagation Models

The important classical propagation models are listed below:

- Hata Model: Used in Urban/Suburban Areas for GSM 900 Band
- Cost 231 -Hata Model: Used for GSM 1800 MHz band

Okumara – Hata Model

In the early 1960's a Japanese scientist by name Okumara conducted extensive propagation tests from mobile systems at different frequencies. The tests were conducted at 200, 453, 922, 1310, 1430 and 1920 MHz. The tests were also conducted for different BTS and mobile antenna heights at each frequency over varying distances between the BTS and the mobile. The Okumara tests are valid for

- 150 - 2000 MHz
- 1-100 KMs
- BTS heights of 30-200 M
- MS antenna height typically 1.5 m (1-10 m)

The results of Okumara tests were graphically represented and were not easy for computer based analysis. Hata took Okumara's data and derived a set of empirical equations to calculate the path loss in various environments. He also suggested correction factors to be used in Quasi open and sub urban areas.

Hata Urban Propagation Model

The general path loss equation is given by

$$L_P = Q_1 + Q_2 \log(f) - 13.82 \log(h_{BTS}) - a(h_m) + \{44.9 - 6.55 \log(h_{BTS})\} \log(d) + Q_0$$

Where.

Lp = path loss in dB.

F = Frequency in MHz.

d = distance between BTS and the mobile (1 -20 Kms)

h_{BTS} = Base station height in meters (30 to 100m)

$a(h_m)$ = Correction required if mobile height is more than 1.5 metres and is given by:

$a(h_m)$ = { 1.1 log(f) - 0.7} h_m - { 1.56 log(f)-0.8} for Urban areas and

= 3.2 {log (11.75 h_m)^2 - 4.97 for Dense urban areas

h_m = mobile antenna height (1-10 m)

Q_1 = 69.55 for frequencies from 150 to 1000 MHz

= 46.3 for frequencies from 1500 to 2000 MHz.

Q_2 = 26.16 for 150 to 1000MHz

= 33.9 for 1500 to 2000 MHz.

Qo = 0dB for Urban

= 3 dB for Dense Urban

The basic equation for the 150-1000 MHz band is given below:

$$\mathbf{Lp = 69.55 + 26.16 \log (f) - 13.82 \log(h_{BTS}) - a (h_m) - \{(44.9-6.55 \log(h_{BTS}) \} \log(d)}$$

CHAPTER-FOUR

LINK BUDGET ANALYSIS

4.1 Overview

The first step in a system design is setting up the RF link budget to model the RF path between the subscriber unit and the base station. This RF link budget accounts for all of the gains and losses along this RF path.

There are two main purposes for establishing an RF link budget for CDMA designs.

- The first main purpose is to establish system design assumptions (such as vehicle loss, building loss, ambient noise margin, maximum subscriber transmit power, etc.) and to specify all other gains and losses in the RF path which are then used as inputs to the Design Tool in the design process.
- The second main purpose of a link budget is to establish an estimate for maximum allowable path loss. This maximum allowable path loss number is used in conjunction with the propagation model of design tool to estimate cell site coverage.

The CDMA RF link budget in this procedure models only the reverse link. The forward link, due to its variability, is accounted for within the simulation step. An RF reverse link budget must be created for each site/sector in the design.

4.2 RF Path Parameters

The designer will need to determine the specific parameters to use in the reverse RF link budget. The values in the link budget are used as inputs to the design tool for maximum allowable path loss images and later for the Design tool CDMA Simulator.

Link budget parameters can be grouped into four categories given below:

Propagation Parameters

- Building Loss
- Vehicle Loss
- Body Loss
- Noise Margin
- RF Feeder Losses
- Antenna Gain

CDMA Parameters

- Interference Margin
- Eb/No

Product Parameters

- Transmit Power
- Receiver Sensitivity

Reliability (Shadow Fade Margin)

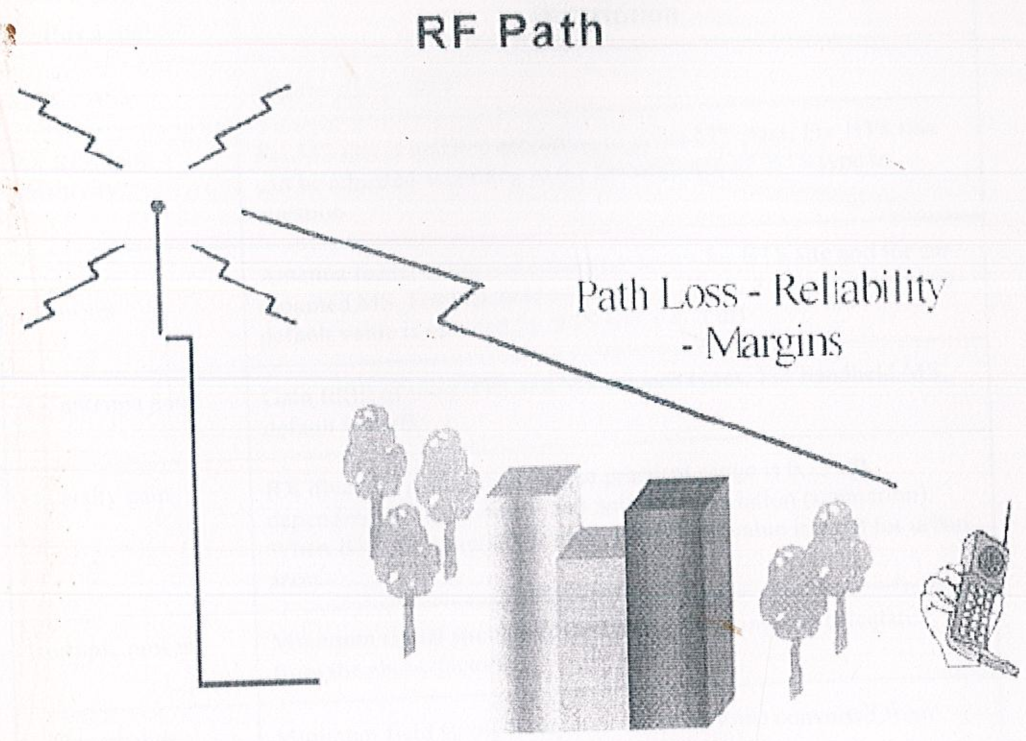

Fig 4.1 RF Path

4.2.1 Assumptions

The CDMA reverse link budget contains simplifying assumptions for Eb/No and Noise rise.

- Eb/No is treated as a constant in the RF link budget.
  - ➢ Varies with the speed of the mobile.
- Ambient Noise Rise is also treated as a constant in the RF link budget.
  - ➢ Noise floor measurements should be made to determine if additional man made noise is present. Man made noise has a greater impact at 800 MHz than at 1.9 GHz.

Parameter	Description
MS CLASS	Mobile power class
RX RF-input sensitivity	For MS this is updated according to given MS class. For BTS this can be adjusted according to the performance of BTS type in question.
Cable loss + connector	Antenna feeder cable and connector losses for BTS site and for car mounted MS. For handheld MS this is 0 dB. In dimensioning some default value is selected for BTS site, e.g. 3 dB
RX antenna gain	Gain (dBi) of used BTS and MS antenna types. For handheld MS, default is 0 dB.
Diversity gain	RX diversity gain. For BTS, the practical range is 0...5 dB depending on environment and antenna installation (separation). When BTS RX diversity is used, the default value is 4 dB for urban areas.
Isotropic power	Minimum signal strength (dBm) in the receiving end calculated from the above factors.
Field strength	Minimum field strength requirement (dBμV/m) converted from isotropic power.
TX RF output peak power	For MS this comes from selected MS class. For BTS this is calculated according to balanced radiolink requirement.
Isolator + combiner + filter	Attenuation of the BTS RF components between TX unit and antenna feeder connector of BTS. The exact value depends on BTS model and configuration, typical values are 3,5 .... 5 dB.
RF peak power (Combiner) output	Transmit power at BTS/MS antenna connector
TX antenna gain	According to selected RX antenna gain
Peak EIRP	Effective Isotropic Radiated Power level
Isotropic path loss	EIRP - minimum RX field strength
Standard deviation	Standard deviation of the signal strength (outdoors). Typical value is 6 ... 8 dB depending on the environment.
BPL average	Average building penetration loss in the target area (for indoor coverage calculation), typically between 8 ... 18 dB.
BPL deviation	Signal deviation indoors (for indoor coverage calculation), typically 8 ... 12 dB.
Area type correction	Area type correction factors for the Okumura-Hata model

RF Link Budget Gains & Losses

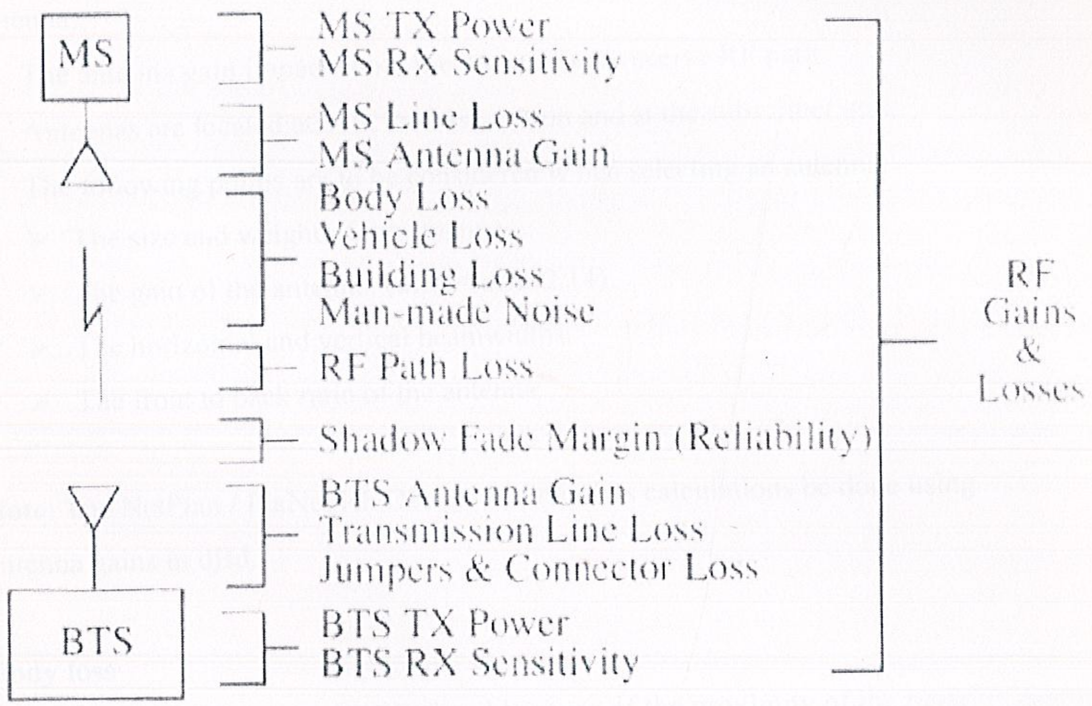

Fig 4.2 Gains and losses

4.2.2 Example Link Budget

A sample link budget for 1.9 GHz using both 13 kB and 8 kb vocoders is prsented here. The values in the columns are examples and differences may exist for the systems you will design.

Portable Tx Power

Minimum effective radiated power from the subscriber unit.

Radiated power (dBm)

PA output power (dBm) - line losses (dB) + Antenna Gain (dBd)

Antenna Gain

The gain of an antenna may be referenced lo a dipole (dBd) or to an isotropic (dBi) antenna.

- The antenna gain impacts both the transmit and receive RF path.
- Antennas are located at both the base station and at the subscriber unit.
- The following points are to be considered w hen selecting an antenna:
  - ➢ The size and weight of the antenna.
  - ➢ The gain of the antenna. (dBd = dBi- 2.14)
  - ➢ The horizontal and vertical beamwidths.
  - ➢ The front to back ratio of the antenna.

Note: The NetPlan / PlaNet RF Design tool requires calculations be done using antenna gains in dBd.

Body loss

Additional degradation of the RF signal because of the proximity of the portable antenna to a person's body. A value of 2 dB is suggested unless a different body loss is specified.

Vehicle loss

The additional loss occurring when a portable is used inside a vehicle could be as high as 12 dB or even greater. If the system is to provide for in-vehicle service, a value of 6 dB is recommended unless a different in-vehicle loss is specified.

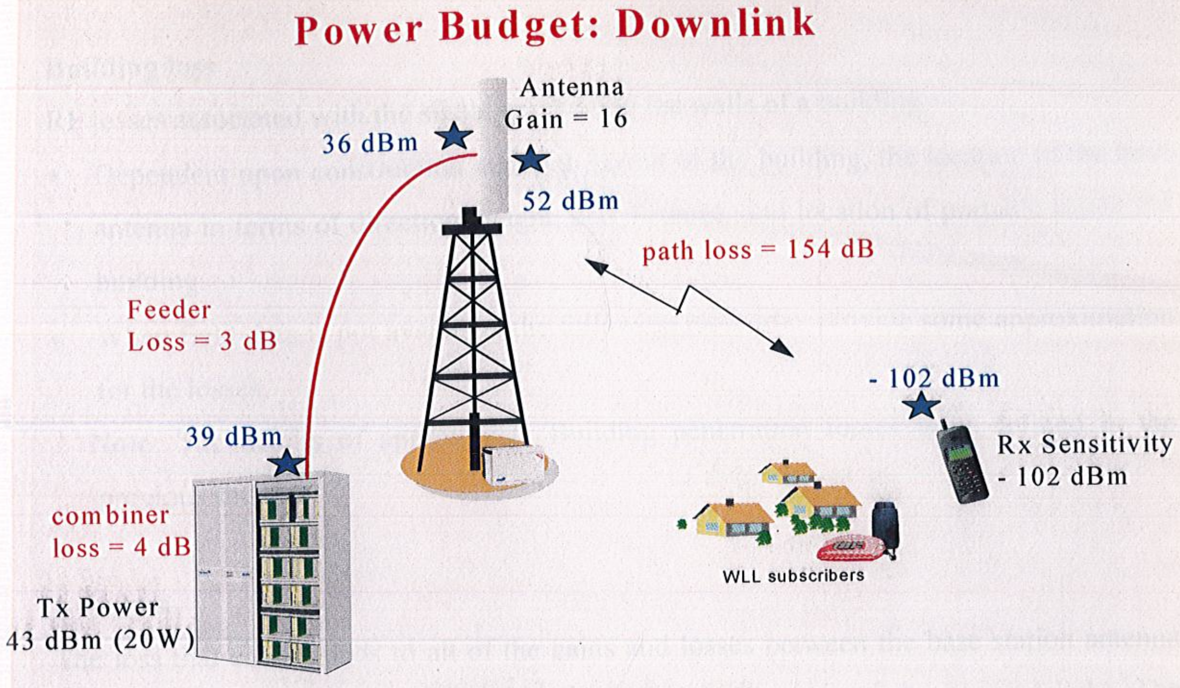

Fig4.3 Downlink budget

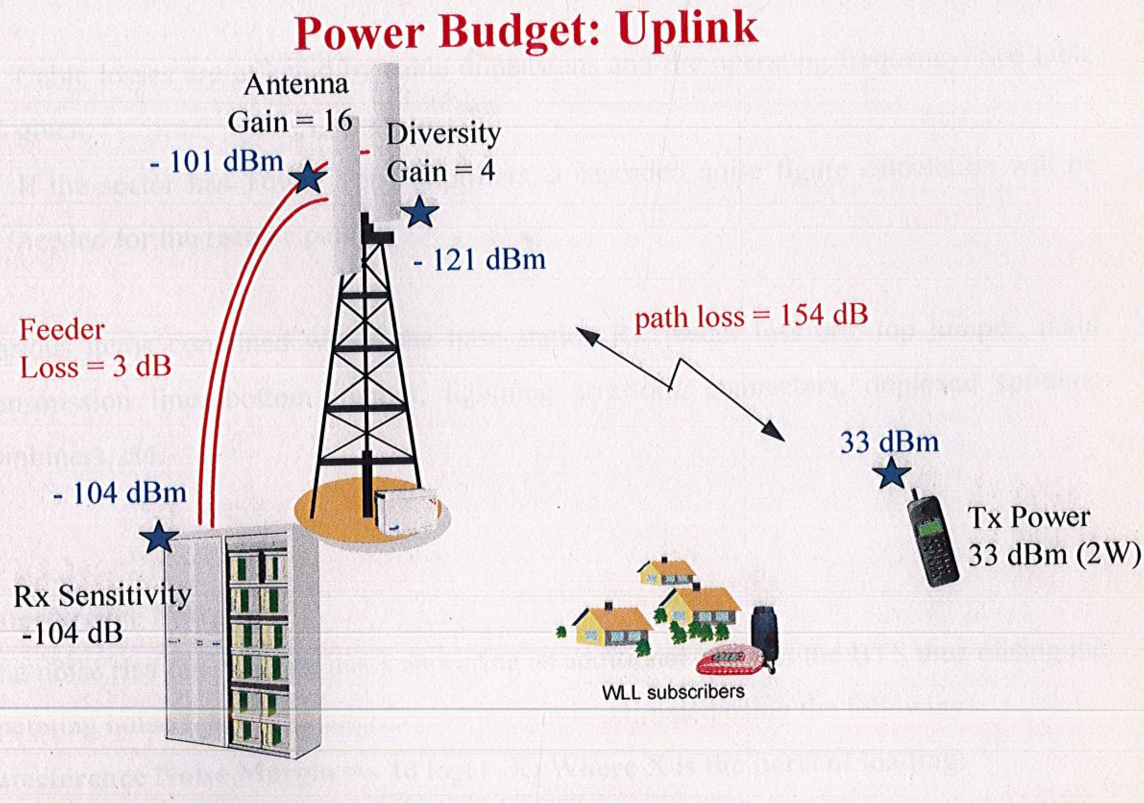

Fig 4.4 Uplink budget

Building loss

RF losses associated with the signal penetrating the walls of a building

- Dependent upon construction material, layout of the building, the location of the base antenna in terms of direction, height, and distance, and location of portable inside the building.
- When field data is not available, the following table may provide some approximation for the losses.

Note: The details of approximate Building penetration losses were defined in the previous section.

Line loss

The loss that corresponds to all of the gains and losses between the base station antenna and the BTS receiver front end (power amplifier in the case of the forward link). The losses for each sector need to be determined.

- Cable losses are affected by cable dimensions and the operating frequency. See table given.
- If the sector has Tower Top Amplifiers, a cascaded noise figure calculation will be needed for the receive path.

Various items contained within the base station RF feeder loss are; top jumper, main transmission line, bottom jumper, lightning arrestors, connectors, duplexed splitters, combiners, etc.

Interference Margin

The noise rise due to other users appearing as additional noise to the BTS thus raising the operating noise floor . The interference margin is estimated using the following:

Interference Noise Margin = - 10 log(1 -X) Where X is the percent loading.

- 75 to 80% loading should be considered the maximum for a CDMA carrier in a system design. This would give a noise rise of approximately 6 to 7 dB.

➢ Reducing the interference margin would increase the coverage area at the expense of capacity.

➢ It is recommended that system designs be based on the projected full loading rather than an initial light loading.

  ✓ Avoids gaps in coverage as loading increases.

Example of Main Transmission Line Losses

Cable Size	850 MHz	1900 MHz
7/8" Foam Dielectric Coax	1.23 dB/100'	1.97 dB/100'
1-5/8" Foam Dielectric Coax	0.767 dB/100'	1.25 dB/100'

Ambient Noise

Environmental (man made) noise.

- Accepted norm is 0 dB for 1.9 GHz and 2 dB for 800 MHz.
- Noise floor testing could be done to determine values to use.

Shadow Fade Margin

A value added to the RF link budget to increase the confidence of achieving a desired signal level.

Base Reciever Sensitivity

A measure of the ability to receive weak signals. The following can be used to calculate Rx Sensitivity:

Base Sensitivity

$$kTB(dBm) + NF(dB) + Eb/No(dB) - PG(dB)$$

The above terms are the next four entries in the Link Budget and are explained below

kTB is bandwidth limited noise floor

k is Boltzmann's constant = $1.38 * 10^{-23}$ W/(Hz K).

T is room temperature in degrees Kelvin which is approximately 290 degrees K. (Zero degrees Kelvin = -273.16 degrees Celsius.)

B is the Bandwidth = $1.2288 * 10^{6}$ Hz.

$kTB = 1.38 \times 10^{-23} \times 290 \times 1.2288 \times 10^{6} = -113$dBm.

NF (Noise Figure)

A measure of the degradation in signal to noise ratio between the input and output ports of a network (receiver). Typical base station noise figures can be 4 to 4.5 dB meaning that half the base stations receivers will have noise figures greater than this and half of the stations will have noise figures less than this.

Values of 6 to 7 dB are used in RF link budget to provide a higher level of confidence in the design. Subscriber unit noise Figures (forward link) for use in simulations should be approximately 10 dB.

Eb/No

Eb /No corresponds to energy per bit over interference plus noise density for a given target Frame Erasure Rate (FER). In digital communications, it is customary to designate one-sided noise density with notation (No). In CDMA, interference is dominated by the noise generated due to other users in the system. The notation, No, in this section refers to the total power density due lo interference and noise.

The appropriate value for the required Eb/No is selected such that the desired frame erasure rate of the received signal is achieved. This gives an indication of the lowest signal strength that the receiver can detect above a certain noise level. In initial CDMA system design phases, an estimate is typically made for the Eb/No value used in the RF link budget and capacity equations.

Unfortunately the Eb/No value does not have a standard derivation method when system performance and capacity analyses are performed. There are many different factors and assumptions, which can impact the Eb/No values and performance of a system. Some of major factors that impact Eb/No values areas follows:

- Desired FER performance
- Data rate
- Subscriber speed
- Number of rays and the power imbalance between the rays
- Delay spread
- Transmit/Receive Diversity methods

Within the RF link budget, a constant value is used for Eb/No. However, in reality, Eb/No varies with the speed of the subscriber unit, the FER target, the number of signals present, etc.

These Eb/No values are used as a first approximation to gain an insight into the reverse path coverage prior to CDMA simulations being performed. When the design process advances to the CDMA simulator, the Eb/No values are obtained from a set of curves within the RF Design Tool that account for subscriber speed, delay spread, and the FER outage criteria.

PG (Processing Gain)

Processing gain is the bandwidth divided by data rate.

- When the data rate is 9600 bps (Rate Set 1). the processing gain is 1228800/9600= 128 (21.07 dB).
- When the data rate is 14400 bps (Rate Set 2). the processing gain is 1228800/14400 = 85.33 (19.3 dB).

Example: Base Station Sensitivity Calculation

The base receiver has

1. Noise Figure of 6 dB
2. CSM5000 chipset which tells us the Eb/No is 5.6 dB for a given FER
3. Processing Gain of 21.1 dB (Rate Set 1 signifies the data rate is 9600 bps.)

BTS Rx Sensitivity = kTB(dBm) * NF(dB) + Eb/No(dB) - PG(dB) kTB

BTS Rx Sensitivity = - 113.1 +6 + 5.6-21.1

BTS Rx Sensitivity = -122.6 dBm

CDMA Link Budget

Frequency (MHz)	800
Vocoder (kb)	8

UPLINK VOICE PATH	Dense Urban	Urban	Suburban	Rural	Rural Open
Portable Tx power (dBm)	23.0	23.0	23.0	23.0	23.0
Portable Tx power (watts)	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*
Portable antenna gain (dBi)	0.0	0.0	0.0	0.0	0.0
Body loss (dB)	0.0	0.0	0.0	0.0	0.0
Portable EIRP (dBm)	23.0	23.0	23.0	23.0	23.0
Portable EIRP (watts)	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*
Base Rx antenna gain (dBi)	18.0	18.0	18.0	18.0	18.0
Base Rx cable loss (dB)	3.0	3.0	3.0	3.0	3.0
Base Rx sensitivity (dBm)	-123.6	-123.6	-123.6	-123.6	-123.6
Base Rx diversity gain (dB)	0.0	0.0	0.0	0.0	0.0
Fade margin (dB)	8.7	8.7	8.7	8.7	8.7
Noise Margin (db)	0.0	0.0	0.0	0.0	0.0
Soft Handoff Gain (dB)	3.5	3.5	3.5	3.5	3.5
System Loading	70%	70%	70%	70%	70%
Interference Margin (dB)	5.2	5.2	5.2	5.2	5.2
Building penetration loss (dB)	24.0	24.0	20.0	15.0	0.0
Uplink path attenuation (dB)	127.1	127.1	131.1	136.1	151.1
Base station antenna height (m)	30	30.0	40.0	40.0	40.0
Portable height (m)	1.3	1.3	1.3	1.3	1.3
Estimated cell radius (km)	0.91	1.11	3.11	10.63	40.53
Estimated cell radius (miles)	0.57	0.69	1.93	6.60	25.17

DOWNLINK VOICE PATH	Balanced Path	Balanced Path	Balanced Path	Balanced Path	Balanced Path
Base Tx power (dBm)	31.4	31.4	31.4	31.4	31.4
Base Tx power (watts)	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*
Base Tx cable loss (dB)	3.0	3.0	3.0	3.0	3.0
Base Tx antenna Gain (dBi)	18.0	18.0	18.0	18.0	18.0
Base EIRP (dBm)	46.4	46.4	46.4	46.4	46.4
Base EIRP (watts)	*43.7*	*43.7*	*43.7*	*43.7*	*43.7*
Portable antenna gain (dBi)	0.0	0.0	0.0	0.0	0.0
Body loss (dB)	0.0	0.0	0.0	0.0	0.0
Portable sensitivity (dBm)	-118.7	-118.7	-118.7	-118.7	-118.7
Fade margin (dB)	8.7	8.7	8.7	8.7	8.7
Interference margin (dB)	5.2	5.2	5.2	5.2	5.2
Noise margin (dB)	0.0	0.0	0.0	0.0	0.0
Building penetration loss (dB)	24.0	24.0	20.0	15.0	0.0
Downlink path attenuation (dB)	127.1	127.1	131.1	136.1	151.1
Estimated cell radius (km)	0.91	1.11	3.11	10.63	40.53
Estimated cell radius (miles)	0.57	0.69	1.93	6.60	25.17
Cell Coverage	91.6%	95.0%	95.0%	95.0%	95.0%
Edge Reliability	80.8%	86.2%	86.2%	86.2%	86.2%

Fig 4.5 CDMA Link budget

4.3 Determining RF design tools to estimate Coverage

The reverse RF link budget is used lo determine a maximum allowable path loss to be used in conjunction with a propagation model to estimate the reverse path coverage area for each cell. In RF Design Tool, when generating coverage based on maximum allowable path loss only, the link budget information is used to calculate the minimum Signal Strength Image Parameter and the cell "ERP" levels.

Since the RF Design tool allow for only one value to be used as the Minimum Signal Strength Image Parameter for the entire system, all site specific variables need to be accounted for in the site's "ERP" term.

"ERP" is referred to here in quotes because if all of the variables of a site (building loss, vehicle loss, line losses, antenna gains, etc.) are included in this term, then it is not really an ERP value. A true ERP (effective radiated power) refers to the power that is being radiated out from an antenna and would include the power out of the base station, the line losses, and antenna gain only.

ERP

Parameter	Unit		Example 13 KB Link Budget	Example 8 KB Link Budget
Portable Tx power	dBm	a	23	23
Portable Ant. Gain	dBd	b	-2.14	-2.14
Body Loss	dB	c	2	2
Vehicle Loss	dB	d	6	6
Building Loss	dB	e	0	0
Base Ant. Gain	dBd	f	14.5	14.5
Line Loss	dB	g	2	2
Interference Margin	dB	h	3	3
Ambient Noise Rise	dB	j	0	0
Shadow Fade Margin	dB	k	5.6	5.6
ERP (Receive Voice) = a+b-c-d-e+f-g-h-j-k	dBm	l	16.76	16.76

Fig 4.6 ERP values

Maximum Allowable Path Loss

Parameter	Unit		Example 13 dB Link Budget	Example 8 dB Link Budget
ERP (Receive Voice)	dBm	x	16.76	16.76
Min. Signal Strength (Cutoff)	dBm	y	-119.1	-121.2
Calculated Path Loss from NetPlan Values (x - y)	dB		135.86	[illegible]
Max. Allowable Path Loss	dB		135.86	[illegible]

Fig 4.7 Pathloss limit

4.4 Impact of Trade-offs on link budget

The RF link budget is important because, in conjunction with a propagation model, it is used to aid in predicting the RF coverage of a site, which ultimately determines the number of cells required for system RF signal coverage and hence the system cost.

The graph shows the impact lo the quantity of sites required due to changes in the RF link budget. For example, if the link budget (maximum allowable path loss) was improved by 5 dB half the number of sites would be required. The graph on the following page is derived using the COST 231 Hata Suburban propagation model. Earlier propagation models may differ slightly from this. Tilts figure can be utilized as a quick aid to help estimate the number of sites required based upon a change made to the link budget. It should be pointed out that other environmental factors may contribute to the following graph not holding true. For instance, in a very hilly terrain location, dB improvements may not provide for extra range if the terrain is blocking the propagation.

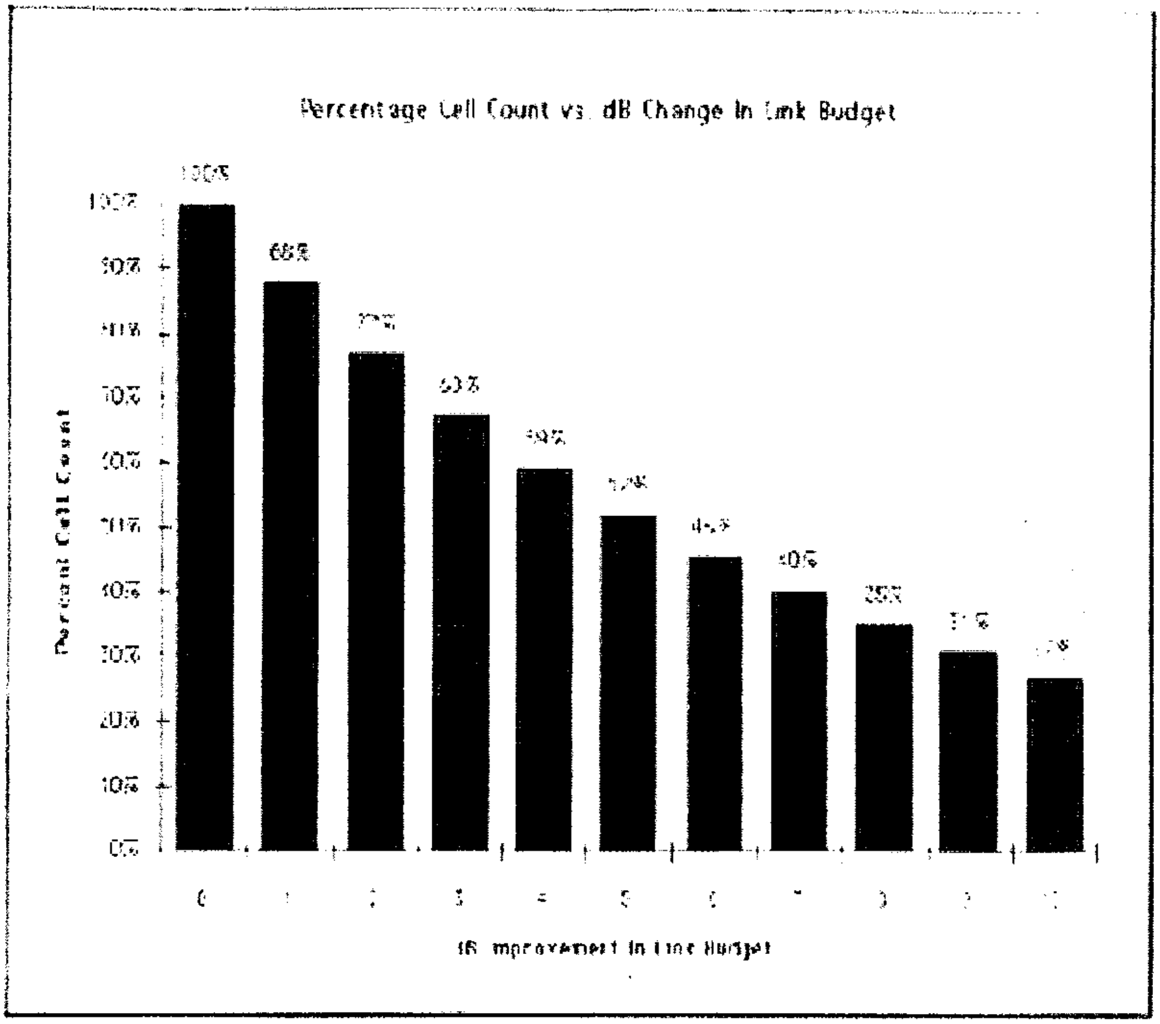

Fig 4.8 Percentage of Cells Based on dB Changes to the RF Link Budget

CHAPTER-FIVE

CLUTTER CLASSIFICATIONS AND ANTENNA SPECIFICATIONS

5.1 Overview

The accuracy of a system design is dependent on the accuracy of the many-databases associated with a planning tool. There are various sources of clutter (morphological) data. Clutter refers to obstructions or forms that are on top of the terrain (buildings, trees or other vegetation, oceans, bays, etc.). Clutter and terrain data are used in conjunction with a propagation model to estimate the coverage for a site or system. Once the clutter type is identified for each region, a virtual height or a loss factor (or both) are associated with each clutter type. The propagation model factors in the loss or associated virtual height for each type of clutter in the area. Clutter for a given region can he determined from such sources as maps or satellite and aerial photography. These sources are studied to determine the type of clutter that exists in each region.

In the cases where maps are used as the only source of clutter data, the coloring of the map gives an indication of the clutter in a region (e.g. green is often used to indicate foliage, blue is often used to indicate water, etc.). The more current or the latest the clutter data is the more accurate the propagation predictions will be.

The satellite and aerial photography give a better indication of clutter type since it is a more detailed depiction of what is on the terrain.

- It allows for better classification of a region since the photograph shows what is actually there.
- For example, it may allow for more detailed classification such as "high density urban", "medium density urban", and "low density urban" rather than just one classification of "urban".

5.2 Brief background of Clutter Codes

Before attempting to describe a procedure for altering clutter data and the associated virtual heights or clutter losses in RF Design Tool, it is necessary first to provide a brief historical perspective. In the earlier versions of Motorola propagation tools, all clutter data was created by Motorola's CAD department by hand-reading maps.

The7 Clutter categories are given below

1. Urban - U
2. Suburban – S
3. forest F
4. Rural - R
5. Water - W
6. Quasi-open —Q
7. Open – O

Fig 5.1 Clutter Classifications

Building Penetration Loss	
Categories of Areas (Clutter)	**Loss**
High Dense Urban	30dB
Dense Urban	24 dB
Urban	18 dB
Sub Urban	15 dB
Rural	10 dB

Fig 5.2 Building penetration losses

Fig 5.3 Hyderabad Digitized Map

5.3 Clutter Environment Descriptions

Dense Urban

Consists of densely built areas with mainly high buildings (over 20 stories). Typically there are few or no trees and vegetation within this area due to the density of buildings. Central parts of Mumbai and New Delhi are examples of dense urban areas. In these environments, even 100-foot cells have micro cell propagation, which is dominated by building location.

Urban

Consists of metropolitan regions , industrial areas and closely spaced residential homes and multi-storied apartments. Building density is high but may be interspersed with trees and other vegetation. Business centers of medium size cities such as Hyderabad and Pune as well as portions of the outer areas of New Delhi and Chandigarh are examples of this environment.

Suburban

Consists mainly of single-family homes, shopping malls and office parks. Significant vegetation, trees and parking lots are intermixed with buildings. Most buildings are 1 to 3 stories but significant exceptions do occur. Significant areas within small and medium cities along with suburban communities surrounding major cities such as shimla are examples of this environment .

Rural

Consists generally of open space with few buildings or residences. Major interconnecting highways, farms, and barren land are found within rural areas. The largest variations in cell coverage area are found in rural areas due to differences in vegetation and terrain.

Clutter Effect

Definitions and the losses related to clutter category plays major role while designing the cellular network. All the clutter categories, defined in the digitized map, need to be verified in the field while conducting the RF survey for the specific city. Losses, for each clutter category, are different for every city i.e. building penetration loss for dense urban clutter category in Central New Delhi is different from Dense Urban Clutter category for Central Chennai. Penetration losses for each clutter category need to be verified before the start of the RF Design using the Tool.

5.4 Antenna Specifications

The primary objective for a proper antenna location and choice of an appropriate diversity scheme is to provide a uniform coverage within the cell area and minimum interference to and from other BTS antennae

Choice of antenna location (cell site) is based on proper containment of coverage and alignment of the sites in to a specific hexagonal pattern. The choice may be limited due to availability pf space, links to BSC etc.

Large coverage obtained by keeping an antenna at a height may not satisfy in-building coverage requirements; In fact, one can rely on the buildings to serve as radio path shields, limiting the coverage area. Also the reflections from the buildings provide coverage to areas. Which would not have been possible in the normal LOS mode? These additional paths consequently increase in-building penetration also.

5.4.1 Antenna Considerations:

- Uniform Coverage in the cell
- Alignment with hexagonal pattern
- Space availability
- Connectivity to BSC/MSC

Urban areas may have the following conditions:

- Several Sites may he needed
- Frequency re use is unavoidable
- In-building penetration is a must.
- Buildings act as RF shield and contain coverage.
- Buildings reflect signals and provide coverage to areas where LOS would have failed.
- Such additional paths improve in-building penetration.
- Antenna at a very high point may not meet In-building coverage requirements.

It may he noted that the highest point in the area may do more harm than good. This is because it may cause interference to other sites and also in-building coverage may be limited because of this. This is explained in the diagram shown below.

- Location of antennae at high points needs careful examination of site coverage, type of area etc

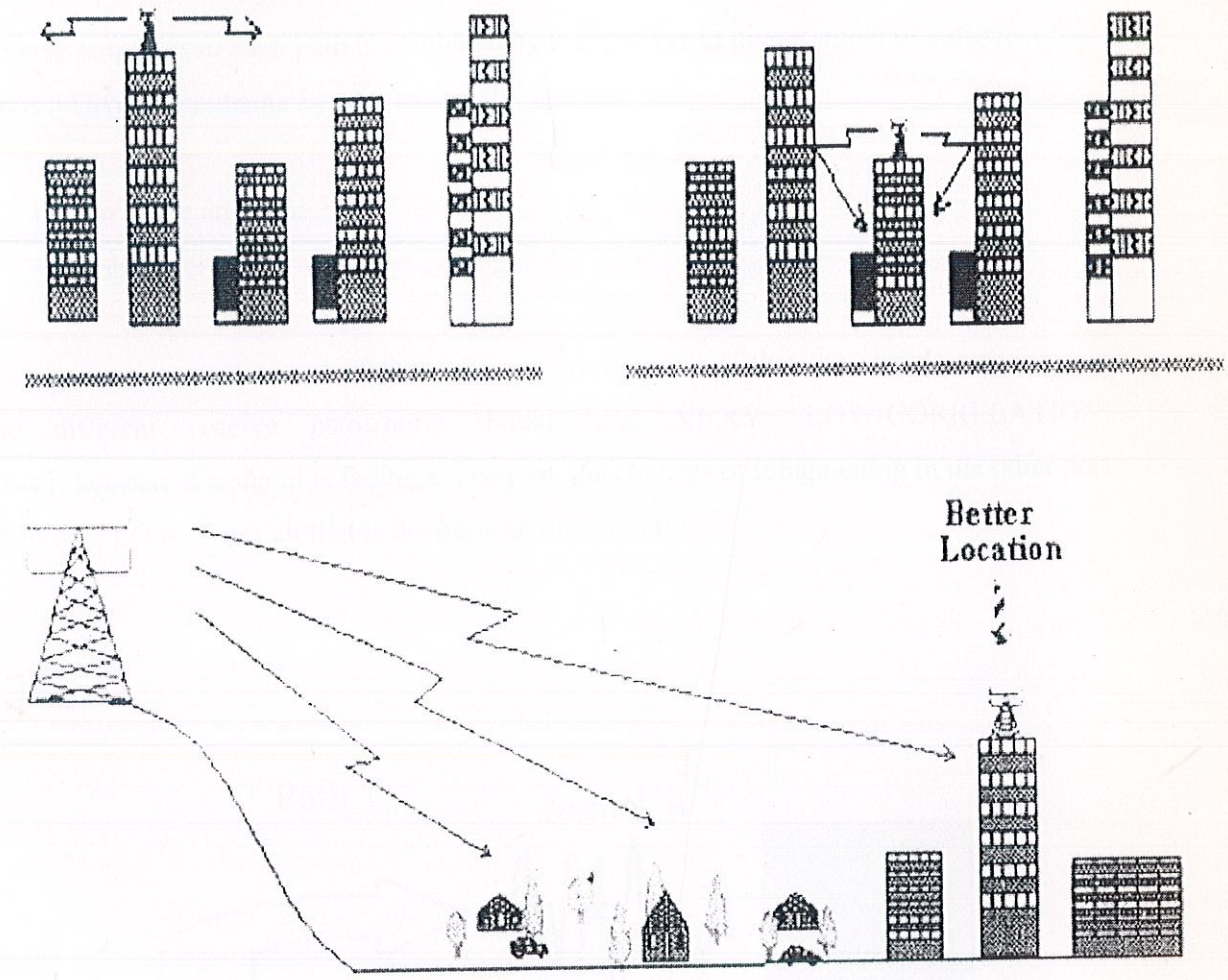

Fig 5.4 Diversity systems

5.4.2 Tackling Multipath Fading

In general we have the following methods lo combat Multi path fading:

- In the Time Domain: Interleaving and Coding
- In the Frequency Domain: Frequency Hopping
- In the Spatial Domain: Space Diversity
- In the Polarization Domain: Polarization Diversity.

5.5Diversity Antenna Systems

In general, a diversity antenna system provides a number of receive paths (normally 2). The diverse output from each path is combined by the recciver to give a signal of sufficient S/N. Thus a Diversity antenna System essentially has:

- Two or More antennae
- A combiner circuitry.

Another major requirement of Diversity antenna systems is that the signals arriving at the different receive paths/ports should have VF.RY LOW CORRELATION. This is because if a signal is fading at one port, the chances of it happening in the other port should he LOW. After all that is the purpose of diversity!

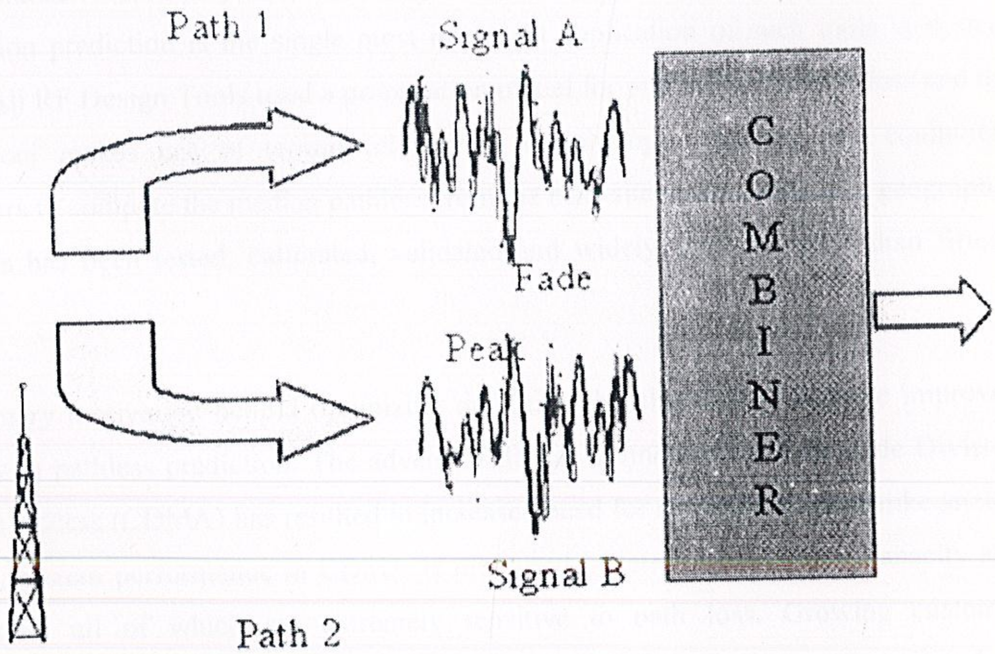

Fig 5.5 Signal combiner

CHAPTER-SIX

MODEL TUNING

6.1 Introduction

Accurate prediction of radio propagation is a prerequisite to achieving an optimum system design. The growing popularity of wireless services along with a variety of emerging technologies, services and frequency bands has kept development of new propagation models at center stage of research activities in the wireless industry- and academia.

The past decade has produced several network planning software tools. While these tools have matured over the years and integrated newer network management features, propagation prediction is the single most important application of such tools in system design. All RF Design Tools used a propagation model for predicting the path loss and the design tool makes use of terrain (elevation), morphology (clutter), and equipment parameters to compute the median pathloss from the base site to the center of a geographic bin. **Xlos** has been tested, calibrated, validated and widely used for more than fifteen years.

The primary motivation behind optimizing or liming the clutter is to achieve improved accuracy in pathless prediction. The advent of digital technology such as Code Division Multiple Access (CDMA) has resulted in increased need for accuracy since, unlike analog systems, system performance in CDMA is measured in terms of coverage, capacity and call quality all of which are extremely sensitive to path loss. Growing customer expectations has also sparked the need for greater accuracy of path loss prediction models. In the past, customer requirements were limited to reliability contours and vendors were not required to identify the uncovered bins. Furthermore, warranty tests were based on subjective call quality tests rather than absolute signal strength measurements. Recently, customers warranty requirements have become more demanding. Vendors are required to warranty all bins predicted to be covered with a high level of confidence and also identify the uncovered areas. Such stringent warranty requirements necessitate use of accurate propagation prediction methods to assure optimum cell site placement and count to avoid expensive relocations and additions.

To maintain its leadership as an infrastructure provider and protect customer's equipment investment it is essential for Motorola to achieve the highest level of accuracy in the initial stages of System design. Motorola's systems engineers integrate tuning of clutter heights for improved accuracy of propagation prediction into the standard design procedure.

6.2 Drive Test

Preliminary Drive Testing will determine the propagation model correction factors for the areas to be designed.

Continuous Wave Measurement, CW test, to be conducted at an anchor site , with a known tower height, known antenna gain using a CW transmitter. After importing the CW test data it will give the slope and intercept values of that particular town to be planned for wireless rollout.

Main Features

- Field strength measurement
  - ➢ Accurate collection in real-time
  - ➢ Multi-channel, averaging capability
- Location Data Collection Methods:
  - ➢ Global Positioning System (GPS)
  - ➢ Dead reckoning on digitized map database using on-board compass and wheel revolutions sensor
  - ➢ A combination of both methods is recommended for the best results
  - ➢ Ideally, a system should be calibrated in absolute units, not just raw received power level indications
  - ➢ Record normalized antenna gain, measured line loss.
- Select sites in each morphology for testing

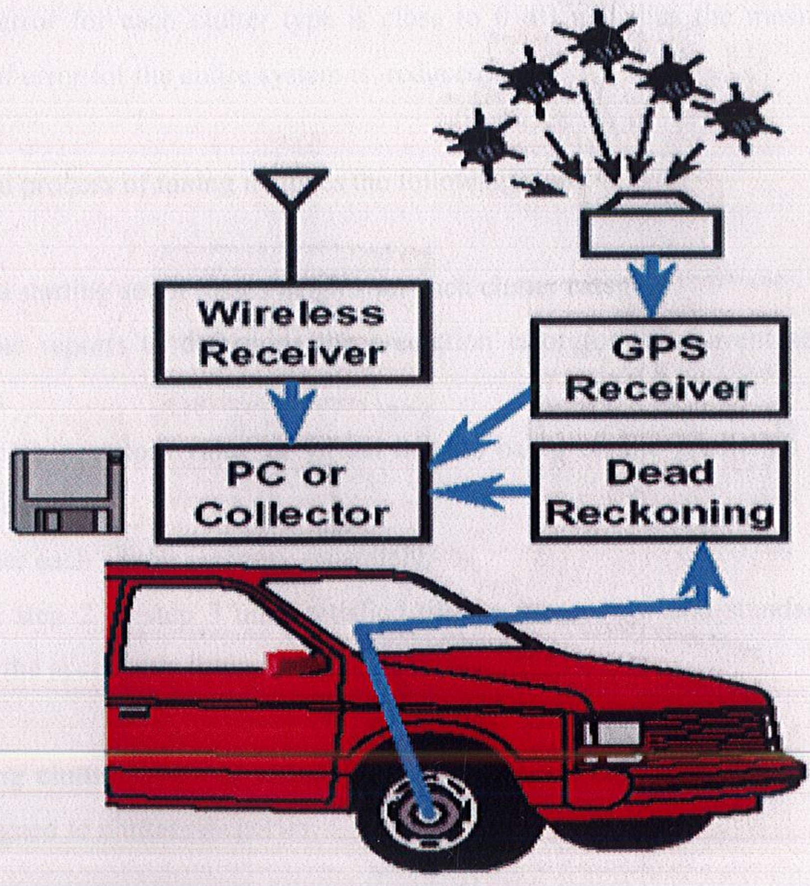

Fig 6.1 Drive test

1. Prepare Car for Data Collection
2. Drive all main thoroughfares and streets within 5km of the test site.
3. Collect Receive Signal Strength Indication data, RSSI, as a function of location,while driving
4. Import the RSSI measurements into a network design Tool.
5. Compare the measured drive test data with typical propagation model used.
6. Adjust the correction factors based on each geographical morphology until the error between the predicted values and the measured value is minimized.
7. Use the correction factors in the preliminary design.

6.3 Tuning Process

The goal of the tuning process is to adjust the virtual clutter heights or clutter losses until the mean error for each clutter type is close to 0 dB and thus the mean and standard deviation of error for the entire system is reduced.

The general process of tuning includes the following steps:

1. Select a starting set of losses/heights for each clutter category.
2. Generate reports to determine the prediction error for the current set of losses or heights.
3. Determine new loss value or virtual heights based on the prediction error for each clutter category.
4. Consider each clutter category separately.
5. Repeat step 2 & step 3 until satisfied till the mean error and standard deviation is within the acceptable limits.

The starting clutter losses or virtual clutter heights are derived from the set of default losses assigned to clutter categories.

CHAPTER-SEVEN

PRELIMINARY RF DESIGN

7.1 Objective

The objective of the Preliminary RF Design is to produce, and review path loss prediction plots. These plots are generated using RF Design Tool inputs based on the link budget (used in calculating the ERP and cutoff levels for Design Tool), enhanced clutter database, terrain database, antenna placement, antenna type, and all other parameters associated with propagation.

Analyzing plots that are based on maximum allowable path loss, can help determine major issues such as coverage holes, cell site placement problems, terrain obstruction issues, and sites which may present interference problems, By identifying these issues early in the design process, some of these issues can be resolved before going through the time and effort of simulations. This allows the simulation process to be used to concentrate on issues that can only be analyzed with the simulator rather than issues that can be addressed by coverage plots based on path loss only.

Once coverage estimates have been run and analyzed, it is suggested that the plots be carefully reviewed. This step is important to make sure that the system coverage from a "path loss only" perspective meets the design expectations (ensure coverage in all areas that are important).

On completion and acceptance of the Preliminary Rf Design, RF Survey is to be conducted for the required city and identify the sites. The details of the survey are stated, in details, in the RF Survey section.

Before start of this phase of RF Design, following quarries needs to be clarified from the customer:

- What is the area of coverage needed?
- What is the level of coverage required?
- Identification of the areas where good in-building coverage is required?
- Market potential areas where extra capacity is required?
- Do we need so many sites? Decide number of sites based on capacity coverage and quality requirements.
- Divide city in lo clutter types such as:
  1. Dense Urban
  2. Urban
  3. Suburban
  4. Quasi Open
  5. Open
  6. Water

7.2 Worked Example

7.2.1 Introduction

An example system has been used to demonstrate the design concepts highlighted in each lesson. The worked example is based on a fictitious customer (B-Com) and city (Sun City). However, the design approach is representative of typical CDMA designs.

Common mistakes will be presented along with some example solutions. Tradeoffs will be discussed as part of each lesson and visually shown in the worked example. The objective is to show how to think through a design and understand what the outputs of the **NetPlan** Simulation tool actually represent.

7.2.2 Assumptions

The following represent the system requirements of the customer (B-Com) and various assumptions used in the worked example.

- Sites: B-Com's budget only allows for 60 BTS sites.
- Vocoder: 13 kb
- Frequency: 1.9/800MHzGHz
- ISI is not an issue for B-Com Sun City design.
- Penetration Loss:
  - Body = -2 dB
  - In-vehicle - -6dB
  - In-building (urban) = -15 dB
  - In-building (dense urban) - -20 dB
- Distribution of User Class:
  - 80% in-vehicle
  - 15% in-building urban
  - 5% in-building dense urban
  - Area Reliability: 95%
  - FER: Target=1%   Outage=3%

- Site Configurations:
  - 3-Sector
  - 36m (120 ft.) tower heights to be used in suburban area.
  - 27m (90 ft,) tower heights to be used in urban area.
  - 36m (120 ft.) tower/building top heights to be used in dense urban area.
- B-Com has provided enhanced clutter data (25-mts resolution).
- B-Com has provided elevation data (25-mts resolution).
- Desired coverage has been defined
- B-Com has provided traffic distribution developed from census data (polygon format).
  - Sun City market population is 750,000
  - B-Com market penetration is 6%
  - The subscriber busy hour usage is 0.02 erlangs/subscriber
  - The speed map will reflect 2 kph speed for in-building clutter and varying speeds according to road class.
    1. Class I roads 80 kph
    2. Class 2 roads 60 kph
    3. Class 3 roads 50 kph
    4. Class 4 roads 40 kph

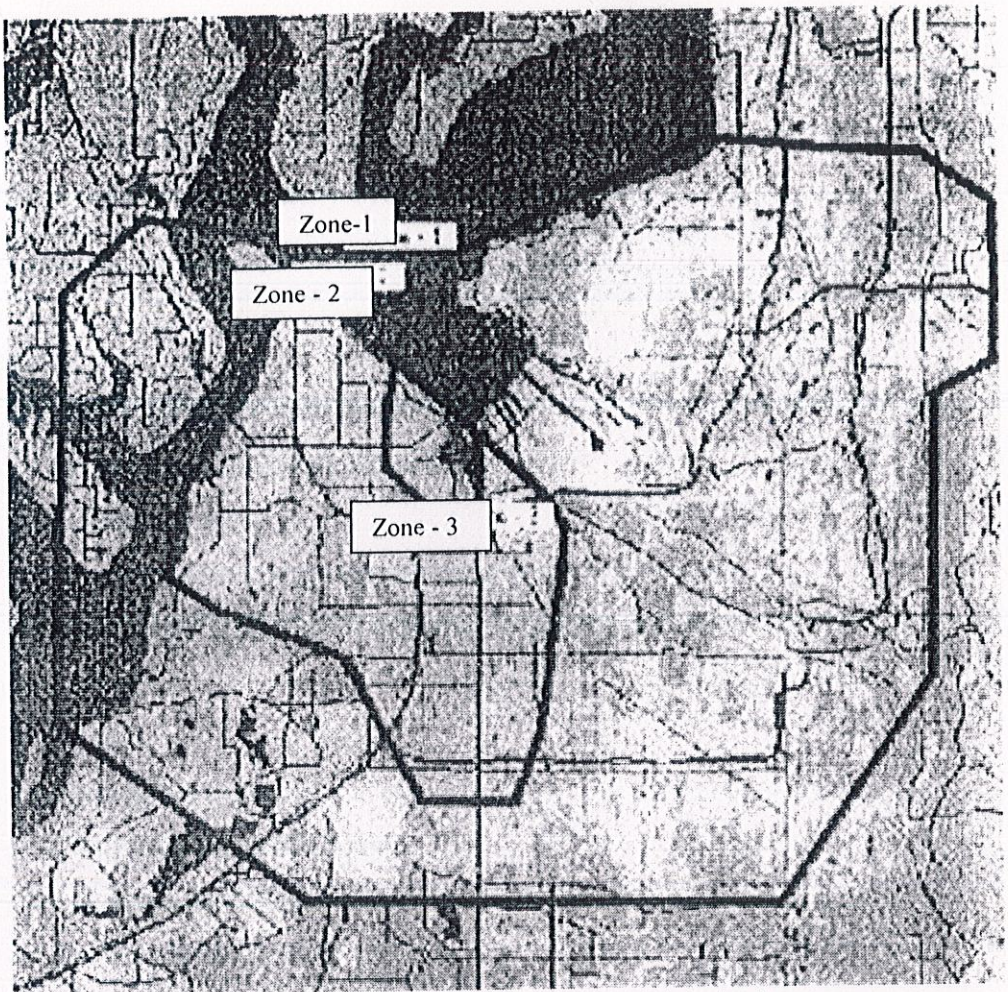

Fig 7.1 zone wise coverage boundary and desired coverage

Zones :

Zone 1 – Sub-Urban

In-Vehicle

Zone 2 – Urban

In-Building

Zone 3 – Dense-Urban

In-Building

7.2.3 Approach for preliminary RF design

Verify Coverage and Identify Problem Areas

The Following information needed before beginning the design of a new system. Required Information

- Geographic area where service is desired
  - Latitude and Longitude of each cell site
  - Antenna models.
  - May also include highways entering or leaving this area
- The "Hot Spots", referring to important locations, such as:
  - Airport
  - Hotels
  - Convention Center
  - Company President's home
- Link budget information such as:
  - Building Loss
  - Vehicle Loss
  - Fade Margin

A coverage plot needs to be created using realistic assumptions. The coverage plot will allow the site acquisition team to start providing information on possible locations and antenna heights. Data from the site acquisition team then needs to be included into the system design. This is an iterative process.

Placing Cells and Generating Coverage

The suggested approach to placing cells to determine coverage is to begin with a few cells and then add a few at a time until the desired area is covered (Recommendation- start positioning the sites from the core of the city).

Determine coverage for a typical site.

- Since clutter has a great influence on coverage. Typical site coverage may need to be determined in each clutter region.
- Display the clutter in the design tool and adjust coloring so that all clutter categories with the same virtual height/ losses have the same color.
- Locate test sites in each of the clutter region/category. This allows for determining typical site coverage in each region. Try to select spots representative of the general terrain (avoid deep valleys and mountains).
- Enter the proper site parameters for the test sites. Set ERP and cutoff levels for the area type (dense urban, urban, suburban, etc.).

Generate coverage images and determine a typical radius of coverage for each clutter category. Several sites are run in each region (rather than just one) so that a better "typical" value can be determined.

Determine Hexagon Radii

- Using these coverage images, determine a best-fit hexagon radius for each clutter category.
- If the radii for the test sites in a particular clutter category are vastly different check the surrounding elevation (terrain) to see if the site was poorly situated.
- If the terrain varies widely, it may not be possible to use the hexagon grid to locate sites. Sites will have to be added one at a time.

Set up Hexagon Grid for a Few Cells

- Create a Hexagon grid for several (5 to 10) sites in the densest area of the system (if Possible in the area where the clutter losses are same).

Place Cells in the Hexagons

- Locate the sites as close to the center of the hexagon as possible
- Display elevation (terrain) information to help in site placement.

Note

The Auto Cell Placement (generally available in all the RF Design tools) feature can assist in placing cells in hexagons. The tool will allow the user to either place the cell in the center of the hexagon or will place the cell on the highest elevation within a chosen search radius.

Run Propagation for the System

- Create the Best Signal Strength and Host Server/Sector images.

Analyze Coverage

- Display the coverage
- Determine any areas that need optimizing.
- Optimizing is necessary for both inadequate coverage and excessive coverage.

Optimize Coverage

The first goal should be resolving the coverage problems by modifying site configuration and/or location. The following provide some suggestions:

- Is the coverage problem over most of the system? If yes, then consider changing the hexagon grid size and relocating the sites.
- If the coverage problem is between just a few cells, modify site configuration and/or location.

- Check terrain and clutter profiles between sites and the area not covered. Determine which site/sites could be used to provide coverage. Possible candidates are:
  1. The site with the least terrain obstructions
  2. The site with lowest clutter losses

Can the site be moved toward the hole in coverage without causing a problem in the other direction? Note that such a change may cause problems in site acquisition and/or interference to other sites. If changing the site location doesn't fill the coverage hole, can a change in antenna height fill the hole? Two effects of increasing antenna height are:

1. Eliminates or reduces terrain/clutter obstructions
2. Changes the slope and intercept for the path loss model resulting in increased signal strength.

Note, however, that such a change may cause problems in site acquisition and/or interference to other sites

.

- Other possible adjustments are to change the antenna model and/or the antenna down tilt.
- Modifications to several sites may be necessary to fill one coverage hole.
- If all else fails, an additional site may be required.

Adjustment to surrounding sites will likely be needed to avoid excess overlap of coverage.

Rerun, analyze, optimize until coverage is adequate. Expand the system by a few sites and repeat the process until system is adequately covered.

7.2.4 Average Cell Radius

Figure given is the tabulated result of four three-sector sites used in each coverage zone to arrive at an average radius value. This shows the initial hexagons placed in their respective zones based on the average radii calculated above.

A few transition boundaries between different sized hexagons may imply incomplete coverage. This is acceptable knowing that the uncovered areas may be serviced by the smaller diameter hexagons.

The smaller diameter hexagons can provide extended coverage into the next zone of the larger diameter hexagons because of the reduced penetration loss (20 dB in-building vs. 6 dB in-vehicle) and differences in the clutter and terrain underlying the areas of concern

Zone 1 (Suburban)
Cell Radius Calculation

Cell/Sector	Radius Km
1-1	2.40
1-2	2.64
1-3	3.12
2-1	1.68
2-2	2.16
2-3	2.40
3-1	2.40
3-2	2.40
3-3	2.88
4-1	2.56
4-2	3.60
4-3	1.52
Average Radius	2.48

Zone 2 (Urban)
Cell Radius Calculation

Cell/Sector	Radius Km
1-1	1.44
1-2	1.28
1-3	1.12
2-1	1.60
2-2	1.60
2-3	1.16
3-1	1.28
3-2	1.40
3-3	0.64
4-1	1.08
4-2	0.96
4-3	1.12
Average Radius	1.22

Zone 3 (Dense Urban)
Cell Radius Calculation

Cell/Sector	Radius Km
1-1	0.50
1-2	0.50
1-3	0.50
2-1	0.70
2-2	1.10
2-3	1.30
3-1	0.70
3-2	1.70
3-3	0.90
4-1	1.10
4-2	1.10
4-3	1.30
Average Radius	0.95

Fig 7.2 Average Radius Calculation

7.2.5 Example Case

Initial Placement of Empty Hexagons Based on Average Calculated Radii

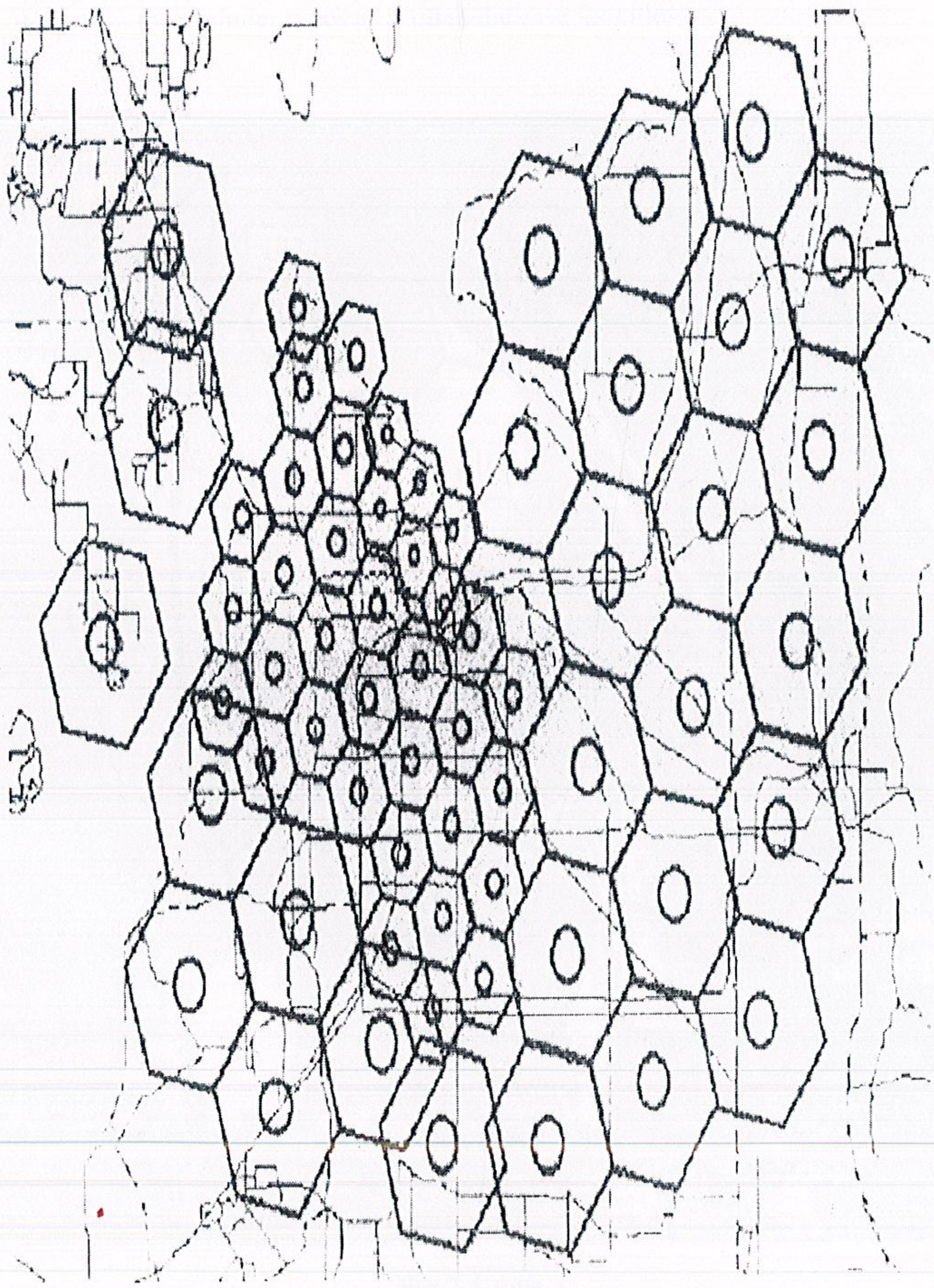

Fig 7.3 Hexagonal cell placement

High Dense Urban-Zone 3

This shows the underlying land use/clutter that each sector's footprint will be encountering. Note that the red colored clutter represents the "city center" and that the Charcoal/black colored clutter represents the "High Density Buildings", both of which have relatively losses as compared to other clutter classes. It can be inferred that more traffic demand will be required from these clutter types as is often the case for cities.

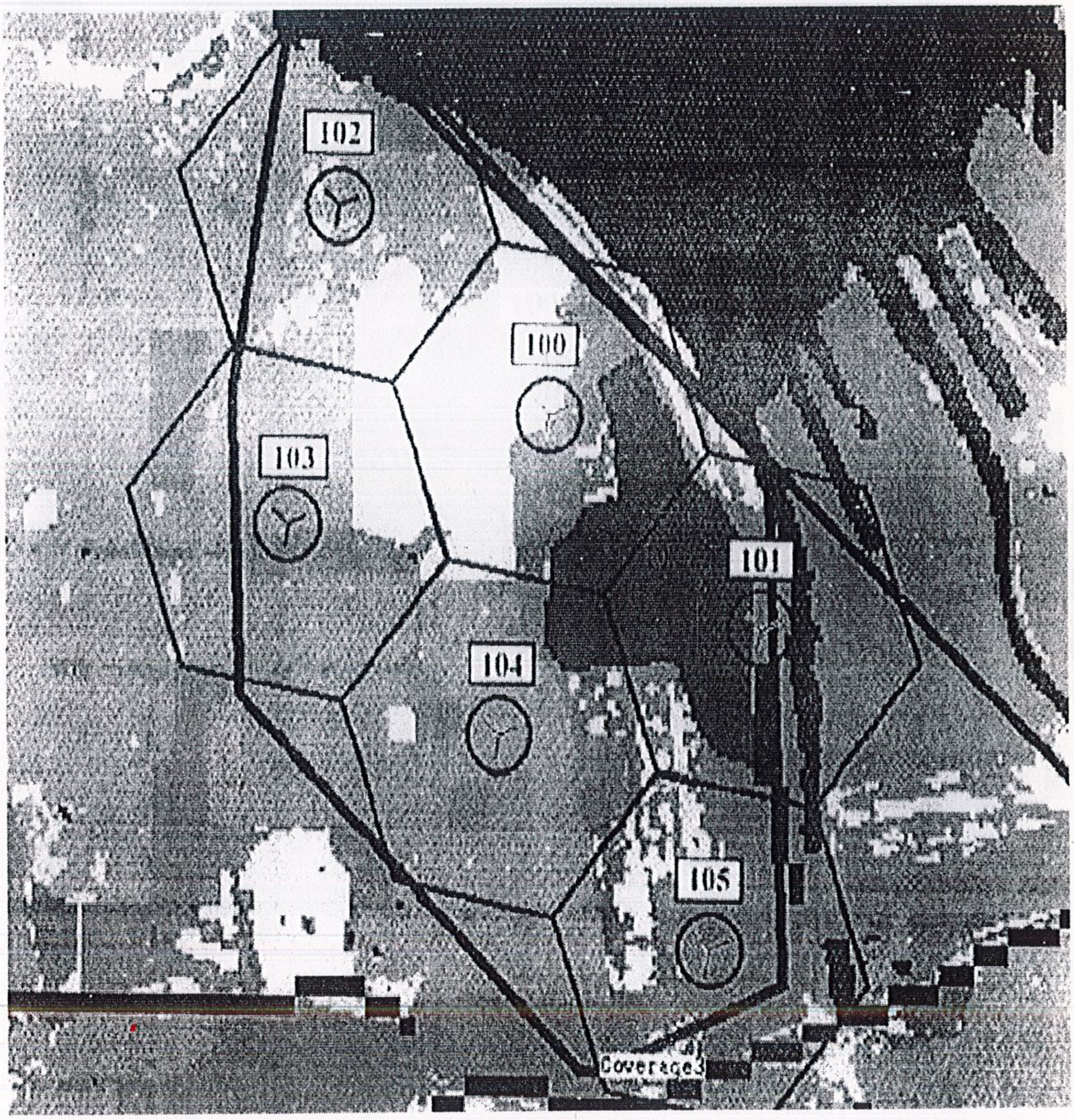

Fig 7.4 zone 3

Coverage hole

The signal strength image for Zone 3 contains a large coverage hole located over the corner of the city. This performance is not acceptable and must be investigated further and corrected before moving on to Zone 2.

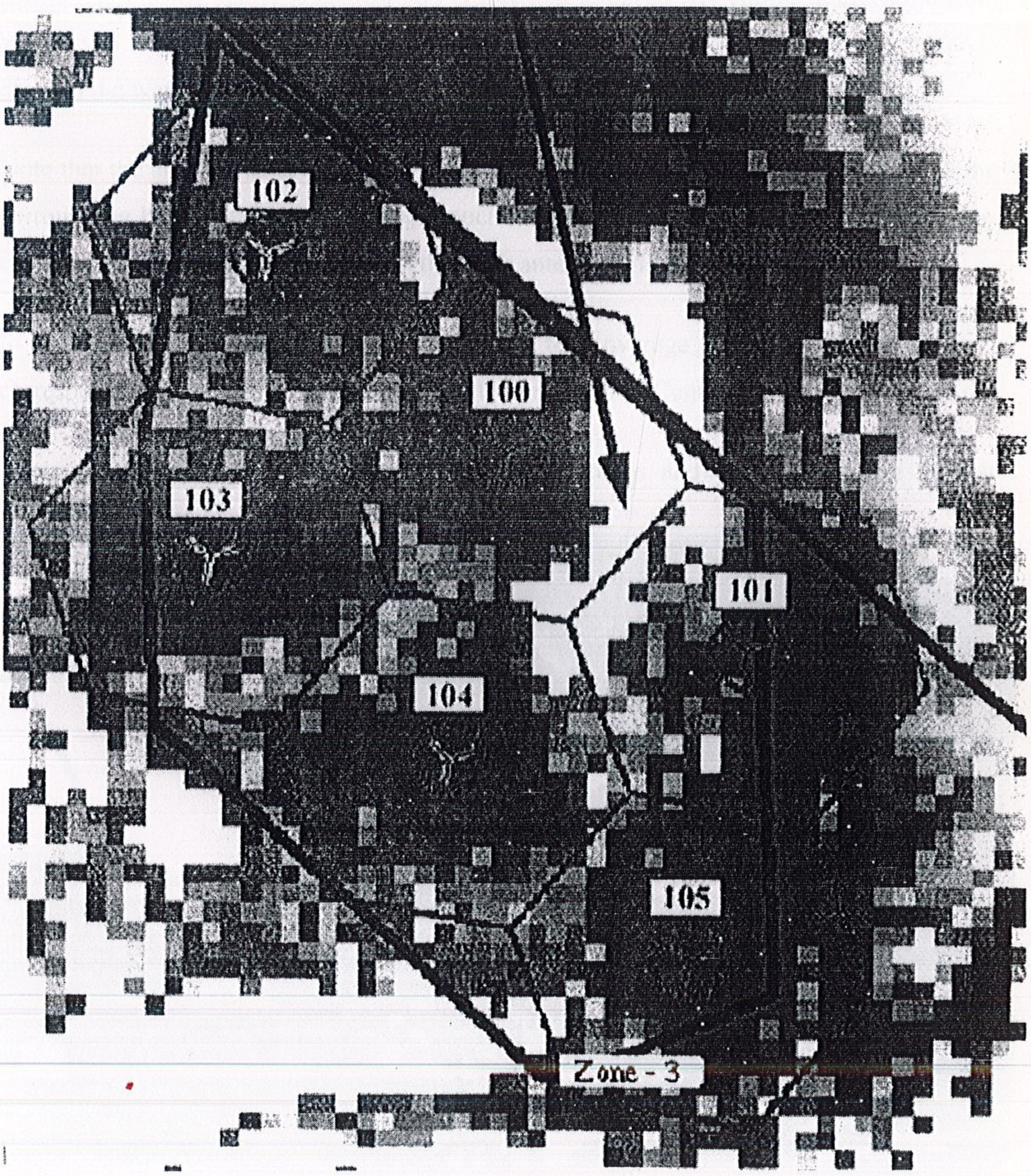

Fig 7.5 coverage hole

Underlying Clutter

It is apparent from examining the elevation image that site 101 has been placed at the foot of a hill. The propagation footprint of the third sector of the site faces the coverage hole (i.e. city center). By looking at the elevation image, in the direction of the coverage hole, shows that the city center is located on the side of a hill. The city climbs in elevation from water level to approximately 100m. This is much higher than the base of site 101, which is close to the water level.

Note that the antenna height of site 101 is 36m, which is high enough to clear most of the surrounding building structures though much shorter than the hill. The portion of the city that's terrain elevation are higher than the site's antenna height will not be covered.

In addition to the increase in terrain elevation, the coverage hole also falls in the area corresponding to the clutter types of Dense Urban and City Center.

These two clutter types have the highest clutter losses and also contain the highest subscriber densities.

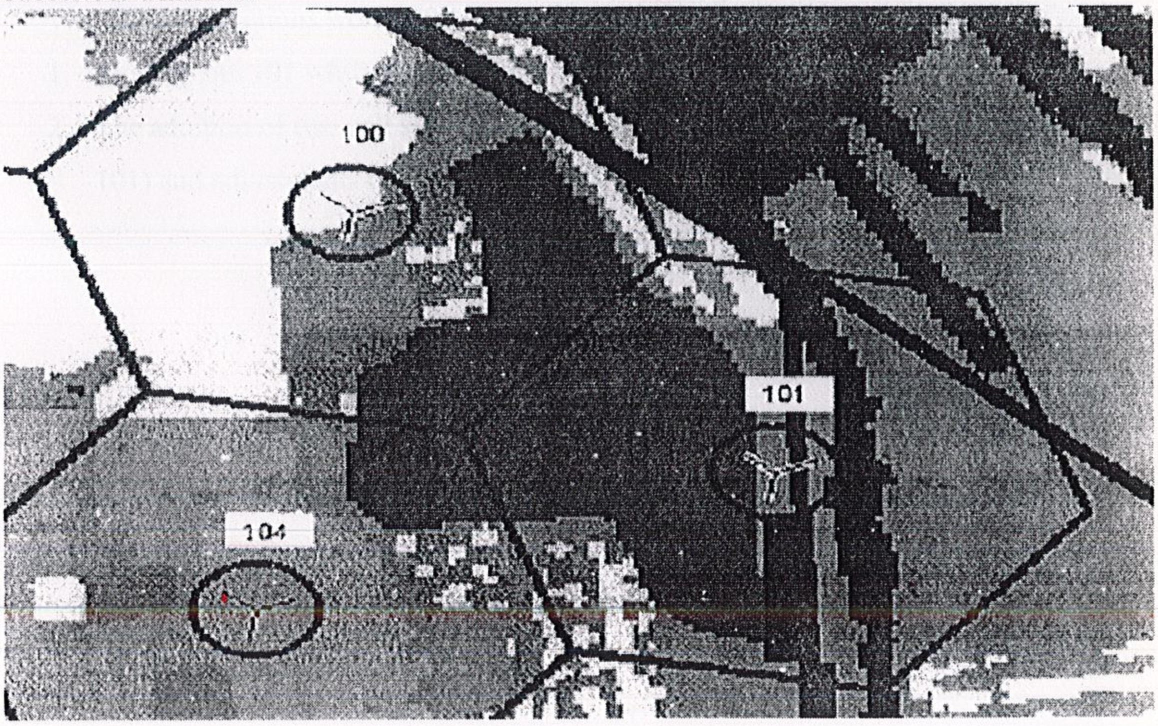

Fig 7.6 Underlying Clutter

Zone I Coverage Image after Optimization

The figure shows the corrections arrived at alter numerous attempts. The first tries taken in correcting the problem Focused on those actions, which would minimize the cost impact on the final design.

1. The first action tried was to alter the antenna tilts (up and down) of the sectors in cell sites 100, 101 and 104 that are associated with the coverage hole.
2. Next, altering the orientation of the antennas in these cell sites was tried.
3. The third action tried was to move the location of the original cell sites.
4. It was specified from B-Com that the tower heights could not be greater than 36m for Zone 3. Therefore an increase of tower height is not an option in this situation.

The following actions were taken to provide coverage in the area:

1. Moving site 101 while changing its antenna orientation and tilts.
2. The addition of two cell sites (106 & 107 which use the same antenna orientation as site 101) and adjustments of their antenna tilts.

Note that the remaining coverage hole north of site 100 is over water and does not require correction.

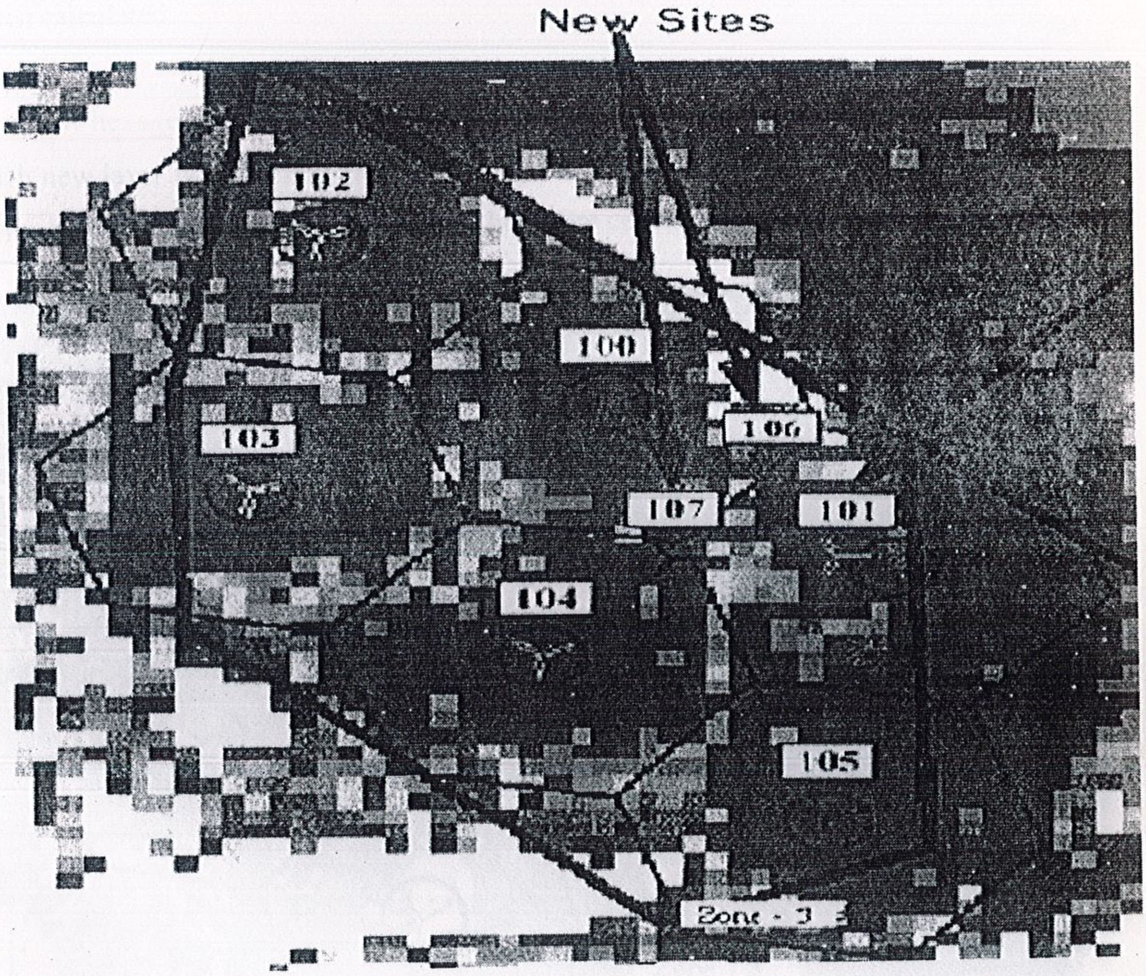

Fig 7.7 Zone 1 after Optimization

Zone 2 and Zone 3

One layer of hexagons/cells has been added to the next propagation region (Zone 2) now that Zone 3 has sufficient coverage. The radius of these new cells reflects the greater calculated radius from the beginning of this section where the cell radius for each zone is been calculated.

The new hexagons/cells will be added one layer at a time. The propagation performance of each new layer is tested and then adjusted before adding another layer. Note that the most dense population center (in Zone 3) now has more cell sites providing service to it

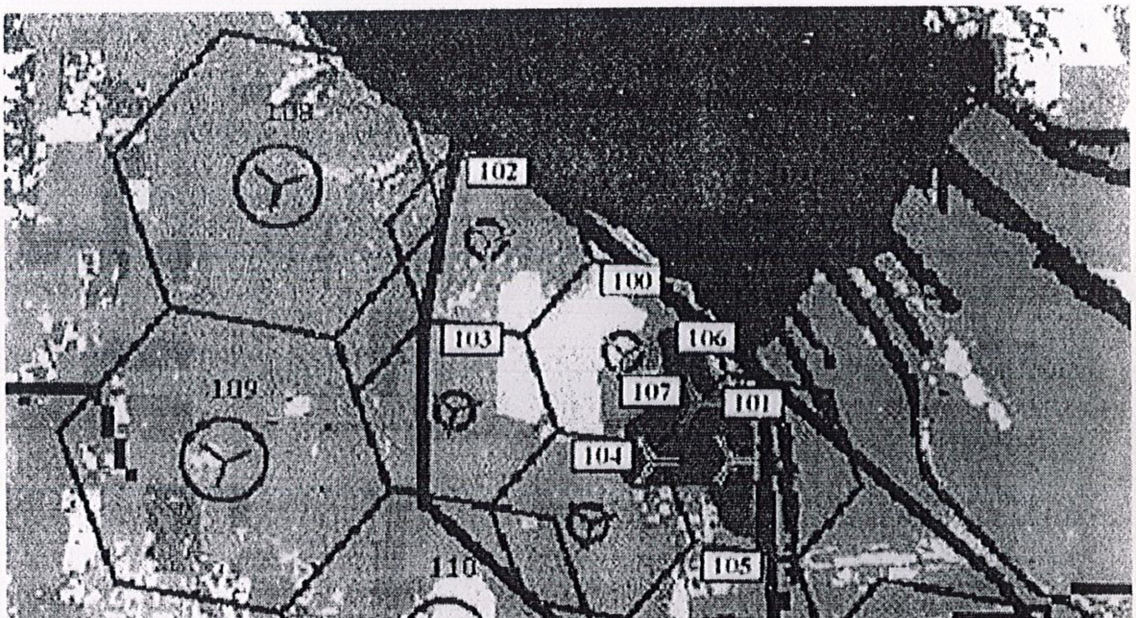

Fig 7.8 Zone 2 after optimization

Bibliography

1. Wireless Communications

   By: Theodore S. Rappaport

2. Mobile Communications

   By : Joschen Schiller

3. CDMA 2000 system for mobile Communication

   By: Vieri Vanghi

   Aleksander Danjonovic

   Branimir Vojcic

4. GSM, CDMA one and 3G systems

   By: Raymond Steele

5. www.Qualcomm.com

6. www.cdg.com