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Subject: **Erkan Tannur, MSc. (Elec. & Elec. Eng.) Thesis-Defence Jury**

Date: **15/05/2002**

You are invited to participate in the examining committee (jury) for the MSc. thesis defence of the above named candidate. The jury & thesis defence will be held on **Monday [10/06/2002]** at **[11:00]** at the Faculty of Engineering, NEU.

The above named MSc. candidate has successfully completed SEVEN MSc. courses. In addition, the candidate has completed his MSc. thesis and was recommended for undergoing his thesis defence by his MSc. supervisor.

The MSc. thesis is entitled: Cellular Network Planning.

The jury will consist of:

Jury Chairman:	Assoc. Prof. Dr. Doğan İbrahim	(Comp. Eng. Dept., NEU)
Jury Members:	Assist. Prof. Dr. Kadri Büründcuk	(Elec. & Elec. Eng. Dept., NEU)
	Assist. Prof. Dr. Doğan Haktanır	(Elec. & Elec. Eng. Dept., NEU)
Supervisor:	Prof. Dr. Fakhraddin Mamedov	(Elec. & Elec. Eng. Dept., NEU)

The "Thesis Defence" will be open for attendance by other staff members and graduate students.

Please confirm your willingness to participate as in the examining committee (jury) so that a copy of the MSc. thesis will be sent to you; use my email address below to confirm.

If you have any previously-arranged engagement at the time of the committee meeting, then let me know as soon as possible to arrange another time.

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NEAR EAST UNIVERSITY

INSTITUTE OF APPLIED AND SOCIAL SCIENCES

CELLULAR NETWORK PLANNING

Erkan Tannur

Master Thesis

Department of Electrical and Electronic Engineering

Nicosia - 2002

Erkan Tannur: Cellular Network Planning

Approval of Director of the Graduate School of Applied and Social Sciences

Prof. Dr. Fakhraddin Mamedov

We certify that this thesis is satisfactory for the award of the degree of Master of Science in Electrical Engineering

Examining Committee in charge:

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Special thanks to my colleague friend Mr. Sohail Zakaria for assisting me and to my Technical Director for giving me permission time to time to complete my thesis.

Finally, I want to thank my family, specially my parents and wife.

ABSTRACT

GSM as a modern Telecommunication System is a complex object. Its implementation are not simple neither is its description.

This thesis aims at providing analysis, systematization and presentation of GSM System including Mobile Switching Center, Base Station and Radio Interface. Cellular Network and its interfacing with Public Switching Telephone Network.

Cell-site planning procedure for 20.000 mobile subscribers is presented as the contribution of the author insolving the investigated problem. The application of the work presented within this thesis is implemented on the city centre of Lefkoşa; the capital of TRNC.

CONTENTS

INTRODUCTION

This thesis is aimed to comprehensive description of the GSM systems including Operation and Maintenance Centre (OMC), Mobile Switching Centre (MSC), Base Station System (BSS), Base Station Controller (BSC), Base Transceiver Station (BTS) systems and design realisation cell planning procedure on the real Lefkoşa map for the 20.000 subscribers. The Thesis consists of the introduction, five chapters and conclusion.

Chapter 1 introduces fundamental of mobile communication system. In this chapter we discuss the GSM system entities. We describe operations and maintenance centre, mobile switching centre, base station system, base transceiver station, interworking function, transcoder function, authentication centre, equipment identity register, visitor location register, echo canceller, mobile station, cell broadcast centre, home location register.

Chapter 2 presents cellular concepts. We described types of cells, such as umbrellacell, macro cell, microcell, cell splitting, corporate cells, picocell.

Chapter 3 is concerned to the base stations and radio interfaces. We consider in details cells, control channels, problems related with handover. RF power control strategy, interdependence of HO and PC, radio channels and structure of the GSM radio interface, base station antennas and radio wave propagation.

Chapter 4 is very important chapter in this Thesis. This chapter gives information about cellular radio network planning, coverage planning, microcell planning, capacity planning, frequency planning, parameter planning, optimisation, network measurements.

Chapter 5 is concerned to cell planning for the 20.000 subscribers (example Lefkoşa City Centre). The number of sites are calculated, carriers, cells for this scenario. Database of Lefkoşa City network, network configuration and transmission plans are designed.

The objectives of the work presented within this thesis are:

- We have to calculation for number of BSC, BTS, Sites, Cells and TRX. This step is very important. We need a right calculation for coverage and capacity.
- We select right types of cells and cell angles and which type of site configuration for each region according to populations.
- This network must be achive good coverage (specially indoor), capacity and good quality of service.
- Our network must be the cheapest in equivalent networks.
- We need a good and real transmission plan and which types of equipments can we use.
- We have to make a frequency planning that without interference (uplink and downlink).
- We select suitable site location on the Lefkoşa City map.

Conclusion presents the significant results, my contribution and future investigations.

1. FUNDAMENTAL OF GSM ARCHITECTURE

1.1 Over View

We will discuss the GSM System Entities and specially Radio Wave Propagation, Propagation in Buildings and Reflection, Diffraction, Effects of Urban and Rural Environments on Propagation. These are very important for cellular planning of Lefkoşa City Centre. Also, Propagation Effects on GSM Frequencies is important. We need them for cellular network planning of Lefkoşa City Centre.

Question:

- What is the solution of weak signal strengh in buildings?

1.2 GSM System Entities

Architecture of GSM System is given in figure 1.1.

1.2.1 Operations and Maintenance Centre (OMC)

Operation and maintenance centre (OMC) has access to both the Gateway (G) MSC and the BSC, handles error messages coming from the network, and controls the traffic load of the BSC and the BTS. The OMC configures the BTS via the BSC and allows the operator to check the attached components of the system. As the cells become smaller and the number of base stations increases, it will not be possible in the future to check the individual stations on a regular basis for transceiver quality.

1.2.2 Gateway MSC

The GMSC is the interface of the cellular network to the PSTN. It is a complete exchange, and with all its registers it is capable of routing calls from the fixed network via the BSC and the BTS to an individual mobile station. The GMSC also provides the network with specific data about individual mobile stations. Depending on the network size , an operator might use several interfaces to the fixed network, thus using several GMSCs or only one. If the traffic within the cellular network requires more exchange capacity than the GMSCs can provide, additional Mobile services Switching Centres (MSC) might coexist with no access to the fixed network. If not otherwise explicitly distinguished from each other, the capabilities of the GMSC and the MSC are the same [12].

1.2.3 Base Station System (BSS)

The fixed end of the radio interface that provides control and radio coverage functions for one or more sites and their associated mobile stations. The BSC and the BTS are part of the BSS.

1.2.4 Base Station Controller (BSC)

BSC monitors and controls several base stations, the number of which depends on the manufacturer and can be between several tens and several hundreds of stations. The chief tasks of the BSC are frequency administration, the control of a BTS, and exchange function. The hardware of the BSC may be located at the same site as the BTS, at its own standalone site, or at the site of the Mobile Switching Centre (MSC). BSC and BTS together form a functional entity sometimes referred to as the Base Station Subsystem (BSS) [10].

1.2.5 Base Transceiver Station (BTS)

The counterpart to a mobile station within a cellular network is the base station (BTS), which is the mobile's interface to the network. A BTS is usually located in the centre of a cell. The transmitting power of the BTS determines the absolute cell size. A base station has between one and sixteen transceivers, each of which represents a separate RF channel. Some of the intelligence, which has incorporated in to analog base stations and the host network, such as measurements on the radio channels as criterion for handover, is now shifted to the mobile stations. Dumping some of the work on the mobile's desk makes the GSM infrastructure cheaper than of some analog systems. The result is that in some less wealthy countries, digital cellular systems are installed instead of analog ones (such as AMPS, NMT, or TACS)

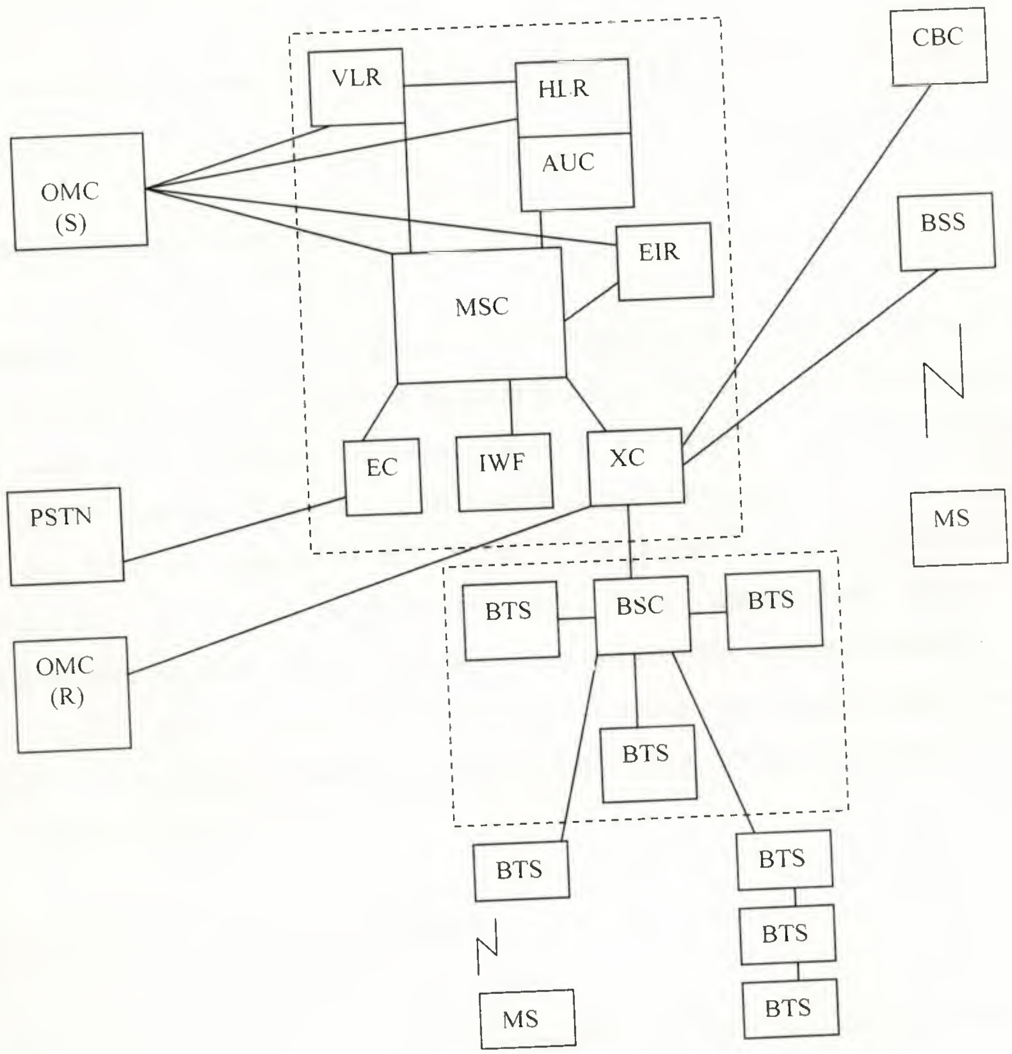


Figure 1.1 The GSM System

1.2.6 Interworking Function (IWF)

Performs data rate adaption between the Public Land Mobile Network (PLMN) and other existing land networks.

1.2.7 Transcoder Function

Converts the signal from 64Kbs A—law to 13Kbs GSM speech, as well as 3 Kbs of Control Information.

1.2.8 Authentication Centre (AUC)

Generates and stores authentication parameters for subscriber identification. Authentication Centre is related to the Home Location Register (HLR). It provides the HLR with different sets of parameters to complete the authentication of a mobile station. The AUC knows exactly which algorithm it has to use for a specific subscriber in order to calculate input values and issue the required results. Since all the algorithms for the authentication procedures are stored within the AUC, they are protected against abuse. The sim card issued in an area assigned to an AUC contains the same algorithms for authentication as the AUC does. If the AUC provides input and output parameters for these algorithms to either the HLR or the Visitor Location Register (VLR), either location register can verify (authenticate) the mobile station.

1.2.9 Equipment Identity Register (EIR)

The data base oriented processing network entity that contains centralised information for validating mobile stations based on their international mobile equipment identity.

1.2.10 Visitor Location Register (VLR)

The data base oriented processing network entity that temporarily contains information for subscribers roaming in a given location area. The data base oriented processing network entity that contains the master data base of the subscribers to a PLMN.

1.2.11 Echo Canceller (EC)

Performs echo suppression for all voice circuits.

1.2.12 Mobile Station (MS)

The radio equipment and man—machine interface that a subscriber needs to access PLMN services.

1.2.13 Cell Broadcast Centre (CBC)

CBC is used for the broadcast of short message on a per cell, location area or PLMN basis.

1.2.14 Home Location Register (HLR)

The HLR stores the identity and user data of all the subscribers belonging to the area of the related GMSC. These are permanent data such as the International Mobile Subscriber Number (IMSI) of an individual user, the user's phone number from the public network, the authentication key, the subscriber's permitted supplementary services, and some temporary data. Temporary data on the SIM include such entries as the address of the current Visitor Location Register (VLR), which currently administers the mobile station the number to which the calls must be forwarded (if the subscriber selects call forwarding), and transient parameters for authentication and ciphering.

The IMSI is permanently stored on the SIM card. The IMSI is one of the pieces of important information used to identify the mobile country code (MCC) and the next two digits are the Mobile Network Code (MNC). Up to ten additional digits of the mobile subscriber identification number (MSIC) complete the IMSI.

The following IMSI: 286 02 542 XXX XX XX identifies a subscriber from Turkey (MCC = 286), who is paying his or her monthly bill to the private operator TELSIM (MNC = 02). The subscriber's network identity number (MSIC) is 542 XXX XX XX.

1.3 Radio Wave Propagation

A radio link between a mobile phone and a base station is rarely consisted purely on a line of sight connection. The major propagation ways are:

1. Line of sight
2. Diffraction
3. Reflection
4. Scattering

1.3.1 Line of Sight (Free Loss)

This is the loss of signal strength that occurs as the radio waves propagated through free space defined as the condition where there are no sources of reflection in the signal path. A basis for the calculation of the path loss is assumed the device is an isotropic radiator. This is a theoretical pin point antenna which radiates equally in every direction. If the device was placed in the middle of a sphere it would illuminated the entire inner surface with an equal field strength. In order to find out what the power is covering the sphere as shown quation 1.1.

$$P = \frac{Pt}{4\pi.d^2} \tag{1.1}$$

Equation 1.1 is used where Pt is the input power to the isotropic antenna and d = the distance from the radiator to the surface of the sphere. This equation 1.1 illustrates the inverse square law that the power decreases with the square of the distance.
In order to work out the power received at a normal antenna the effective aperture (Ae) of the receiving antenna must be calculated.

$$Ae = \frac{\lambda^2}{4\pi} \tag{1.2}$$

The actual received power can be calculated as follows,

$$Pr = P.Ae \tag{1.3}$$

Now if P is substituted with the formula for the power received over the inner surface of a sphere and Ae with its formula the result is

$$Pr = \frac{Pt}{4\pi d^2} \times \frac{\pi^2}{4\pi} \tag{1.4}$$

This is the ratio of the actual received power to the transmitted power from an isotropic radiator and can be calculated by the formula (1.5)

$$20\log \frac{4\pi.d}{\lambda}.Logs \tag{1.5}$$

Equations are used to make the figures more manageable. Note that the equation 1.5 is dependant on distance and frequency. The higher the frequency the shorter the wavelength and therefore the greater the path loss.
The equation 1.6 above is based on units measured in meters. To make the (1.6) more convenient it can be modified to use kilometre and Megahertz for the distance and frequency. It becomes equation (1.6)

Free Space Loss = 32.0 + 2Ologd + 2Olog f dBs (1.6)

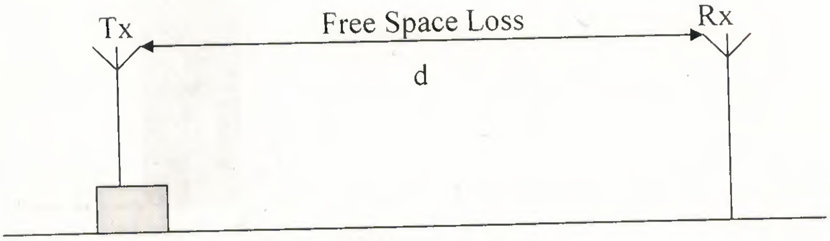


Figure 1.2 Line of Sight (Free Space Loss)

1.3.2 Effects of Urban and Rural Environments on Propagation

Reflection, refraction, diffraction, scattering, attenuation, changes in polarisation, Rayleigh and Rician fading, multipath fading. At the frequency range used for GSM it is important to consider the effects that objects in the path of the radio wave will have on it. As the wave length is approximately 30 cm for GSM900 and distance 15 cm for GSM1800, most objects in the path will have some effect on the signal. Such things as vehicles, buildings, office fittings even people and animals will all affect the radio wave in one way or another. The main effects can be summarised as follows: diffraction, attenuation, reflection, scattering and polarisation changes.

a) Diffraction

Is where a radio wave is bent off its normal path. This happens when the radio wave passes over an edge, such as that of a building roof or at street level that of a corner of a building. The amount of diffraction that takes place increases as the frequency used is increased. Diffraction can be a good thing as it allows radio signals to reach areas where they would not normally be propagated.

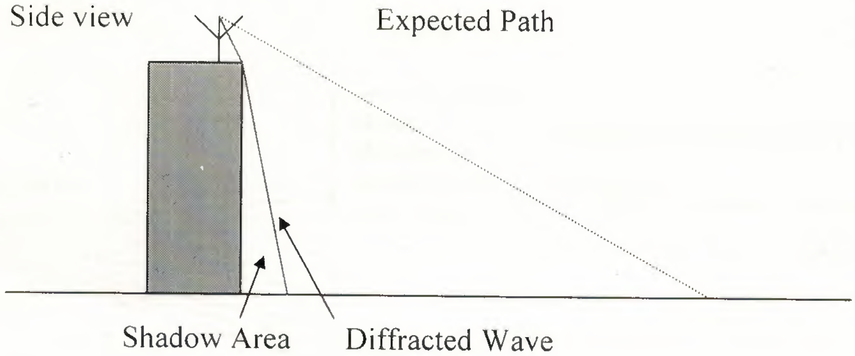


Figure 1.3 Diffraction (side view)

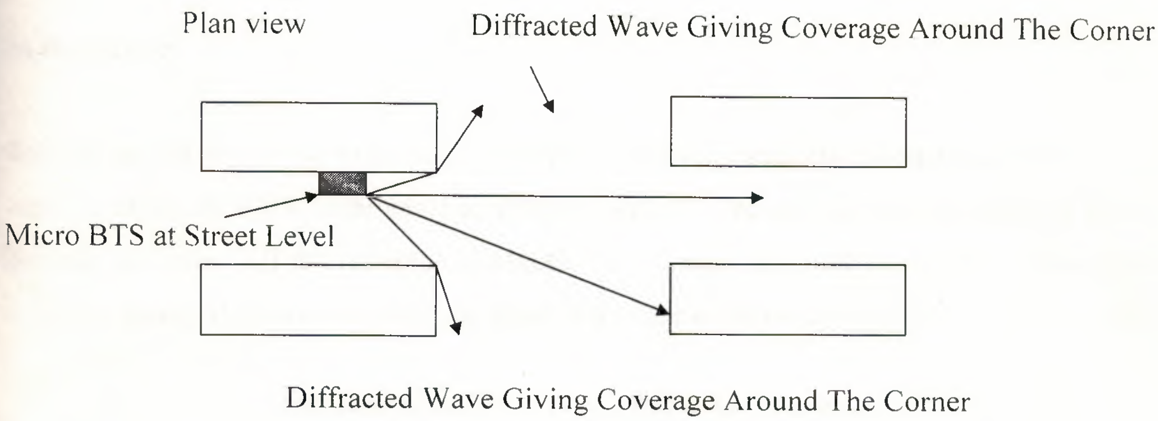


Figure 1.4 Diffraction (plan view)

b) Attenuation

This will be caused by any object obstructing the wave path causing absorption of the signal. The effects are quite significant at GSM frequencies but still depend on the type of materials and dimensions of the object in relation to the wavelength used. Buildings, trees and people will all cause the signal to be attenuated by varying degrees.

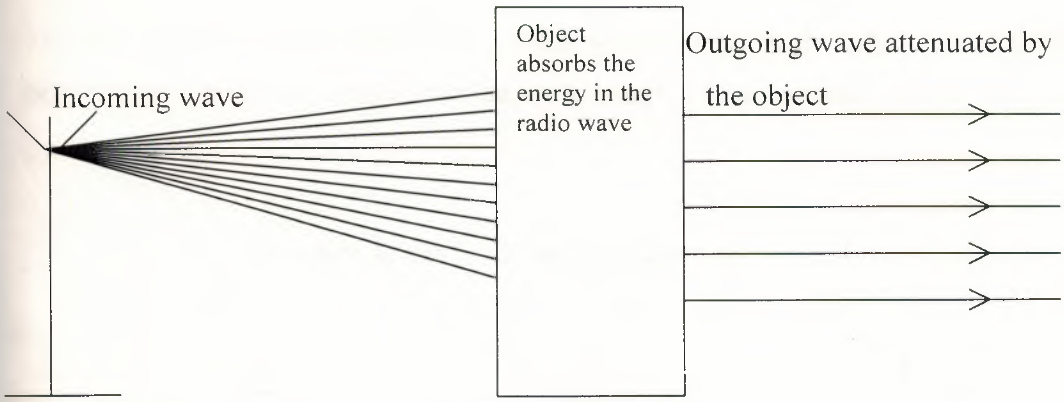


Figure 1.5 Attenuation

b) Reflection

This is caused when the radio wave strikes a relatively smooth conducting surface. The wave is reflected at the same angle at which it arrived. The strength of the reflected signal depends on how well the reflector conducts. The greater the conductivity the stronger the reflected wave. This explains why sea water is a better reflector than sand.

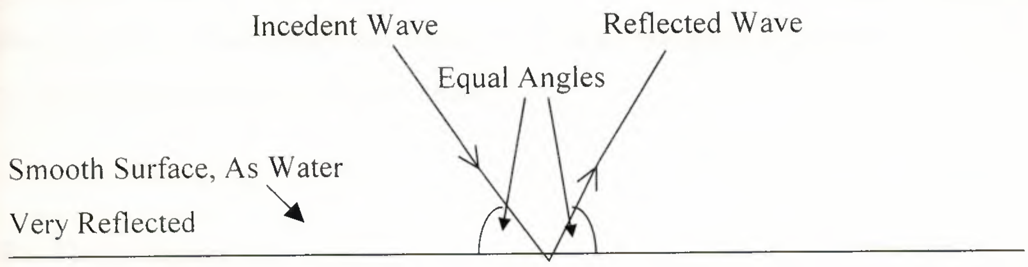


Figure 1.6 Reflection

d) Scattering

This occurs when a wave reflects of a rough surface. The rough surface and the relationship between the size of the objects and the wave length will determine the amount of scattering that occurs.

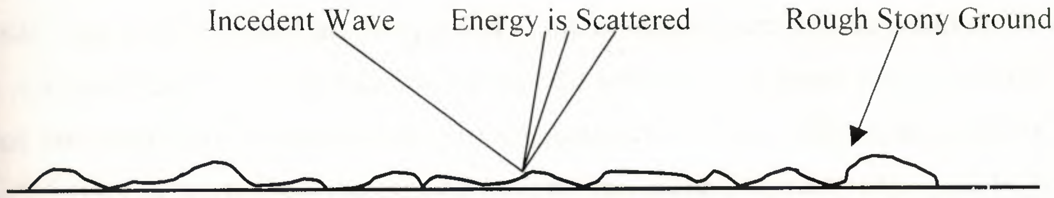


Figure 1.7 Scattering

e) Polarization Changes

This can happen any time with any of the above effects due to atmospheric conditions and geomagnetic effects such as the solar wind striking the Earths atmosphere. These polarisation changes mean that a signal may arrive at the receiver with a different polarisation than that which the antenna has been designed to accept. If this occurs the received signal will be greatly attenuated.

1.3.3 Plane Earth Loss

The free space loss as stated was based solely on a theoretical model and is of no use by itself when calculating the path loss in a multipath environment. To provide a more realistic model the earth in its role as a reflector of signals must be taken into account. When calculating the plane earth loss the model assumes that the signal arriving at the receiver consists of a direct path component and a reflective path component. Together these are often called the Space wave. The equation 1.7 for calculating the plane earth loss is

$$L = 20\log\frac{d^2}{h_1.h_2} \qquad (1.7)$$

This takes into account the different antenna heights at the transmitter and receiver. Although this is still a simple representation of path loss. When this formula is used is implies the inverse fourth law as opposed to the inverse square law. So for every doubling of distance there is a 12dB loss instead of 6dB with the free space loss calculation. The final factors in path loss are the ground characteristics. These will increase the path loss even further depending on the type of terrain. The ground characteristics can be divided into three groups: Excellent ground. For example sea water, this provides the least attenuation so a lower path loss. Good ground. For example rich agricultural land, moist loamy lowland and forests. Poor ground. For example Industrial or urban areas, rocky land. These give the highest losses and are typically found when planning Urban cells.

Free Space Loss

Free Space Loss =32 +20 logd +20 logf

f= Frequency in MHz

d= Distance in km

Plane earth Path Loss (Lpe)=

Free Space Loss α $1/d^2$

Plane Earth Loss α $1/d^4$

$$L = 20\log\frac{d^2}{h_1.h_2}.\text{dBs} \qquad (1.8)$$

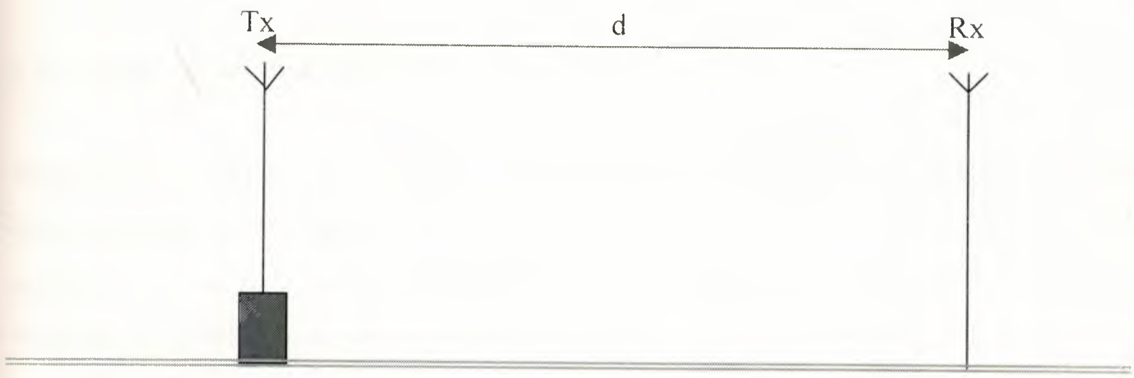


Figure 1.8 Path Loss Increases 6dB for a Doubling of d.

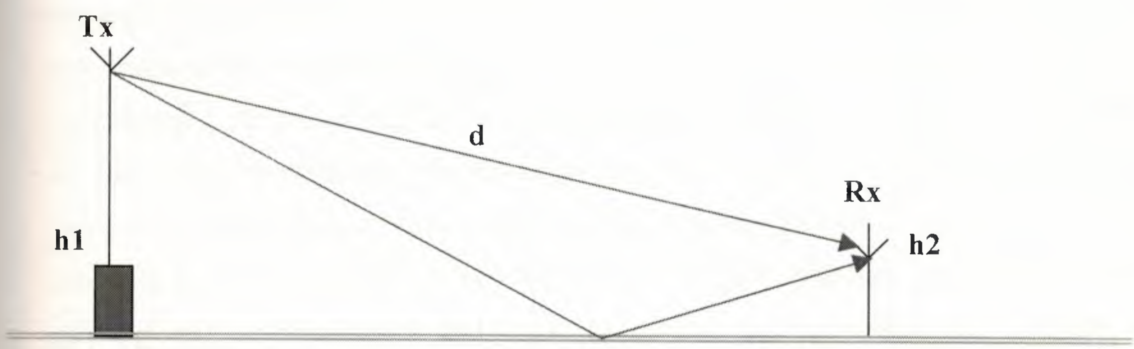
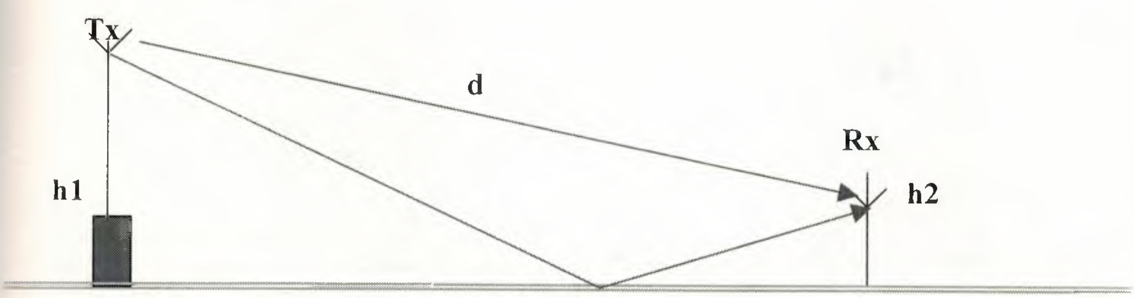


Figure 1.9 Plane Earth Loss Includes one Earth Reflector. Path Loss Increases 12dB for a doubling of d.



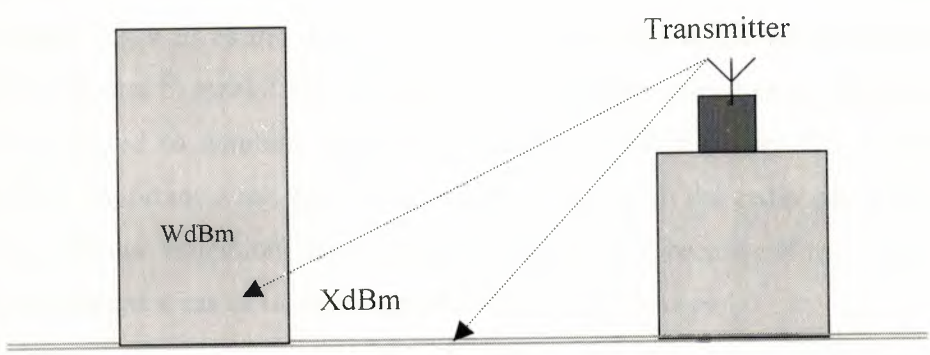
Plane earth + correction factor for type of terrain.

Path loss increases 12dB for a doubling of d+A factor for type of terrain.

Figure 1.10 Path Loss

1.3.4 Propagation in Buildings

With the increased use of hand portable equipment in mobile cellular systems combined with the increased availability of cordless telephones, it has become essential to study RF propagation into and within buildings. When calculating the propagation loss inside a building, a building loss factor is added to the RF path loss. This building loss factor is included in the model to account for the increase in attenuation of the received signal when the mobile is moved from outside to inside a building. This is fine if all users stood next to the walls of the building when making calls, but this does not happen, so the internal distance through which the signal must pass which has to be considered. Due to the internal construction of a building, the signal may suffer form spatial variations caused by the design of the interior of the building. The building loss tends to be defined as the difference in the median field intensity at the adjacent area just outside the building and the field intensity at a location on the main floor of the building. This location can be anywhere on the main floor. This produces a building median field intensity figure which is then used for plotting cell coverage areas and grade of service. When considering coverage in tall buildings, coverage is being considered throughout the building, if any floors of that building are above the height of the transmitting antenna a path gain will be experienced.



XdBm: Signal strengh outside building **Building insertion loss (dBm) =X-W=BdBm**

Figure 1.11.a Propagation in Buildings

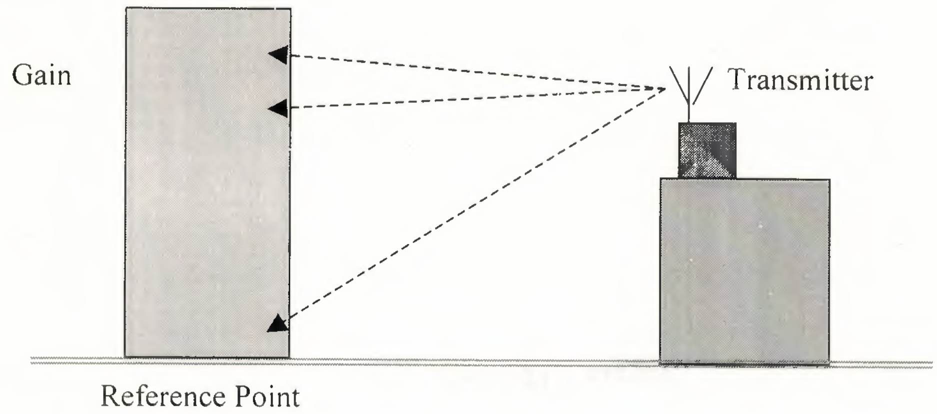


Figure 1.11.b Propagation in Buildings

1.3.5 Propagation Effects On GSM Frequencies

Frenzel Zone

The Frenzel Zone (pronounced frenzel) actually consists of several different zones, each one forming an ellipsoid around the major axis of the direct propagation path. Each zone describes a specific area depending on the wavelength of the signal frequency. If a signal from that zone is reflected of an obstacle which protrudes into the zone, it means that a reflected signal as well as the direct path signal will arrive at the receiver. Radio waves reflected in the first Frenzel Zone will arrive at the receiver out of phase with those taking the direct path and so combine destructively. This results in a very low received signal strength. It is important when planning a cell to consider all the radio paths for obstacles which may produce reflections from the first Frenzel zone because if they exist it is like planning permanent areas of no coverage in certain parts of the cell.

In order to calculate whether or not this condition exists the radius of the first Frenzel zone at the point where the object is suspected of intruding into the zone must be calculated. The equation 1.9 is as follows:

$$F_1 = \sqrt{\frac{d_1 . d_2 . \lambda}{d}} \qquad (1.9$$

Where d1 = Distance from tx antenna to the obstacle.

d2 = Distance from rx antenna to the obstacle.

λ = Wavelength of the carrier wave.

d = Total Path Length.

Once the cell coverage has been calculated the radio path can be checked for any objec intruding into the first Frenzel zone. Ideally the link should be planned for no intrusions b in some cases they are unavoidable. If that is the case then the next best clearance for t first Frenzel zone is 0.6 of the radius.

When siting a BTS on top of a building care must be taken with the positioning and heig of the antenna to ensure that the roof edge of the building does not intrude into the fi frenzel zone in figure 1.12 and with equation 1.9. Propagation effects on GSM Frequencie

Frequency = 900Mhz Wavelength = 30cm

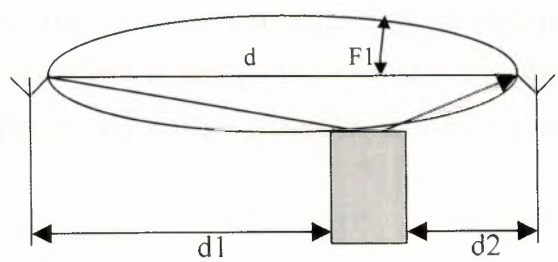


Figure 1.12 Frenzel Zone

1.3.6 Propagation-Rayleigh and Rician

As a result of the propagation effects on the transmitted signal the receiver will pick up the same signal which has been reflected from many different objects resulting in what is known as multipath reception. The signals arriving from the different paths will all have travelled different distances and will therefore arrive at the receiver at different times with different signal strengths. Because of the reception time difference the signals may or may not be in phase with each other. The result is that some will combine constructively, resulting in a gain of signal strength while others will combine destructively resulting in a loss of signal strength.

The receiving antenna does not have to be moved very far for the signal strength to vary by many tens of dBs. For GSM 900 a move of just 15cm or half a wavelength will suffice to observe a change in signal strength. This effect is known as multipath fading. It is typically experienced in urban areas where there are lots of buildings and the only signals received are from reflections and refractions of the original signal. This type of environment has been described by Rayleigh. He analysed the signal strength along a path with a moving receiver and plotted a graph of the typical signal strength measured due to multipath fading. The plot is specifically for non line of sight and is known as Rayleigh distribution. Where the signal path is predominantly line of sight with insignificant reflections of ref ractions arriving at the receiver, this is know as Rician distribution. There are still fades in signal strength but they rarely dip below the threshold below which they will not be processed by the receiver.

Fading

The largest traffic capacity requirements for a mobile system are generated in areas that can be classified as urban. This factor causes problems due to the fact that the antenna location can be below the height of the surrounding buildings (hence no line of sight) and possibly located in close proximity to these surrounding buildings. Therefore the propagation of the radio link between base site and mobile station tends to occur by means of scattering and multiple reflections from the surrounding buildings. This means that the RF signal arrives at the receiver via a multitude of paths so the RF signal at any one point in time may be high or low depending upon whether the various RF components combine constructively or destructively. When this occurs a multipath field is said to exist. The location of the receiving antenna does not have to change by much to alter the received RF signal by several tens of dB. This rapidly changing signal is basically a spatial phenomenon. When a receiver is mounted upon a vehicle and this vehicle is moving continuously through the field, the receiver not only experiences this spatial phenomenon but also experiences a time related variable signal which is created by the vehicles movement which causes a doppler shift. A convenient distinction is often made between the short-term multipath effects and the long-term variations of the median path loss. These RF signal fluctuations are known as fading. The rapid fluctuations caused by the multipath are known as fast fading. Whilst the much longer term fluctuation in the mean RF signal level received is known as slow fading. This latter effect is caused by movement over distances large enough to produce gross variations in the overall path between the base station and the mobile station.

1.3.7 Receive Signal Strength

A moving vehicle in an urban environment seldom has a direct lone-of-sight path to the base station. The propagation path contains may obstacles in the form of buildings, other structures and even other vehicles. Because there is no unique propagation path between transmitter and receiver, the instantaneous field strength that the mobile and base receivers sees exhibits a highly variable structure.

The received signal at the mobile is the net result of many waves that arrive via multiple paths formed by diffraction and scattering. The amplitudes, phase and angle of arrival of the waves are random and the short term statistics of the resultant signal envelope approximate a Rayleigh distribution.

This analysis of the multipath environment within an urban area leads to the conclusion that within the designated macro cell environment the signal amplitude emitted from the mobile exhibits fading with a Rayleigh distribution [8]. Should a micro cell be employed, where part of a cell coverage area be predominantly line of sight than Rician Distribution will be exhibited.

1.4 Summary

We discussed the GSM System Entities and specially discussed Radio Wave Propagation, Propagation in Buildings and Reflection, Diffraction, Effects of Urban and Rural Environments on Propagation.

Answer:

- We have to use suitable antenna types, output power of BTS and site location is very important for propagation.

2. CELLULAR CONCEPT

2.1 Over View

We will discussed cellular concept, umbrella cells, macro cells, micro cells, cell splitting, corporate cells, pico cells.

Question:

- Which type of cell is the best for Lefkoşa City Centre, why?

2.2 Cellular Principles

Cells can be called omni directional with equal coverage in all directions from the base station, or sectorised with the base station antennas pointing to different directions [1].
The major problems with radio distribution arise from electromagnetic wave propagation. The power of radio waves decreases with the inverse of the squared distance (d^{-2}); however, it must be remembered that this applies only in empty space. As a consequence, propagation at ground level in an urban environment with different obstacles is more difficult. A second problem is spectrum scarcity: the number of simultaneous radio communications supported by a base station is therefore limited.

Cellular coverage allows a high traffic density in a wide area despite both problems at the expense of infrastructure cost and of complexity. Because of the limited transmission range of the terminals, cellular system is based on a large number of receptions and transmission devices on the infrastructure side (the base stations), which are scattered over the area to cover a small geographical zone called a cell.

2.3 Umbrella Cells

A cell can be defined as an umbrella cell if the cell has a relatively large coverage area or the cell has a high traffic load, and inside the coverage area of the umbrella cell there are one or more cells.

When the cell-splitting technique was first applied, the operators realized that a freeway crossing within very small cells caused a large number of handovers among the different small cells. Since each handover requires additional work by the network, it is not particularly desirable to increase the number of such events. This is particularly true on European freeways, where the average speed is very high. The time a mobile on such a European freeway would stay in one cell decreases with increasing speed. Umbrella cells were introduced. Figure 2.1 to address this problem. In an umbrella cell, power is transmitted at a higher power level than it is within the underlying microcells and at a different frequency. This means that when a mobile that is travelling at a high speed is detected as a fast mover, it can be handed off to the umbrella cell rather than tie up the network with a fast series of handoffs. Such a mobile can be detected from its propagation characteristics or distinguished by its excessive handoff demans. In this cell, the mobile can stay for a longer period of time, thus reducing the workload for network.

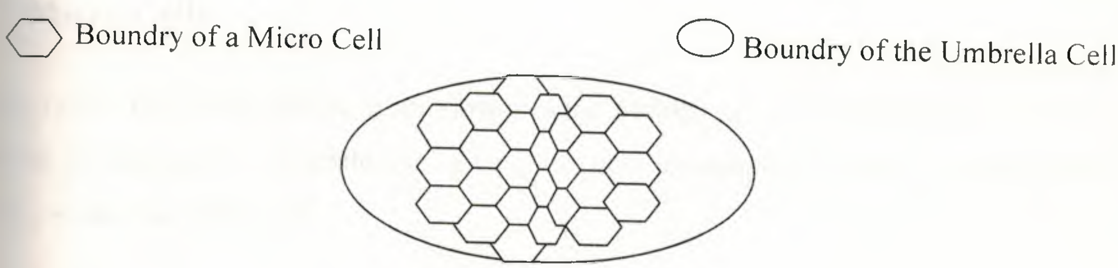


Figure 2.1 Umbrella Cells

2.4 Macro Cells

Implemented specifically to cater for the fast moving Mobile Subscribers and to provide a fall-back service in the case of coverage holes and pockets of interference in the micro cell layer. Macro cells form an umbrella over the smaller micro cells.

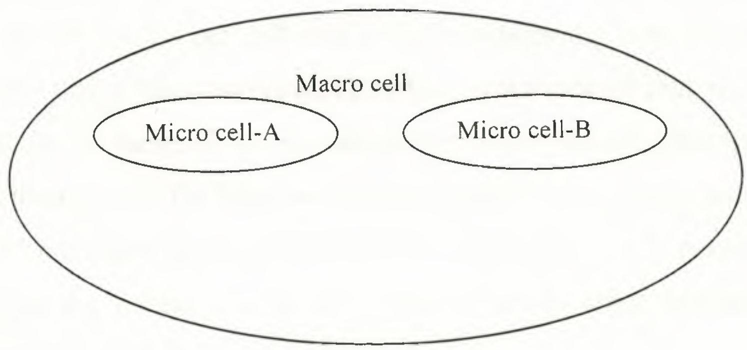


Figure 2.2 Micro Cells and Macro Cells

2.5 Micro Cells

Micro cells handle the traffic from slow-moving mobile subscribers. The micro cells, as shown in the diagram opposite, can give contiguous coverage over the required areas of heavy subscriber traffic [9].

2.6 Cell Splitting

As the number of subscribers grew larger, the density within these networks also became higher. The operators and radio engineers had to look for new capacity funds. A rather basic idea was to split the existing space into smaller portions, thus multiplying the number of channels available. A long with this simple scheme, the power levels used in these cells decreased, making it possible to reduce the size of reduce the size of batteries required for mobile stations. With the decreased power required for mobiles came decreased size and weight. This made the networks more attractive to new users. As the traffic within a particular cell increases, the cell is split into smaller cells. This is done in such a way that cell areas, or the individual component coverage areas of the cellular system, are further divided to yield yet more cell areas. The splitting of cell areas by adding new cells provides for an increasing amount of channel reuse and, hence, increasing subscriber serving capacity. Decreasing cell radii imply that cell boundaries will be crossed more often. This will result in more handoffs per call and a higher processing load for subscriber. Simple calculations show that a reduction in a cell radius by a factor of four will produce about a tenfold increase in the handoff rate per subscriber. Since the call processing load tends to increase geometrically with the increase in the number of subscribers, with cell splitting the handoff rate will increase exponentially. Therefore, it is essential to perform a cost –benefit study to compare the overal cost of cell splitting versus other available alternatives to handle increased traffic load.

Groving by Splitting Cell 4 into Cells of Small Size

Figure 2.3 Cell splitting

2.7 Corporate Cells

Corporate cell is a special cell intended to offer an extensive coverage inside a company's building. Normally it is a picocell including an antenna network. Depending on the billing system and possible IN features in the switch, phone calls made by company's phones inside the building are cheaper than the normal tariff. In that case the coverage of the corporate cell should be everywhere inside the building better than the service of the neighbouring base stations. It is impossible to guarantee that the calls will always be done using the corporate cell since in case of congestion, for example, the call can be rerouted to another cell. Therefore it is very important to monitor the traffic load in the corporate cell.

2.8 Pico Cells

Typical service areas where mobile phones are expected to operate are office buildings, parking garages, shopping centres, subway stations, department stores, factories and housing areas. Depending on the situations, the cells and antennas can be installed indoors. This is what is called a picocell. The indoor coverage requirements must be taken into consideration when planning coverage outdoors. By selecting an appropriate site for a cell outdoors, it may be possible to use it to provide adequate coverage for indoor office areas. The typical cell transmitting power is below 2 watts and the base station equipment and antennas are installed indoors. The coverage area radius varies from 10 to 100 meters, providing coverage for several floors of the building.

2.9 Summary

We discussed cellular concept, umbrella cells, macro cells, micro cells, cell splitting, corporate cells, pico cells.

Answer:

- Macro cell is the best type of cell for Lefkoşa City Centre. Because, too many buildings in City Centre and population is high. So, we need high capacity and good signal level in building.

3. BASE STATIONS AND RADIO INTERFACE

3.1 Over View

We will discuss in this chapter about base stations and radio interfaces, control cahannels, handover types, RF control strategy, radio channels and structure of the GSM Radio interface, timing advanced and frame structure, GSM Radio interface, radio frequency channels and bands for GSM, base station antennas, down tilting, diversity, power splitter, antenna configurations.

3.2 Base Transceiver Station (BTS)

A base station is normally understood as the whole station, i.e. it includes all necessary equipment and antenna installations. A Base Transceiver Station (BTS) is the base station device. A site is the location and equipment room, where the base station is placed. One site includes normally 1-3 BTSs. A cell is the service area covered with one BTS. One BTS has normally 1-6 Transceiver Units (TRX). If sectorised cells are used, we can get better coverage in the main beam direction and more capacity than by using omni directional antennas. The more the antenna directs the signal to a narrow sector, the more gain we can get to the main beam direction. Network capacity can be increased by using sectorised cells since the same frequency can be re-used closer and more often than with omni antennas as the radiation pattern of directed antennas in the back beam direction is remarkably reduced.

There are currently two main types of base station equipment racks: racks wired for Omni cell BTS only and racks for 1, 2 or even 3 sectorised cells. It is not practical to re-wire Omni cell racks to sectorised racks. The BTSs can be configured in many different ways. Nowadays a full-size sectorised rack can include up to six TRXs which can be configured for example in three cells with 2+2+2 TRXs, or for two cells, with 3+3 TRXs with an extension rack the capacity can be extended beyond six TRXs. Normal base station equipment racks are about *1,5* m high. The weight is typically approximately 150 kg. There are also so called outdoor cabinets available which can be installed on a rooftop or on the ground. The latest technology offers integrated, very small, low-power mini base stations, that can be mounted on walls or poles together with e.g. radio minilinks. The maximum number of TRXs in the mini BTS is typically two and the size is about the same as a normal TV-set. The latest base station models are micro BTSs, only 50 cm x 30 cm x 20 cm in size and the weight is less than 20 kg. The capacity so far is only one TRX, however.

A problem with mini or micro BTSs is the capacity limitation. If more TRXs are needed it is normally possible to chain two BTSs to work as one BTS serving with double capacity. The price of this kind of solution is high.

3.3 Control Channels

In GSM 900 system one physical radio channel is divided into eight time slots. Each time slot has one or more logical channels which can be traffic or control channels. There are different types of control channels used.

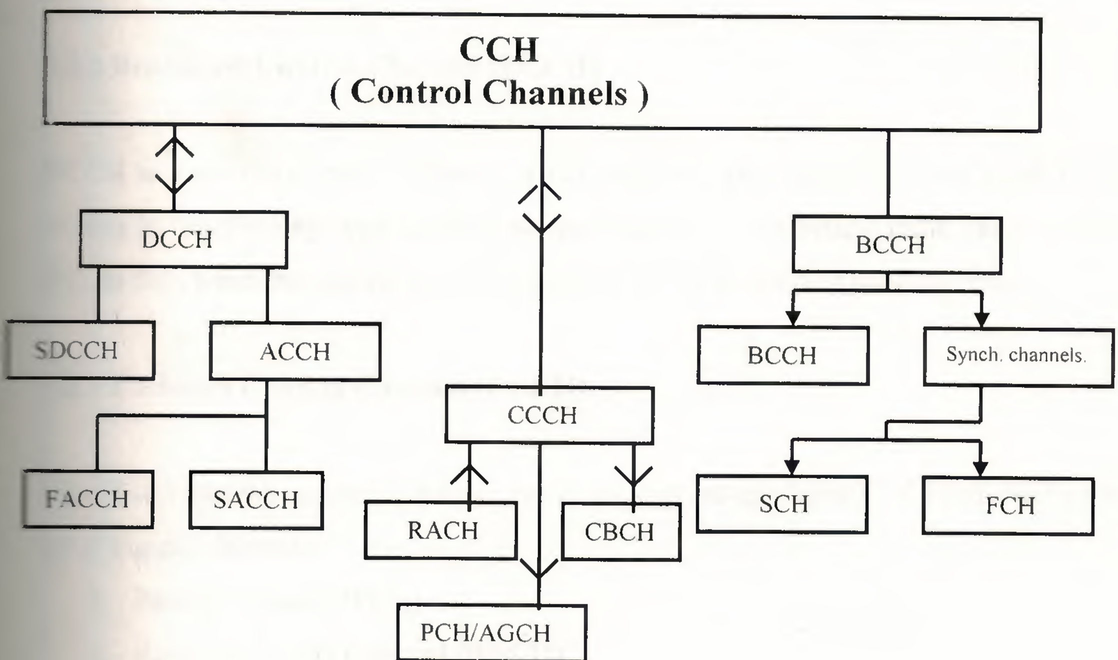


Figure 3.1 Control Channels

3.3.1 Dedicated control channels (DCCH)

Dedicated control channels are used to both directions and it is allocated for one user at once. This channel has signalling for call set-up, maintain, and call release. There are three types of dedicated control channels:

1. Stand Alone dedicated Control Channel (SDCCH)
2. Slow Associated Control Channel (SACCH)
3. Fast Associated Control Channel (FACCH)

SDCCH channel is used only for call set-up. At least one time slot must be allocated for SDCCH channel. This time slot can not be used as a speech channel.

SACCH channel transfers call related information during the call, for example power control commands and measurement results to the base station. SACCH locates on a traffic channel time slot.

FACCH channel is used to transfer information that can not be transferred on the SACCH channel. This channel locates on a traffic channel, as well.

3.3.2 Broadcast Control Channel (BCCH)

BCCH is a one-way control channel which end cell specific information to all the mobile phones in the coverage area. Mobile phones measure that physical radio channel that sends BCCH data when measuring signal strength of the neighbouring base stations.

3.3.3 Common Control Channel (CCCH)

CCCH is a two-way channel that is used in the call set-up phase. CCCH channel consists of three logical channels.

1. Paging Channel (PCH)
2. Random Access Channel (RACH)
3. Access Grant Channel (AGCH)

Paging channel is used to when someone tries to call to a mobile phone.

Random access channel is used when the mobile phone sends the first burst to the base station.

Access grant channel is used to allocate a traffic channel to a mobile phone that has responded on the RACH channel.

3.4 Location Area

The location of a mobile phone is known within an accuracy of a location area (LAC). When a call is coming to a mobile phone the call is sent through all the base stations locating in one location area. When a mobile phone moves to another location area. the phone makes a location update. Typically each BSC has its own location area. This is, however, not necessary. Several BSC areas can form one LAC. When planning location areas, it is important to know that location update causes signalling traffic, which can lead to SDDCH congestion if a LAC border situates in a place where there is a heavy traffic. During the location area change there is a short time period, during which the phone is not connected to the network for a short time. At this time the incoming calls go to the voice mail or to an announcement machine. If the location area is too big, pagings to the mobile phones cause too much load to the system.

3.5 Cell Selection

In idle state and in the beginning of call set-up mobile phone selects the base station offering the strongest signal. With rxLevAccessMin parameter we define the minimum signal level that the phone must receive from the base station before the phone can lock to the cell in question.

3.6 Handover

The handover decisions made by the BSC are based on the measurement results reported by the MS/BTS and various parameters set for each cell. The parameters control the handover in the BSC. By changing the values of the parameters it is possible to affect the handover decisions at all stages of the procedure: measurement processing, threshold comparison and decision algorithm [5]. All parameters are administered on a cell-by-cell basis by means of the O&M; that is, by using the local MMI in the BSC site or the Operation and Maintenance Centre (OMC).

3.6.1 Handover Types

The possible types of handover are the following:

1. Intra-BTS handover
2. Intra-BSC handover;
3. Inter-BSC (MSC) handover.

The handover may take place during a call from a traffic channel (TCH) to a traffic channel. An intra-BTS handover can take place either to a radio timeslot on a new carrier or to a different timeslot on the same carrier. A handover may also take place from a dedicated control channel (DCCH) to a dedicated control channel during the initial signalling period of call set-up. The parameter Enable Sdcch HO indicates whether the handover from a DCCH to a DCCH is enabled. As far as the. algorithm is concerned, the handover from a DCCH to a DCCH does not differ from the handover from a TCH to a TCH. During the call set-up phase in situations of congestion (Directed Retry Procedure) a handover can take place from a dedicated control channel (DCCH) of the serving cell to a traffic channel of an adjacent cell.

3.6.2 Handover Causes

A handover is normally caused by radio criteria, but the handover algorithm present is also able to perform handovers caused by four other reasons:

1. Due to congestion in the call set-up phase, a handover from a DCCH of the serving cell to a traffic channel (TCH) of an adjacent cell, that is, Directed Retry Procedure (DRP).
2. The MSC requests the BSC to perform a specified number of handovers from one specified cell to other specified cells, that is, Traffic Reason Handover (TRH).
4. BSC internal traffic control (for example, a handover from an umbrella cell to a microcell).
5. An order from the channel administration to empty the cell by means of the handover procedure (for example, because of changes in the radio network configuration).

The BSC uses different handover decision algorithms for handovers caused by normal radio criteria and handovers caused by other reasons than radio criteria. When an MS moves from one cell coverage area to another, the radio link measurements show low signal level (RXLEV) and/or quality (RXQUAL) on the current serving cell and a better RXLEV available from a neighbouring cell, or the neighbouring cell allows communication with a lower RF power level. The crucial principle for the BSC selecting the target cells for the handover caused by radio criteria is that the neighbouring cell must be better than the current serving cell in order for the handover to be useful. If the handover is caused by other reasons than radio criteria, it is not necessary for the target cell to be better than the serving cell. It suffices that the target cell serves the call well enough; for example, a handover from an umbrella cell to a microcell is performed whenever the call can be maintained on the neighbouring microcell.

Target Cell Evaluation

The evaluation on the preferred list of the target cells is based on:

1. The radio link measurements
2. The priority levels of the neighbouring cells;
3. The load of the neighbouring cells which belong to the local BSS.

First the BSC defines and selects those cells which meet the requirements for the radio link properties, and then it ranks the cells according to the priority levels and the load of the neighbouring cells with the exceptions of the imperative handover procedure and the traffic reason handover procedure when the BSC rinks the cells only according to radio link properties.

3.6.3 RF Power Control Strategy

The RF power control strategy employed by the BSC defines the RF power command that is signalled to the MS, and the RF power level that is used by the BTS. The RF power control optimises the RF output power of the MS and the BTS and simultaneously ensures that the signal level required at the BTS/MS is sufficient to maintain adequate speech/data quality. The RF power level to be employed in each case is based on the measurement results reported by the MS/BTS and on the various parameters set for each cell. All parameters controlling the power control procedure are administered on a cell-by-cell basis by means of the O&M. By changing the values of the parameters, it is possible to affect the RF power control at all stages of the procedure [4].

3.6.4 Interdependence of HO and PC

The Power Control (PC), for both the BTS and the MS, runs independently in parallel with the handover, but in such a way that the power control knows the status of the handover and vice versa, that is, the BSC does not try to adjust the MS/BTS power level in the current serving cell and execute a handover to a neighbouring cell simultaneously. The BSC determines which RF power level the mobile station that has been handed over will use as the initial RF power in the target cell. The default initial RF power level is the maximum RF power that an MS is permitted to use on a traffic channel in the target cell but, in the case of an intra-BSC handover, the PC/HO algorithm is also able to optimise the actual RF power level so that the RF power level is lower if the radio link properties of the target cell are good.

Optimisation of the MS power level in a handover cuts down the probability of high RF power peaks in the uplink after HOs. This way it reduces the uplink interference in the radio network. This property is controlled by the parameter MsPwrOptLevel, which is set independently for each adjacent cell by means of the O&M. Optimisation of the MS power level in a handover is an optional feature.

With a proper choice of the PC and HO thresholds, the BSC maintains call quality by means of power control, and proposes handover only when the MS actually reaches the border of the serving cell. If both the HO and PC threshold conditions are fulfilled, the handover has greater priority than the power control. If the handover cannot be performed, power increase may be used as first aid.

[illegible] Umbrella Handover

A cell can be defined as an umbrella cell if the cell has a relatively large coverage area or the cell has a high traffic load, and inside the coverage area of the umbrella cell there are one or more cells. Since the umbrella cell offers often the best coverage, the phone calls tend to begin in that cell. However, if the cell is defined to work as an umbrella cell, BSC checks if any of the neighbours to which an umbrella handover is allowed to be done, has a sufficient signal strength level. The level can be lower than the signal from the umbrella cell, but if the underlying cell provides a signal which is good enough for a good quality connection, an umbrella handover will be executed. In this way we can transfer traffic from one dominating cell to surrounding ones.

3.6.6 Handover Priority

If two or more criteria for a handover (HO) are present simultaneously, the priority order is the following:

1. HO: Uplink quality,
2. HO: Downlink quality,
3. HO: Uplink level,
4. HO: Downlink level,
5. HO: MS-BTS distance,
6. HO: Better cell (PBGT or Umbrella),
7. PC: lower thresholds (uplink and downlink as well as quality and level),
8. PC: upper thresholds (uplink and downlink as well as quality and level).

3.7 Timing Advanced and Frame Structure

3.7.1 Timing Advanced and Power Control

To simplify the design of the mobile, the GSM Recommendations specify an offset of three time slots between the BSS and MS timing thus avoiding the necessity for the mobile to transmit and receive simultaneously. The facing diagram illustrates this.

However, the synchronisation of a TDMA system is critical because bursts have to be transmitted and received within the "real time" time slots allotted to them. The further the mobile is from the base station then, obviously, the longer it will take for the bursts to travel the distance between them. The GSM base station caters for this problem by instructing the MS to advance its timing (i.e. transmit earlier) to compensate for the increased propagation delay.

This advance is then superimposed upon the 3 time slot nominal offset, as shown figure 3.2

"Power Control" is an optional feature of the GSM air interface which allows the operator to not only compensate for the distance from mobile to base station as regards timing, but can also cause the base station and mobile to adjust their power output to take account of that distance. The closer the mobile is to the base station, the less the power it and the base station will be required to transmit [13]. This feature saves radio battery power at the mobile, and helps to reduce co-channel and adjacent channel interference.

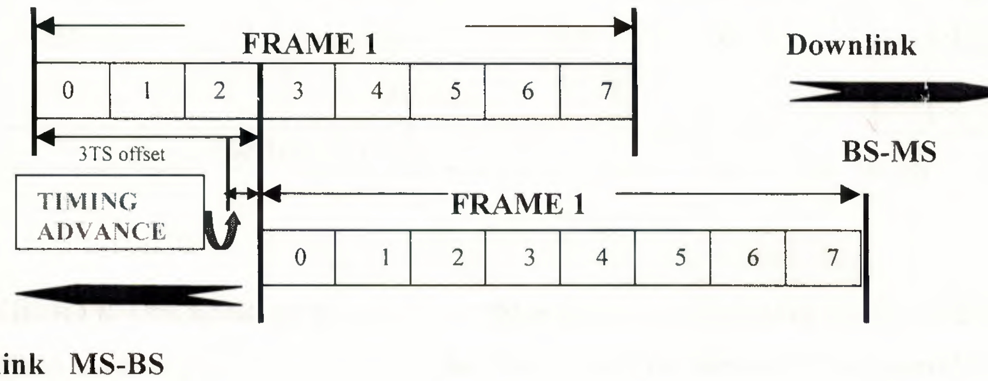


Figure 3.2 Timing Advanced

3.7.2 Frame Structure

Burst

The diagram shows the five types of burst employed in the GSM air interface and shows that all bursts, of whatever type, have to be timed so that they are received within the appropriate time slot of the TDMA frame. The "burst" is the sequence of bits transmitted by the base station or mobile the "time slot" is the discrete period of real time within which it must arrive in order to be correctly decoded by the receiver.

1. Normal Burst: The normal burst carries traffic channels (both voice and data) and all types of control channels. It is bi-directional. A normal burst is the most common burst in the GSM system and is transmitted in one time slot either from the base station or from the mobile station. There are eight time slots in a TDMA frame. The actual user data occupy only a portion of the time slot, and the remainder of the bits are reserved for a host of control functions and some demodulating aids. Shown in Table 3.1.

Table 3.1 Structure of a Normal Burst.

T 3	Coded Data 57	S 1	Training Sequence 26	S 1	Coded Data 57	T 3	GP 8.25

148 Bit =546.12μs

a) Tail Bits(T): This small group consists of three bits at the beginning and the end of each burst and is used as guard time. The tail bit time covers the periods of uncertainly during the ramping up and down of the power bursts from the mobile in accordance with the power versus time template shown. The tail bits are always set to zero. Coincidentally, the demodulation process requires some initial zero bit values.

b) Coded Data: These two times, of 57 bits each, contain the actual transmitted signaling data, or user data. Included and mixed in with the user's payload data are channel coding bits , which are used in the receiver to help recover the original data. For now, you should think of the coding bits as packing material that protects the freight [15]. Large parts of the remainder of this chapter explain channel coding, or data protection.

c) Stealing Flag (s): These two bits are an indication to the decoder (in the receiver) of whether the incoming burst is carrying signalling data, which are usually messages the radios use to maintain the link between themselves, or whether the burst is carrying user data. The indicating flag is needed because signalling data are very important and go to different places than user data go. Another word for user data is traffic.

d) Training Sequence: This is a fixed bit sequence known to both the mobile and the base station, which lets radios syncronize their receivers with the burst. Syncronization lets receivers interpret the recovered data correctly. It might not be fully clear why this bit pattern is required, since all the timing seems to be well defined so far. The reason the include the training sequence in each normal burst is to compensate for the effects of multipath fading [7]. We learned a little about multipath and its destructive influence on TDMA systems.

e) **Guard Period (GP):** It probably seems odd to specify fractions of a bit, so instead it should be considered as a defined time, rather than as actual data bits. No data are transmitted during the guard period, which is reserved for the ramping time. Taking the bit length defined in the system as 3.69µs/bit, the guard period can be calculated as 8.25 bits. 3.69µs/bit = 30.4 µs, which is appoximately the time used during power ramping. During this time, two consecutive bursts from two mobiles may overlap (i.e, the previous burst ramps down and the current burst ramps up) [2]. No data are transmitted during the ramp time (GP), and communication is not disturbed while radios are ramping their RF power outputs.

2. Frequency Correction Burst: This burst carries FCCH downlink to correct the frequency of the mobile's local oscillator, effectively locking it to that of the base station. Since timing is a critical need in the system, the base station has to provide the means for a mobile station to synchronize with the master frequency of the system. To achive this, the base station transmits, during the certain known intervals, a pure sine wave signal for the period of exactly one time slot. What a comfort this must be for the mobile. Due to the nature of the type of modulation used in GSM, this can be accomplished by simply sending a fixed sequence of zeros (000…) in the time slot.

3. Synchronisation Burst: So called because its function is to carry SCH downlink, synchronising the timing of the mobile to that of the base station. When a mobile station starts to synchronize with the network, it first looks for and detects only the frequency where the base channel is located. The mobile does not yet have a key with which to demodulate and decode the information provided in the forward base channel, which is information that contains some valuable system parameters. As was explained previously, the key is one of the eight defined training sequences.

Table 3.2 Structure of the Frequency Correction Burst.

T	Fixed bit sequnce	T	GP
3	142	3	8.25

148 Bit = 546µs

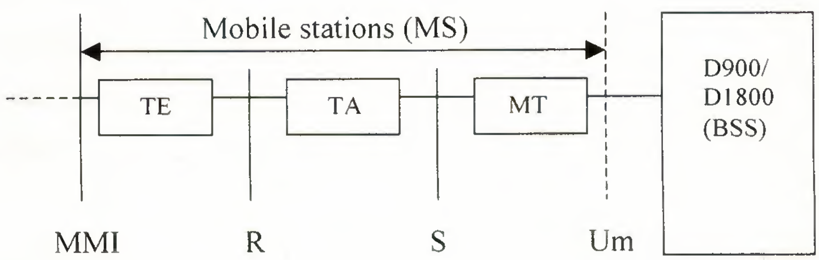
4. Dummy Burst: Timeslot 0 of the BCCH carrier will always contain control channel information but depending on configuration the remaining seven timeslots may be used to support additional control channel information or a traffic channel. If any of the remaining seven timeslots are idle then Dummy bursts must be inserted as all eight timeslots on the BCCH carrier must always be active.

5. Access Burst: This burst is of much shorter duration than the other types. The increased guard period is necessary because the timing of its transmission is unknown this is due to the unknown quantity of the mobile's location and the lack of timing advance information at this point during the call set up process.

3.8 GSM Radio Interface

The GSM radio interface Um is required for supporting universal use of any compatible mobile station (MS) in any GSM compatible PLMN.

Figure 3.3 shows the reference configuration according to GSM specifications at the radio interface Um [3]. The reference configuration for a mobile station shows the reference points (R;S) of interfaces (MMI,Um) and function groups (TE ,TA , MT).



R, S Reference points

Um Radio interface

TE Terminal adapter

MT Mobile termination

MMI Man Machine Interface (user interface)

Figure 3.3 Reference Configuration at the GSM Radio Interface.

3.8.1 Interface Functions

The following functions are executed by the mobile termination (MT):

terminal capabilities.

Provision of the MMI (for subscriber controlled input, SCI)

Radio link termination

Channel adaption and user data rate adaption

Channel management

Flow control of signalling and user data

User data encryption

Mobility management

Error protection

The following functions are executed by D900/D1800 (BSS): data link layer functions for signalling over the radio link.

Call setup functions between MS and BSS

Radio Link Termination

User Data Rate Adaption

Radio Link Management

Speech Transcoding

Handover Functions

Error Protection

3.8.2 Structure of the GSM Radio Interface

PLMNs use the Frequency Division Multiple Access (FDMA) procedure in which each traffic channel or control channel is assigned a Radio Frequency Channel (RFCH). The radio frequency channels are separated from one another by analog filters. D900/D1800 operates with a combination of FDMA and Time Division Multiple Access (TDMA) with eight time division traffic channels or control channels transmitted over one radio frequency channel. This means that one transmitter and one receiver support 8 physical traffic channel pairs in the case of half rate channels. This reduces the space and energy requirements in the base transceiver stations (BTS) compared with analog radio networks. A physical traffic channel is defined by the frequency range of an RFCH pair and a time slot in the TDMA frame.

3.8.3 Radio Frequency Channels and Bands For D900

According to the GSM standards the Um interface is used between the BTS antenna and the MS. The D900 provides the GSM primary band (890-915 MHz for uplink, 935-960 MHz for downlink) as well as the GSM extended band (880-915 MHz for uplink, 925-960 MHz for downlink). With FDMA 124 (174 for extended band) discrete duplex radio frequency channels are available: 124 (174) downlink channels for transmission from the MS to the BSS and 124 (174) downlink channels for transmission from the BSS to the MS. With TDMA the number of channels is increased by a factor of 8 to 992 (1392 for GSM extended band) physical duplex traffic channels in the case of full rate channels [9]. With pure half rate operation, twice the number of physical duplex traffic channels available for a TDMA system. With dual rate operation (full rate and half rate), a value which is practically between a pure full rate and a pure half rate operation is produced for a TDMA system. The specifications of the radio frequency bands are as follows:

GSM primary band (P-GSM 900)

- Carrier frequencies of the BSS receivers (uplink): fup(n) = (890+0,2xn) MHz

with Absolute Radio Frequency Channel, ARFCN 1<=n<=124)

- Carrier frequencies of the BSS transmitters (downlink): Fdown (n)=fup(n)+45MHz

Radio frequency channel spacing: 200 kHz

Duplex spacing: 45 MHz

- GSM extended band (E-GSM 900)

Carrier frequencies of the BSS receivers (uplink):

Fup(n)=(890+0.2 x n)MHz+

with ARFCN 0<=n<124)

[890+0.2 x (n-1024)] MHz

with ARFCN 975<=n<=1023)

- Carrier frequencies of the BSS transmitters (downlink):

fdown (n) = fup (n)+45 MHz

Radio frequency channel spacing: 200 kHz

Duplex spacing: 45 MHz

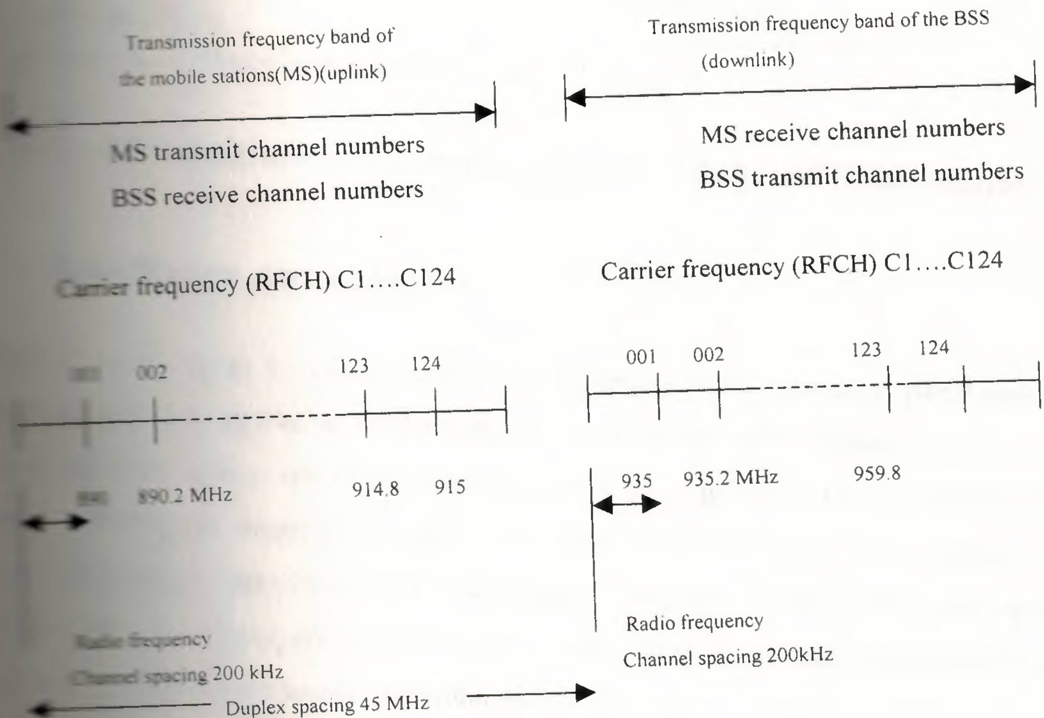
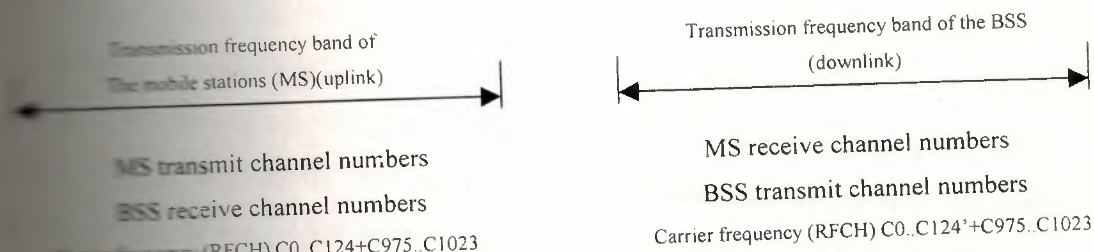


Figure 3.4 Radio Frequency Channel Distribution For D900 BSS (GSM Primary Band)



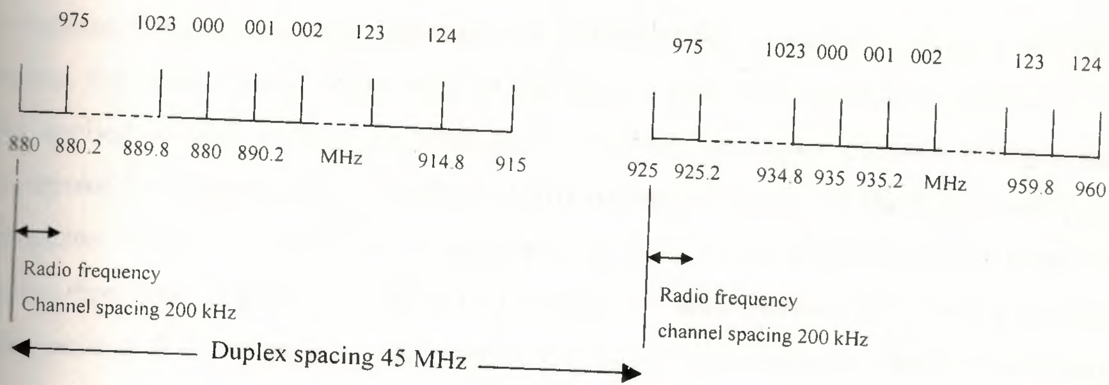


Figure 3.5 Radio Frequency Channel Distribution For D900 BSS (GSM Extended Band)

3.9 Base Station Antennas

There is a wide range of base station antenna types available. Nowadays panel antennas are most popular. The size of an antenna increases according to the antenna gain. In city areas especially, the physical size of an antenna can be a limiting factor. For GSM 900 the largest panel antennas are about 2,5m high fibre-glass covered boxes. In city areas diversity improves receiver sensitivity and interference tolerance. If only one antenna can be installed, the transmitter and receiver can be connected to one single antenna by using a duplex filter. The most important antenna parameters are:

1. Horizontal beam width
2. Vertical beam width
3. Antenna gain
4. Front to back ratio
5. Side lobe characteristics

Horizontal -3dB beam width (lobe) defines the width of the coverage area. Normally, antennas with 60, 90, 120. or 360° (omni) beam width are used. It has to be remembered that the coverage area of a cell does not end at the -3 dB point, it describes rather the area with a maximum coverage.

Vertical beam width depends on the gain of the antenna. The greater the gain, the narrower the vertical beam. In a cells with relatively low antenna height (<100 m) compared to the area altitude to be covered this is not a problem. But, if the antennas are on a top of a mountain, the radiation of the antenna may go beyond the area to be covered. If such a risk exists, the vertical beam width must be considered. Electrical or mechanical down tilt can be applied in such a case. Antenna gain describes how many decibels stronger signal compared to a dipole (dBd) or isotropic (dBi) antenna is radiated to the main beam (-3 dB) direction. 0 dBd =2.1 dBi. Front to back ratio describes the gain between the main and back beam directions. A great (> 25 dB) value is desired. Also important is the front/back ratio of the antenna. It describes how many decibels difference is in the gain between the directions 0° & 180°. The greater the separation, the better the antenna is since back beam radiation is normally not a desired phenomenon.

There are different ways to install the base station antennas. Typically antennas are installed on a mast, rooftop or on a wall. Figure 3.6 shows typical antenna installation configurations. Configuration B is the best solution because sufficient attenuation between the Transmitter (TX) and Receiver (RX) antennas is guaranteed. In configuration A there may be a small risk that the TX signal leaks to the RX antennas. This configuration can be used if the horizontal beam width of the antennas is < 12O°. If diversity is not necessary or possible, installation according to configuration C is recommended. When a place for two antennas is available as in configuration D, it is possible, by using a duplex filter to connect one antenna both for transmitting and receiving and the second antenna is used for diversity. If only a very limited space is available, installation E can be used. In this case diversity is not possible.

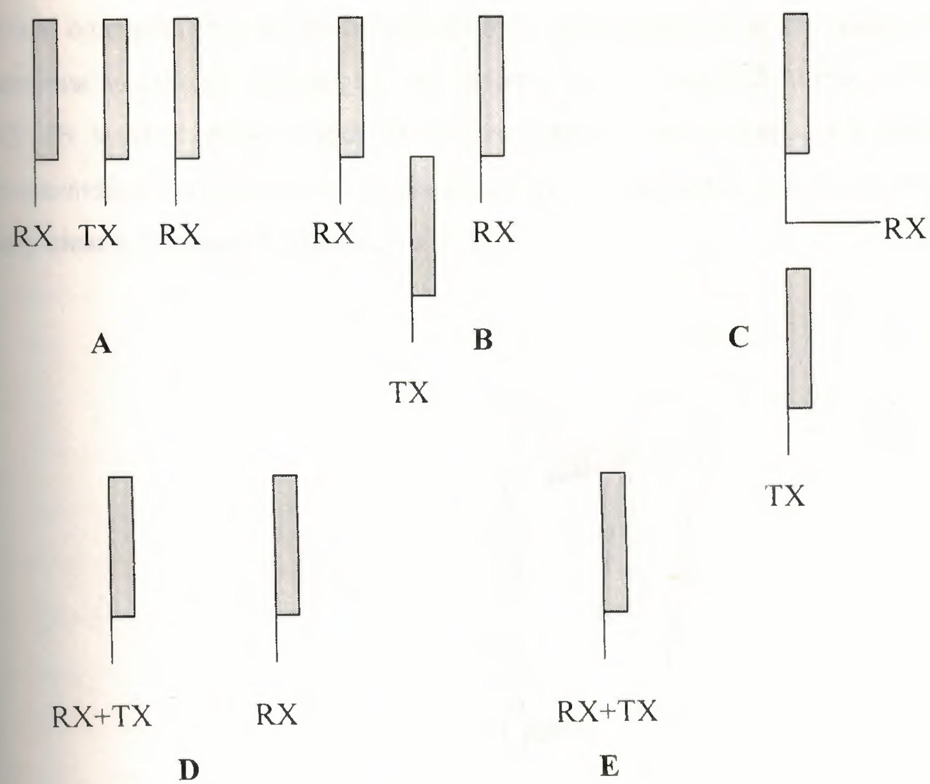


Figure 3.6 Different Antenna Installation Configuration.

3.9.1 Down Tilting

By down tilting a base station antenna coverage and interference area can be reduced. In addition to that, field strength increases near the antenna. For example, when the cell size has to be reduced and new cells will be built around the existing one, down tilting may be a suitable solution. Also, for totally new cells, if the antennas must be installed in a position which would offer too large coverage area, down tilting can be useful.

Antenna can be tilted either mechanically or electrically. Special mounting brackets are needed for mechanical down tilting. This should be noticed when planning the antenna installation. An advantage of electrical down tilting is that also the back lobe and side lobes are down tilted. In mechanical down tilting the back lobe will be up tilted. By up tilting an electrically down tilted antenna the same amount as the tilt angle, back beam will be down tilted considerably. The advantage of down tilting depends on the vertical beam width of the antenna and the surroundings of the antenna. The tilt angle should be at least as great as the -3 dB vertical beam width of the antenna. In micro cells, the reflections from the surrounding buildings affect to the coverage area so much that down tilting does not have any clear advantage. In figure 3.7.

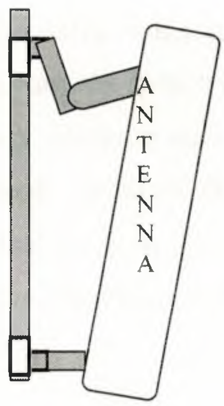


Figure 3.7 Down Tilting

3.9.2 Diversity

Space diversity enhances the receiving sensitivity of the base station by receiving uplink signal with two antennas. The diversity gain depends on the height of base station antennas, frequency range and the distance between the receiving antennas. Diversity antennas should be installed on the same vertical height with a distance from each other calculated according to the following formula:

Where $d>h/10$, **d** = horizontal distance between receiving antennas,

h = hight of the antennas

In the case of a GSM 900 network, the space should be at least 4 m. The advantage of the space diversity is greatest in city areas where radio signals reflect from many surfaces. In the countryside, especially when building a base station on a top of a mountain or big hill or on a high tower, the gain is very small unless the space between receiving antennas is increased. A typical minimum value for diversity gain is 2 dB.

In city areas and indoor solutions a polarisation diversity can be useful because the radio signal is not purely vertically polarised due to reflections. There are also cross polarised antennas available. The gain of a polarisation diversity is some 2 to 5 dB in a case of a micro cell.

A so called pseudo diversity is a cell configuration for power splitter solution where a power splitter is used in transmitting, but the two receiving antennas are connected to diversity receivers, in this way one power splitter in the receiving branch can be omitted and the receiving sensitivity will be increased. Therefore the transmitting power can be raised approximately 2 dB compared to a normal power splitter configuration. Frequency diversity is obtained when a slow frequency hopping function is used.

3.9.3 Power Splitter

A power splitter is a device which divides the radio signal into two parts. In mobile communication, splitters dividing the power 1:1 are normally used, giving half the power level (3 dB attenuation) in two antenna branches. The loss in the receiver branch is also three decibels due to an impedance matching in the splitter.

Figure 3.8 presents a normal power splitter configuration (A) and a pseudo diversity (B) structure. By using a pseudo diversity arrangement the loss of the received power can be reduced to some 1 dB when compared to a two-cell solution without diversity. This enables to increase the TX power by 2 dB.

With a power splitter it is possible to save one TRX at one site in low-traffic areas when instead of building two separate cells, only one cell with antennas directed in two directions is built. When more capacity is needed only one additional Transceiver (TRX) has to be installed to provide more capacity. This two TRX configuration gives 40 % more capacity than a two-cell solution where one TRX is installed in each cell. Use of a power splitter may cause some problems with coverage. Naturally 3 dB power loss reduces the coverage area a little, in the side beam areas of the cell where two signals received from both antennas are at an equal field strength level, the received signal level can vary rapidly when the two signal with slightly different phases are summed. This problem will not arise close to the base station.

With power splitters it is possible to reduce the investments to a network especially in rural areas when not only TRXs, but also BSC capacity can be saved. A typical place for a cell with power splitter is a base station covering a road going close by the site and located in a place where neighbouring base stations are close enough to give continuous coverage.

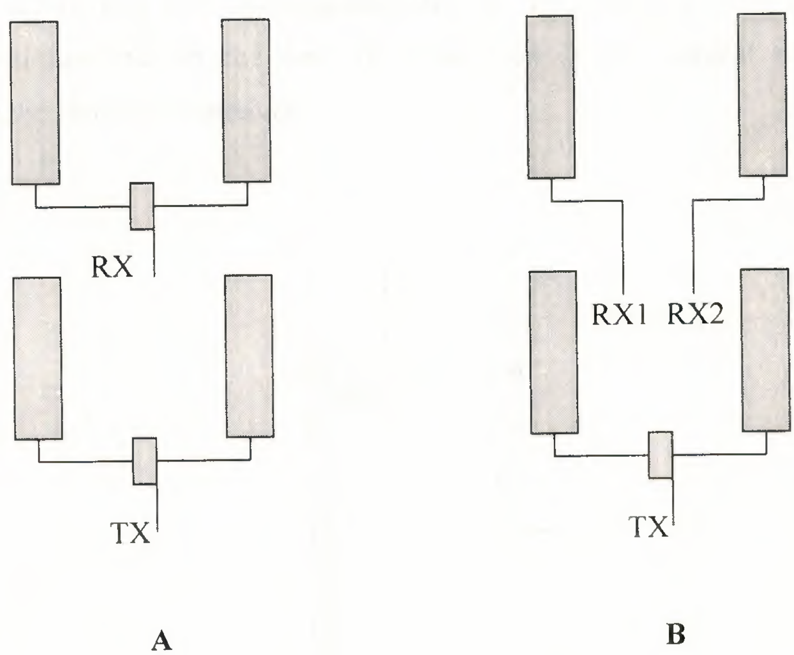


Figure 3.8 Power Splitter Configuration.

3.9.4 Antenna Configurations

Configuration of Omnidirectional Antennas

Seperation requirements for isolation.

a) **Vertical Separation**

Requirements: Tx-Tx and Tx-Rx: 30 dB

Pre-condition: No influence from tower structure, ie. more than 2m between antennas and tower. (a in fugure 3.9)

Vertical seperation: Tx-Tx and Tx-Rx : Minimum 0.2 m (k in figure 3.9)

Additional information

Antennas on the same axist with a separation of 0.2 m will actually have more than 40 dB isolation but 0.2 m is a practical separation to use. This value is valid for all types of omnidirectional antennas as the near field radiation in the vertical direction is not dependent on the gain of the antenna.

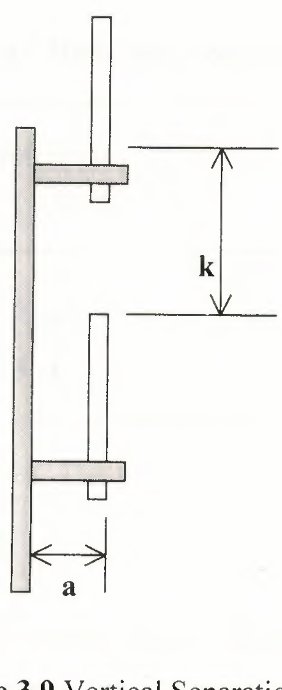


Figure 3.9 Vertical Separation

b) Horizontal Separation

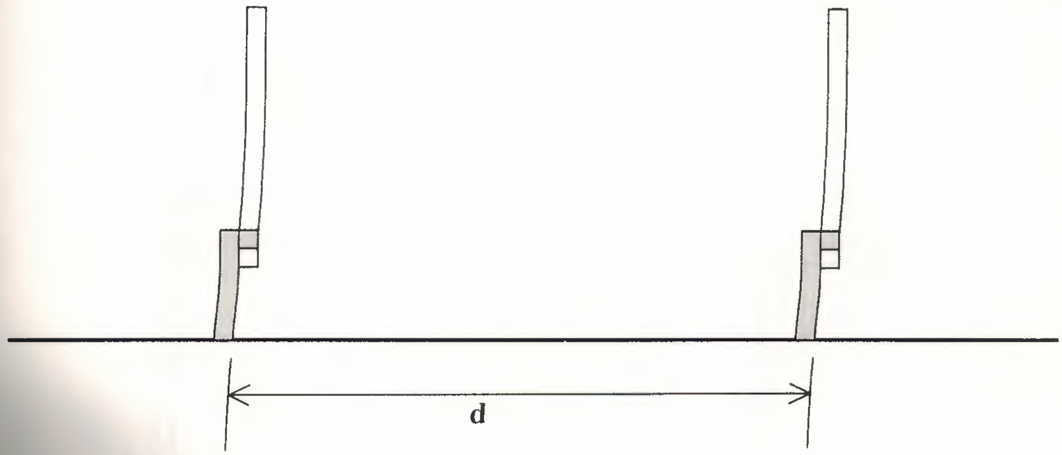


Figure 3.10 Horizontal Separation

Requirements: Tx-Tx and Tx-Rx: 30 dB

Horizontal separation: see table 3.3 below

Table 3.3 Horizontal Separation

Omni antenna Gain dBi	900 MHz	1800 / 1900 MHz
<10	3 m	1,5 m
>10	5 m	2,5 m

Additional Information

The horizontal distance between a Tx antenna and RX antenna or between two Tx antennas is dependent on the gain of the antennas.

The horizontal separation distance is considerably higher compared to vertical separation, as the antennas are in the main radiation fields.

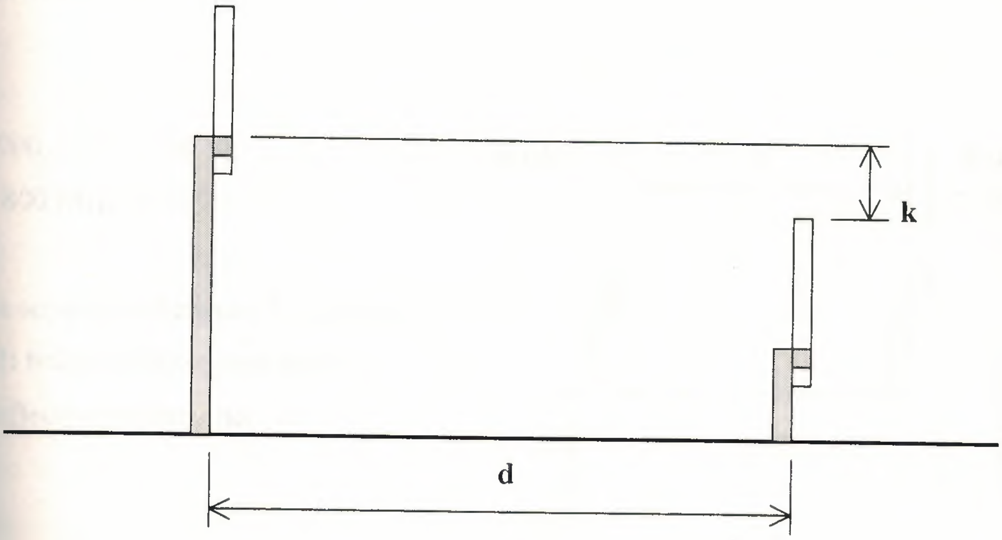


Figure 3.11 Combined Vertical / Horizontal Separation.

The following is valid for 900 MHz and 1800/1900 MHz

Requirements: Tx-Tx and Tx-Rx:30 dB

Combined separation: Vertical (k): minimum 0.5 m

Horizontal (d): no limitation

Additional information

The combined vertical/horizontal separation is common in systems with two receiver antennas for diversity if the Rx antennas are horizontally separated. The required 30 dB isolation will be achieved, if 0.5m vertical separation, k, is maintained, irrespective of horizontal separation, d. see figure 3.11.

b) Diversity Separation and Antenna Height

The relationship between the desirable diversity separation and the antenna height is shown in figure 3.12

900 MHz a>H/10

1800 MHz a>H/20

a: separation between Rx antennas

H: height of mast plus building (effective antenna height)

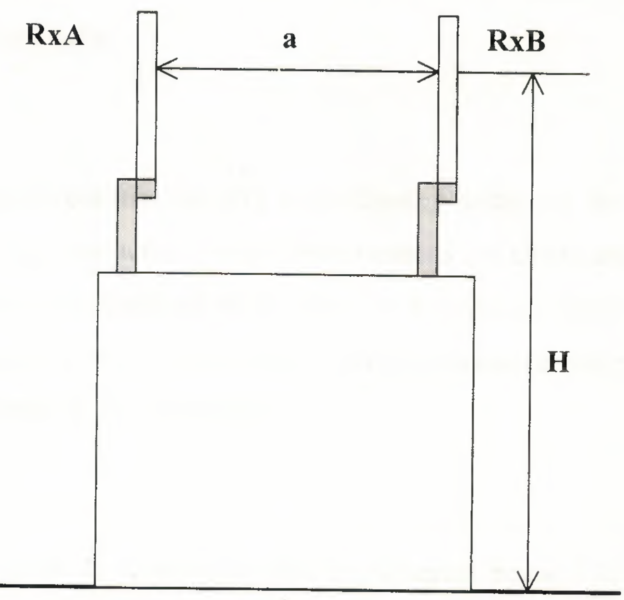


Figure 3.12 Diversity and Antenna Height.

d) Horizontal Separation for Diversity

The horizontal separation between the antennas shall be as stated in table 3.4 below

Table 3.4 Horizontal Separation for Space Diversity

	900 MHz	1800/1900 MHz
Minimum:	4m	2m
Recommended:	6m	3m

e) Vertical Separation for Diversity

Diversity improvement is also achieved by vertical separation of the antennas. For the same improvement as for the horizontal separation the vertical separation should be appoximately 5 times the horizontal value. This is valid for medium and large cells. For small cells in built up areas, a lower value can be acceptable, in extreme cases down to the same value as for horizontal separation. In other words, 4-6m (900MHz) or 2-3m (1800/1900 MHz) vertical separation can be sufficient for very small cells.

f) Nearby Obstacles

Nearby obstacles are defined in this document as reflecting or shadowing materials that can obstruct the beam in a negative way. Only obstacles within 30m distances are considered in reality the building if the antennas are to be installed on the roof of a building. Obstacles further away e.g. surrounding buildings close to the base station. Can also act as reflecting or shadowing obstacles but are not considered in this document.

g) Roof Mounting

The dominating obstacle is the roof itself. It is possible that the antenna beam will be distorted, if the antenna is too close to the roof. In other words, the antenna must be installed at a minimum height above the roof or other obstacles. In figure 3.13

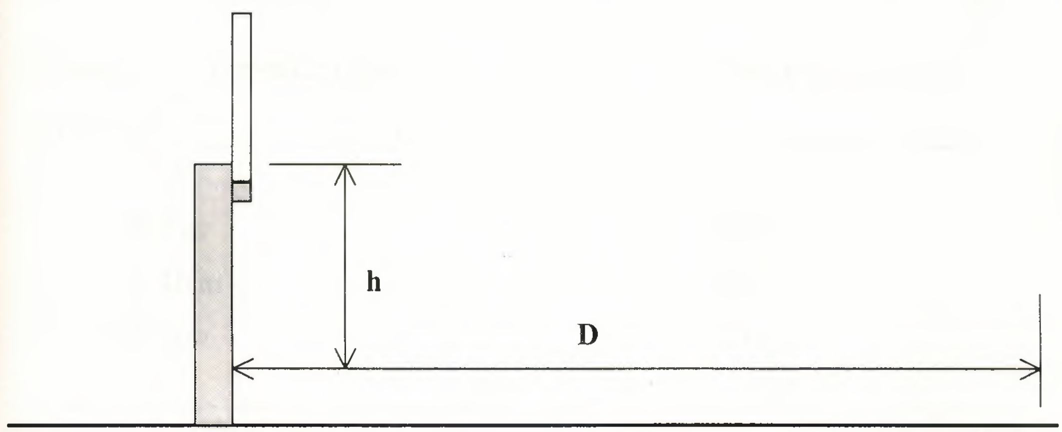


Figure 3.13 Height of Antenna Above Roof.

A practical planning rule is to keep the first fresnel zone free. For 900MHz the minimum recommended height above the roof is given by table 3.5 for 1800/1900 MHz the minimum height is given by table 3.6 these values are valid irrespective of antenna tilt.

Table 3.5 900 MHz Height of Antenna Above Roof

Distance (d) to obstacle edge (obstacle)	Height (h) above roof
0-1m	0.5m
1-10m	2m
10-30m	3m
>30m	3.5m

If possible, use 2m as the minimum height if there is a risk that people can walk close to the antenna.

Table 3.6 1800/1900 MHz Height of Antenna Above Roof.

Distance (d) to obstacle edge (obstacle)	Height (h) above roof
0-2 m	0.5 m
2-10 m	1m
>10 m	2 m

If possible, use 2m as the minimum height if there is a risk that people can walk close to the antenna.

3.10 Summary

We discussed in this chapter about base stations and radio interfaces, control cahannels, handover types, RF control strategy, radio channels and structure of the GSM Radio interface, timing advanced and frame structure, GSM Radio interface, radio frequency channels and bands for GSM, base station antennas, down tilting, diversity, power splitter, antenna configurations. We selected panel antenna type. This antenna type is suitable for cellular network planning of Lefkoşa City Centre. Poropagation of panel antenna is the best, because; we can change direction, tilting and different antenna configuration.

4. CELLULAR RADIO NETWORK PLANNING

4.1 Over View

We will mention about cellular radio network planning, coverage planning, micro cell planning, capacity planning, frequency planning, parameter planning, optimisation and network measurements.

4.2 Planning Principles

Cellular radio network planning is devided in to four major parts:

1. Coverage Planning
2. Capacity Planning
3. Frequency Planning
4. Parameter Planning

Different theoretical models for cell site locations have been introduced in books. The models suit, however, only for capacity calculations, not for cell plan. The models have some restrictions: Terrain is assumed to be totally flat, traffic either evenly distributed or there is only one small area with very high traffic [11]. All the cells should be of the same size and antenna heights should be equal. In practice, this is not possible. The real plan should take into account the local conditions and capacity demand.

When planning a new cell or a new cell site certain things have to be considered because a new cell site is a very expensive investment. The new cell should cover the area what needs to be covered. The interference area of the cell should be very limited. In fact, the difference between the coverage and interference area should be as small as possible. When deciding the cell size the future capacity demand must be considered. Unnecessary overlapping coverage should be avoided. However, when building good indoor coverage, coverage will be overlapping outdoors.

*The antenna heights in the countryside can be even 70-80m. In the city areas height of 20-*40 m is sufficient. When microcells will be built microcell antennas will be installed below the level of the rooftops.

If good indoor coverage is a target, a line of sight between the base station and the area to be covered is desired to ensure sufficient coverage. Different ways to get information of areas which have a lack of coverage are:

1. Customer feedback
2. Marketing Department
3. Traffic and quality reports
4. Knowledge of the topography and residential, business etc. areas
5. Network testing, field strength measurements
6. Competitors` cells

According to that information a list of new cells and sites can be generated. Normally there are lost of cells more in the list than what can be implemented in the near future. The possible new cell locations should be ranked according to the importance of the cell in question. When a decision of a new cell is made the following issues must be considered:

1. Is a new cell site needed?
2. Planned coverage area
3. Is it possible to cover the whole area with one site only?
4. How much traffic is estimated for the new cell?

It is important that we don`t try to cover two rather closely from each other situating areas with one cell if it seems to be a compromise that doesn`t give coverage to either of the areas. If a compromise cell is built, possibly two additional cells are needed to cover the two areas. In that case the first cell site in the middle is totally unnecessary. Too much overlapping coverage between the cells should be avoided. In order to quarantee properly working handovers, a certain amount of overlapping coverage must be between the neighbouring cells. By adjusting handover parameters the location where the handover takes place can be controlled. Problems can arise in a microcellular network in places where the signal strength can drop rapidly. For example, when going out of a building or a tunnel.

4.3 Coverage Planning

The aim of coverage planning is to create a sufficient coverage area, to achieve the required capacity within the frequency range available, to reach good quality and to minimise the costs of the network.

As a starting point, we have:

1. The preliminary number of base stations and channels needed (derived from the capacity plan)
2. The topology of the service area
3. Propagation models
4. System and equipment specifications
5. Service quality requirements

4.3.1 Planning Assumptions

All the areas to be covered should have a continuous coverage in order to avoid "coverage islands". Service will be offered to hand mobiles indoors in city and residential areas and continuous car phone coverage on the roads.

The network roll out strategy is based on marketing studies.

4.3.2 Cell Size Hierarchy

The cell size structure of a network varies according to the local circumstances, in rural areas maximum coverage can be the main target, but in city areas the capacity normally limits the possible cell size. Typical cell size radius for 3-6 km. for small cells 1-3 km and for microcells a couple of hundred meters. A BTS antenna gain of 13 dBi (8 dBd) for GSM

1988

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To: **Dr. F. Mamedov, Dr. D. İbrahim, Dr. K. Bürüncük, Dr. D. Haktanır**
Subject: **Erkan Tannur, MSc. (Elec. & Elec. Eng.) Thesis-Defence Jury**

Date: **15/05/2002**

You are invited to participate in the examining committee (jury) for the MSc. thesis defence of the above named candidate. The jury & thesis defence will be held on **Monday [10/06/2002]** at **[11:00]** at the Faculty of Engineering, NEU.

The above named MSc. candidate has successfully completed SEVEN MSc. courses. In addition, the candidate has completed his MSc. thesis and was recommended for undergoing his thesis defence by his MSc. supervisor.

The MSc. thesis is entitled: Cellular Network Planning.

The jury will consist of:

Jury Chairman:	Assoc. Prof. Dr. Doğan İbrahim	(Comp. Eng. Dept., NEU)
Jury Members:	Assist. Prof. Dr. Kadri Bürüncuk	(Elec. & Elec. Eng. Dept., NEU)
	Assist. Prof. Dr. Doğan Haktanır	(Elec. & Elec. Eng. Dept., NEU)
Supervisor:	Prof. Dr. Fakhraddin Mamedov	(Elec. & Elec. Eng. Dept., NEU)

The "Thesis Defence" will be open for attendance by other staff members and graduate students.

<u>Please confirm your willingness to participate as in the examining committee (jury) so that a copy of the MSc. thesis will be sent to you; use my email address below to confirm.</u>

If you have any previously-arranged engagement at the time of the committee meeting, then let me know as soon as possible to arrange another time.

Assoc. Prof. Dr Adnan Khashman
Graduate Studies Coordinator
Faculty of Engineering, NEU.
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NEAR EAST UNIVERSITY

INSTITUTE OF APPLIED AND SOCIAL SCIENCES

CELLULAR NETWORK PLANNING

Erkan Tannur

Master Thesis

Department of Electrical and Electronic Engineering

Nicosia - 2002

Erkan Tannur: Cellular Network Planning

Approval of Director of the Graduate School of Applied and Social Sciences

Prof. Dr. Fakhraddin Mamedov

We certify that this thesis is satisfactory for the award of the degree of Master of Science in Electrical Engineering

Examining Committee in charge:

Assoc. Prof. Dr. Doğan İbrahim, Computer Engineering Department, NEU

Assist. Prof. Dr. Kadri Bürüncük, Electric & Electronic Engineering Department, NEU

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First, I want to thank Prof.Dr. Fakhraddin Mamedov to be my advisor. Under his guidance. I successfully overcome many difficulties and learn a lot about Mobile Communications. In each discussion, he explained my questions patiently, and I felt my quick progress from his advises. I asked him many questions about GSM 900&1800 and he always answered my questions quickly and in detail.

Special thanks to my colleague friend Mr. Sohail Zakaria for assisting me and to my Technical Director for giving me permission time to time to complete my thesis.

Finally, I want to thank my family, specially my parents and wife.

ABSTRACT

GSM as a modern Telecommunication System is a complex object. Its implementation are not simple neither is its description.

This thesis aims at providing analysis, systematization and presentation of GSM System including Mobile Switching Center, Base Station and Radio Interface. Cellular Network and its interfacing with Public Switching Telephone Network.

Cell-site planning procedure for 20.000 mobile subscribers is presented as the contribution of the author insolving the investigated problem. The application of the work presented within this thesis is implemented on the city centre of Lefkoşa; the capital of TRNC.

CONTENTS

INTRODUCTION

This thesis is aimed to comprehensive description of the GSM systems including Operation and Maintenance Centre (OMC), Mobile Switching Centre (MSC), Base Station System (BSS), Base Station Controller (BSC), Base Transceiver Station (BTS) systems and design realisation cell planning procedure on the real Lefkoşa map for the 20.000 subscribers. The Thesis consists of the introduction, five chapters and conclusion.

Chapter 1 introduces fundamental of mobile communication system. In this chapter we discuss the GSM system entities. We describe operations and maintenance centre, mobile switching centre, base station system, base transceiver station, interworking function, transcoder function, authentication centre, equipment identity register, visitor location register, echo canceller, mobile station, cell broadcast centre, home location register.

Chapter 2 presents cellular concepts. We described types of cells, such as umbrellacell, macro cell, microcell, cell splitting, corporate cells, picocell.

Chapter 3 is concerned to the base stations and radio interfaces. We consider in details cells, control channels, problems related with handover. RF power control strategy, interdependence of HO and PC, radio channels and structure of the GSM radio interface, base station antennas and radio wave propagation.

Chapter 4 is very important chapter in this Thesis. This chapter gives information about cellular radio network planning, coverage planning, microcell planning, capacity planning, frequency planning, parameter planning, optimisation, network measurements.

Chapter 5 is concerned to cell planning for the 20.000 subscribers (example Lefkoşa City Centre). The number of sites are calculated, carriers, cells for this scenario. Database of Lefkoşa City network, network configuration and transmission plans are designed.

The objectives of the work presented within this thesis are:

- We have to calculation for number of BSC, BTS, Sites, Cells and TRX. This step is very important. We need a right calculation for coverage and capacity.
- We select right types of cells and cell angles and which type of site configuration for each region according to populations.
- This network must be achive good coverage (specially indoor), capacity and good quality of service.
- Our network must be the cheapest in equivalent networks.
- We need a good and real transmission plan and which types of equipments can we use.
- We have to make a frequency planning that without interference (uplink and downlink).
- We select suitable site location on the Lefkoşa City map.

Conclusion presents the significant results, my contribution and future investigations.

1. FUNDAMENTAL OF GSM ARCHITECTURE

1.1 Over View

We will discuss the GSM System Entities and specially Radio Wave Propagation, Propagation in Buildings and Reflection, Diffraction, Effects of Urban and Rural Environments on Propagation. These are very important for cellular planning of Lefkoşa City Centre. Also, Propagation Effects on GSM Frequencies is important. We need them for cellular network planning of Lefkoşa City Centre.

Question:

- What is the solution of weak signal strengh in buildings?

1.2 GSM System Entities

Architecture of GSM System is given in figure 1.1.

1.2.1 Operations and Maintenance Centre (OMC)

Operation and maintenance centre (OMC) has access to both the Gateway (G) MSC and the BSC, handles error messages coming from the network, and controls the traffic load of the BSC and the BTS. The OMC configures the BTS via the BSC and allows the operator to check the attached components of the system. As the cells become smaller and the number of base stations increases, it will not be possible in the future to check the individual stations on a regular basis for transceiver quality.

1.2.2 Gateway MSC

The GMSC is the interface of the cellular network to the PSTN. It is a complete exchange, and with all its registers it is capable of routing calls from the fixed network via the BSC and the BTS to an individual mobile station. The GMSC also provides the network with specific data about individual mobile stations. Depending on the network size , an operator might use several interfaces to the fixed network, thus using several GMSCs or only one. If the traffic within the cellular network requires more exchange capacity than the GMSCs can provide, additional Mobile services Switching Centres (MSC) might coexist with no access to the fixed network. If not otherwise explicitly distinguished from each other, the capabilities of the GMSC and the MSC are the same [12].

1.2.3 Base Station System (BSS)

The fixed end of the radio interface that provides control and radio coverage functions for one or more sites and their associated mobile stations. The BSC and the BTS are part of the BSS.

1.2.4 Base Station Controller (BSC)

BSC monitors and controls several base stations, the number of which depends on the manufacturer and can be between several tens and several hundreds of stations. The chief tasks of the BSC are frequency administration, the control of a BTS, and exchange function. The hardware of the BSC may be located at the same site as the BTS, at its own standalone site, or at the site of the Mobile Switching Centre (MSC). BSC and BTS together form a functional entity sometimes referred to as the Base Station Subsystem (BSS) [10].

1.2.5 Base Transceiver Station (BTS)

The counterpart to a mobile station within a cellular network is the base station (BTS), which is the mobile's interface to the network. A BTS is usually located in the centre of a cell. The transmitting power of the BTS determines the absolute cell size. A base station has between one and sixteen transceivers, each of which represents a separate RF channel. Some of the intelligence, which has incorporated in to analog base stations and the host network, such as measurements on the radio channels as criterion for handover, is now shifted to the mobile stations. Dumping some of the work on the mobile's desk makes the GSM infrastructure cheaper than of some analog systems. The result is that in some less wealthy countries, digital cellular systems are installed instead of analog ones (such as AMPS, NMT, or TACS)

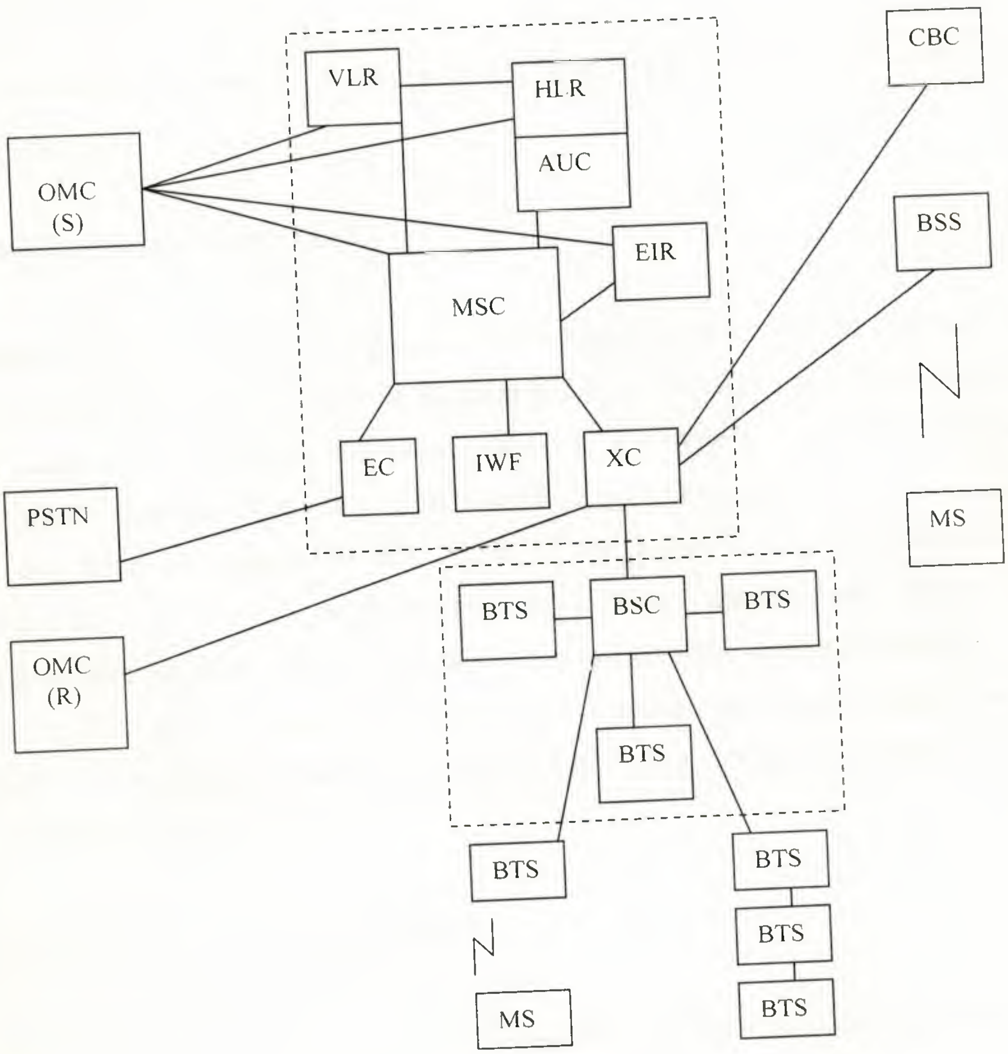


Figure 1.1 The GSM System

1.2.6 Interworking Function (IWF)

Performs data rate adaption between the Public Land Mobile Network (PLMN) and other existing land networks.

1.2.7 Transcoder Function

Converts the signal from 64Kbs A—law to 13Kbs GSM speech, as well as 3 Kbs of Control Information.

1.2.8 Authentication Centre (AUC)

Generates and stores authentication parameters for subscriber identification. Authentication Centre is related to the Home Location Register (HLR). It provides the HLR with different sets of parameters to complete the authentication of a mobile station. The AUC knows exactly which algorithm it has to use for a specific subscriber in order to calculate input values and issue the required results. Since all the algorithms for the authentication procedures are stored within the AUC, they are protected against abuse. The sim card issued in an area assigned to an AUC contains the same algorithms for authentication as the AUC does. If the AUC provides input and output parameters for these algorithms to either the HLR or the Visitor Location Register (VLR), either location register can verify (authenticate) the mobile station.

1.2.9 Equipment Identity Register (EIR)

The data base oriented processing network entity that contains centralised information for validating mobile stations based on their international mobile equipment identity.

1.2.10 Visitor Location Register (VLR)

The data base oriented processing network entity that temporarily contains information for subscribers roaming in a given location area. The data base oriented processing network entity that contains the master data base of the subscribers to a PLMN.

1.2.11 Echo Canceller (EC)

Performs echo suppression for all voice circuits.

1.2.12 Mobile Station (MS)

The radio equipment and man—machine interface that a subscriber needs to access PLMN services.

1.2.13 Cell Broadcast Centre (CBC)

CBC is used for the broadcast of short message on a per cell, location area or PLMN basis.

1.2.14 Home Location Register (HLR)

The HLR stores the identity and user data of all the subscribers belonging to the area of the related GMSC. These are permanent data such as the International Mobile Subscriber Number (IMSI) of an individual user, the user's phone number from the public network, the authentication key, the subscriber's permitted supplementary services, and some temporary data. Temporary data on the SIM include such entries as the address of the current Visitor Location Register (VLR), which currently administers the mobile station the number to which the calls must be forwarded (if the subscriber selects call forwarding), and transient parameters for authentication and ciphering.

The IMSI is permanently stored on the SIM card. The IMSI is one of the pieces of important information used to identify the mobile country code (MCC) and the next two digits are the Mobile Network Code (MNC). Up to ten additional digits of the mobile subscriber identification number (MSIC) complete the IMSI.

The following IMSI: 286 02 542 XXX XX XX identifies a subscriber from Turkey (MCC = 286), who is paying his or her monthly bill to the private operator TELSIM (MNC = 02). The subscriber's network identity number (MSIC) is 542 XXX XX XX.

1.3 Radio Wave Propagation

A radio link between a mobile phone and a base station is rarely consisted purely on a line of sight connection. The major propagation ways are:

1. Line of sight
2. Diffraction
3. Reflection
4. Scattering

1.3.1 Line of Sight (Free Loss)

This is the loss of signal strength that occurs as the radio waves propagated through free space defined as the condition where there are no sources of reflection in the signal path. A basis for the calculation of the path loss is assumed the device is an isotropic radiator. This is a theoretical pin point antenna which radiates equally in every direction. If the device was placed in the middle of a sphere it would illuminated the entire inner surface with an equal field strength. In order to find out what the power is covering the sphere as shown quation 1.1.

$$P = \frac{Pt}{4\pi . d^2} \tag{1.1}$$

Equation 1.1 is used where Pt is the input power to the isotropic antenna and d = the distance from the radiator to the surface of the sphere. This equation 1.1 illustrates the inverse square law that the power decreases with the square of the distance.

In order to work out the power received at a normal antenna the effective aperture (Ae) of the receiving antenna must be calculated.

$$\mathrm{Ae} = \frac{\lambda^2}{4\pi} \tag{1.2}$$

The actual received power can be calculated as follows,

$$\mathrm{Pr} = \mathrm{P.Ae} \tag{1.3}$$

Now if P is substituted with the formula for the power received over the inner surface of a sphere and Ae with its formula the result is

$$\mathrm{Pr} = \frac{\mathrm{Pt}}{4\pi \mathrm{d}^2} \times \frac{\pi^2}{4\pi} \tag{1.4}$$

This is the ratio of the actual received power to the transmitted power from an isotropic radiator and can be calculated by the formula (1.5)

$$20\log\frac{4\pi.\mathrm{d}}{\lambda}.\mathrm{Logs} \tag{1.5}$$

Equations are used to make the figures more manageable. Note that the equation 1.5 is dependant on distance and frequency. The higher the frequency the shorter the wavelength and therefore the greater the path loss.

The equation 1.6 above is based on units measured in meters. To make the (1.6) more convenient it can be modified to use kilometre and Megahertz for the distance and frequency. It becomes equation (1.6)

$$\text{Free Space Loss} = 32.0 + 20\log d + 20\log f \text{ dBs} \quad (1.6)$$

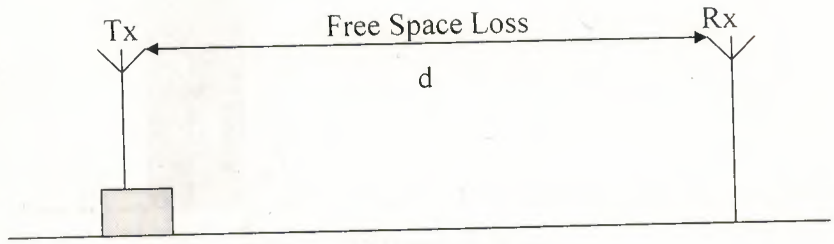


Figure 1.2 Line of Sight (Free Space Loss)

1.3.2 Effects of Urban and Rural Environments on Propagation

Reflection, refraction, diffraction, scattering, attenuation, changes in polarisation, Rayleigh and Rician fading, multipath fading. At the frequency range used for GSM it is important to consider the effects that objects in the path of the radio wave will have on it. As the wave length is approximately 30 cm for GSM900 and distance 15 cm for GSM1800, most objects in the path will have some effect on the signal. Such things as vehicles, buildings, office fittings even people and animals will all affect the radio wave in one way or another. The main effects can be summarised as follows: diffraction, attenuation, reflection, scattering and polarisation changes.

a) Diffraction

Is where a radio wave is bent off its normal path. This happens when the radio wave passes over an edge, such as that of a building roof or at street level that of a corner of a building. The amount of diffraction that takes place increases as the frequency used is increased. Diffraction can be a good thing as it allows radio signals to reach areas where they would not normally be propagated.

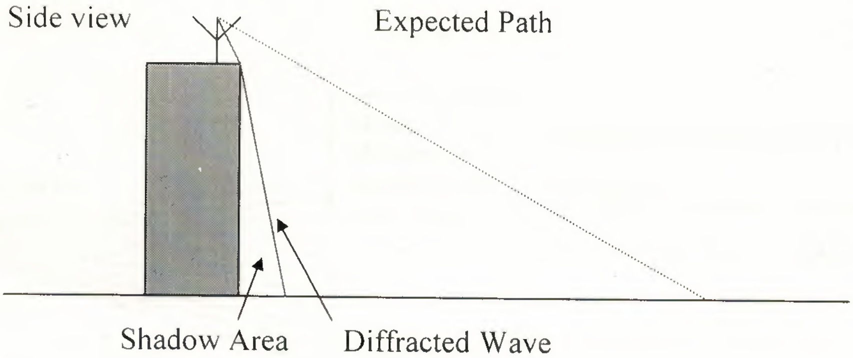


Figure 1.3 Diffraction (side view)

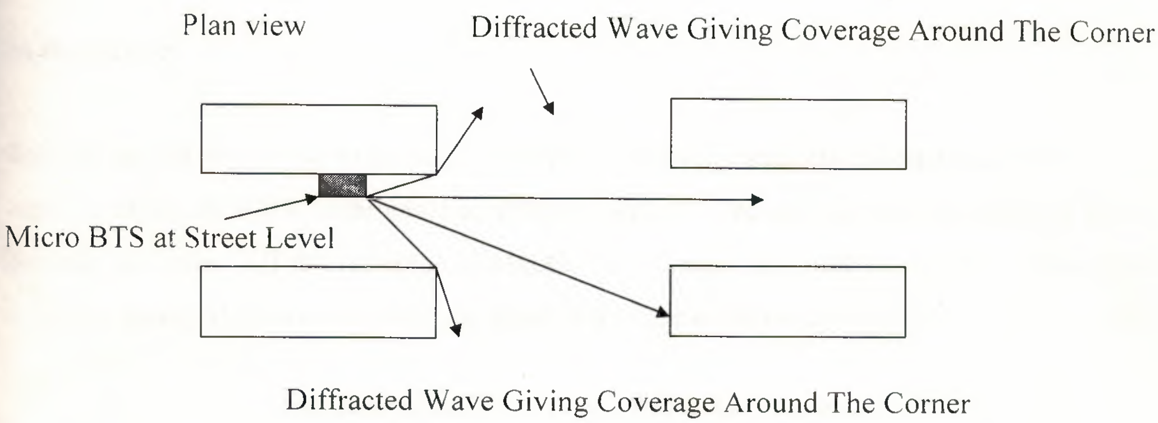


Figure 1.4 Diffraction (plan view)

b) Attenuation

This will be caused by any object obstructing the wave path causing absorption of the signal. The effects are quite significant at GSM frequencies but still depend on the type of materials and dimensions of the object in relation to the wavelength used. Buildings, trees and people will all cause the signal to be attenuated by varying degrees.

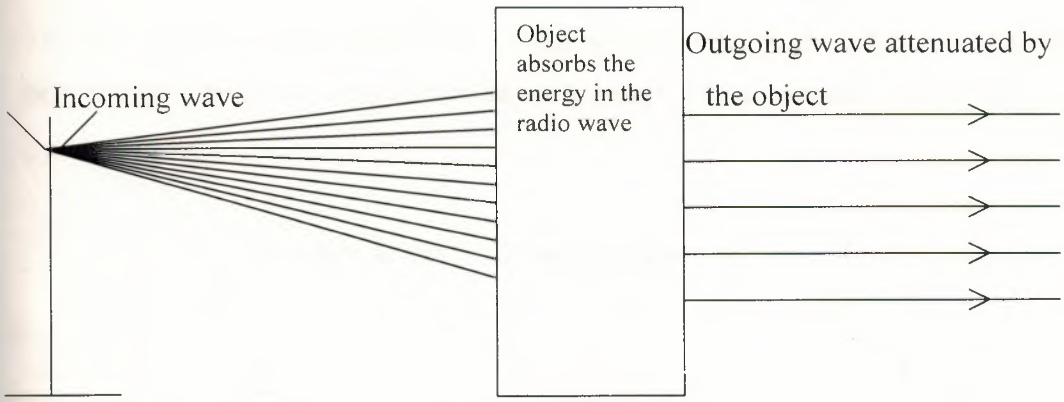


Figure 1.5 Attenuation

b) Reflection

This is caused when the radio wave strikes a relatively smooth conducting surface. The wave is reflected at the same angle at which it arrived. The strength of the reflected signal depends on how well the reflector conducts. The greater the conductivity the stronger the reflected wave. This explains why sea water is a better reflector than sand.

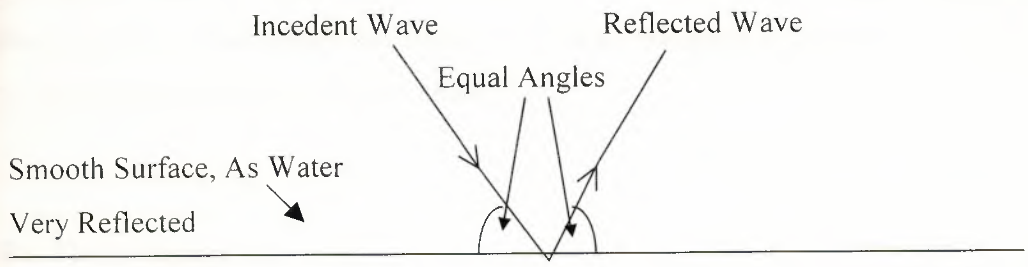


Figure 1.6 Reflection

d) Scattering

This occurs when a wave reflects of a rough surface. The rough surface and the relationship between the size of the objects and the wave length will determine the amount of scattering that occurs.

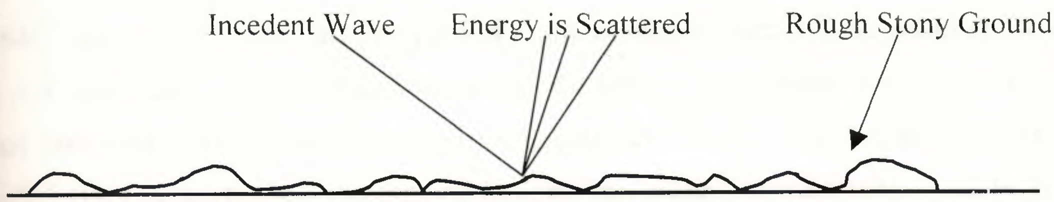


Figure 1.7 Scattering

e) Polarization Changes

This can happen any time with any of the above effects due to atmospheric conditions and geomagnetic effects such as the solar wind striking the Earths atmosphere. These polarisation changes mean that a signal may arrive at the receiver with a different polarisation than that which the antenna has been designed to accept. If this occurs the received signal will be greatly attenuated.

1.3.3 Plane Earth Loss

The free space loss as stated was based solely on a theoretical model and is of no use by itself when calculating the path loss in a multipath environment. To provide a more realistic model the earth in its role as a reflector of signals must be taken into account. When calculating the plane earth loss the model assumes that the signal arriving at the receiver consists of a direct path component and a reflective path component. Together these are often called the Space wave. The equation 1.7 for calculating the plane earth loss is

$$L = 20\log \frac{d^2}{h_1.h_2} \tag{1.7}$$

This takes into account the different antenna heights at the transmitter and receiver. Although this is still a simple representation of path loss. When this formula is used is implies the inverse fourth law as opposed to the inverse square law. So for every doubling of distance there is a 12dB loss instead of 6dB with the free space loss calculation. The final factors in path loss are the ground characteristics. These will increase the path loss even further depending on the type of terrain. The ground characteristics can be divided into three groups: Excellent ground. For example sea water, this provides the least attenuation so a lower path loss. Good ground. For example rich agricultural land, moist loamy lowland and forests. Poor ground. For example Industrial or urban areas, rocky land. These give the highest losses and are typically found when planning Urban cells.

Free Space Loss

Free Space Loss =32 +20 logd +20 logf

f= Frequency in MHz

d= Distance in km

Plane earth Path Loss (Lpe)=

Free Space Loss α $1/d^2$

Plane Earth Loss α $1/d^4$

$$L = 20\log \frac{d^2}{h_1.h_2} .\text{dBs} \tag{1.8}$$

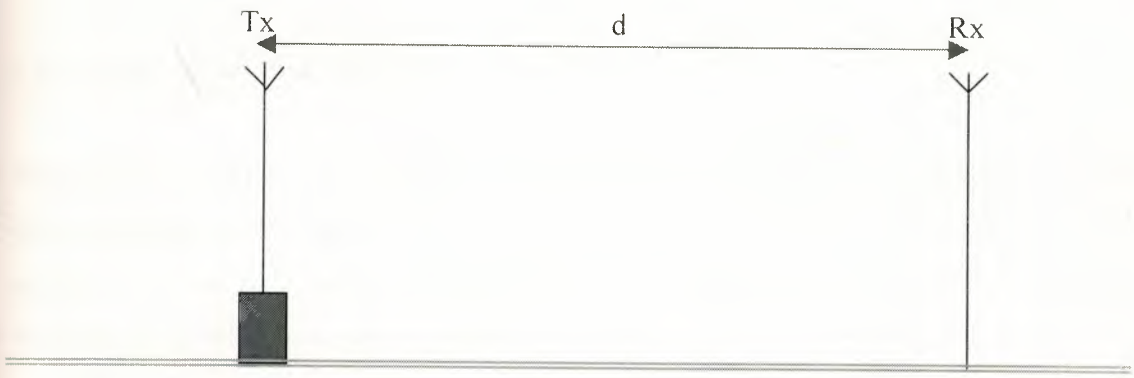


Figure 1.8 Path Loss Increases 6dB for a Doubling of d.

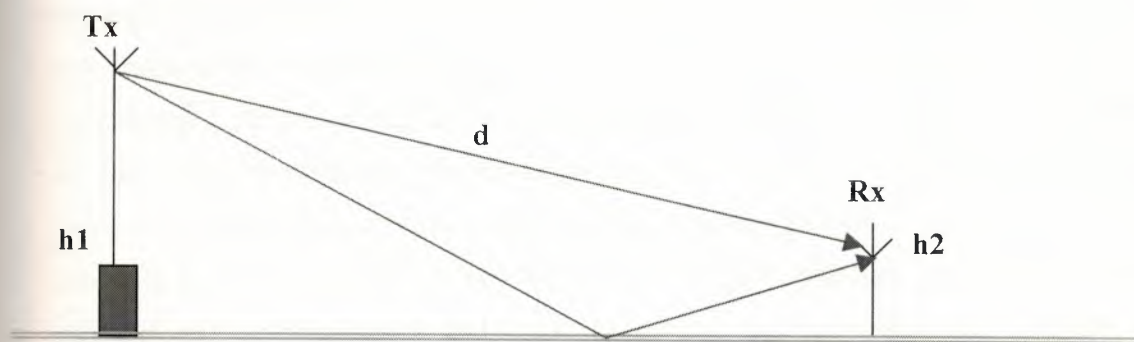
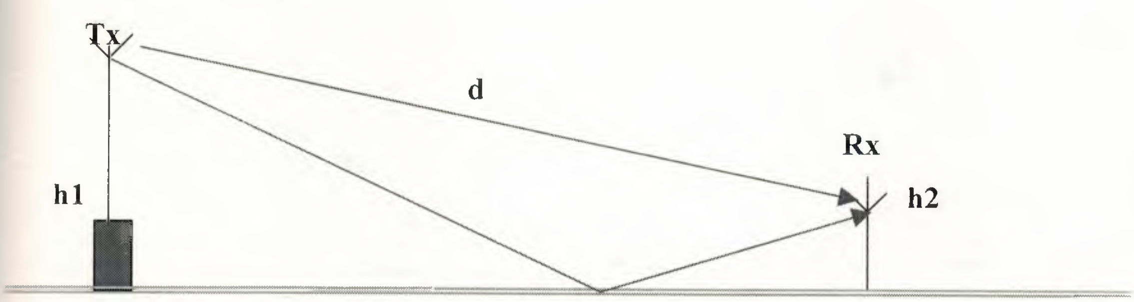


Figure 1.9 Plane Earth Loss Includes one Earth Reflector. Path Loss Increases 12dB for a doubling of d.



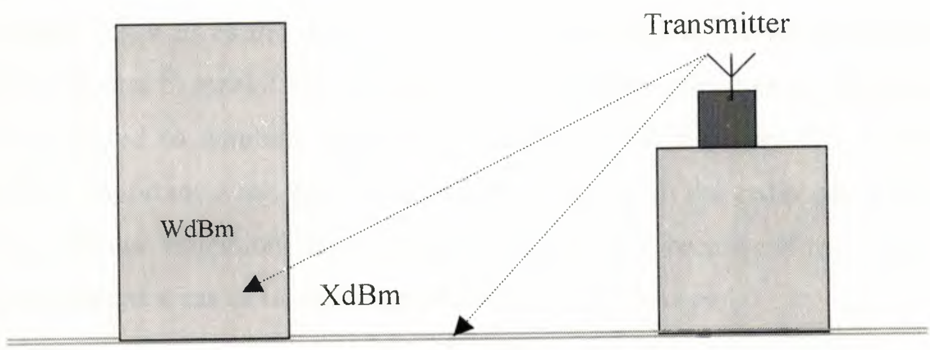
Plane earth + correction factor for type of terrain.

Path loss increases 12dB for a doubling of d+A factor for type of terrain.

Figure 1.10 Path Loss

1.3.4 Propagation in Buildings

With the increased use of hand portable equipment in mobile cellular systems combined with the increased availability of cordless telephones, it has become essential to study RF propagation into and within buildings. When calculating the propagation loss inside a building, a building loss factor is added to the RF path loss. This building loss factor is included in the model to account for the increase in attenuation of the received signal when the mobile is moved from outside to inside a building. This is fine if all users stood next to the walls of the building when making calls, but this does not happen, so the internal distance through which the signal must pass which has to be considered. Due to the internal construction of a building, the signal may suffer form spatial variations caused by the design of the interior of the building. The building loss tends to be defined as the difference in the median field intensity at the adjacent area just outside the building and the field intensity at a location on the main floor of the building. This location can be anywhere on the main floor. This produces a building median field intensity figure which is then used for plotting cell coverage areas and grade of service. When considering coverage in tall buildings, coverage is being considered throughout the building, if any floors of that building are above the height of the transmitting antenna a path gain will be experienced.



XdBm: Signal strengh outside building **Building insertion loss (dBm) =X-W=BdBm**

Figure 1.11.a Propagation in Buildings

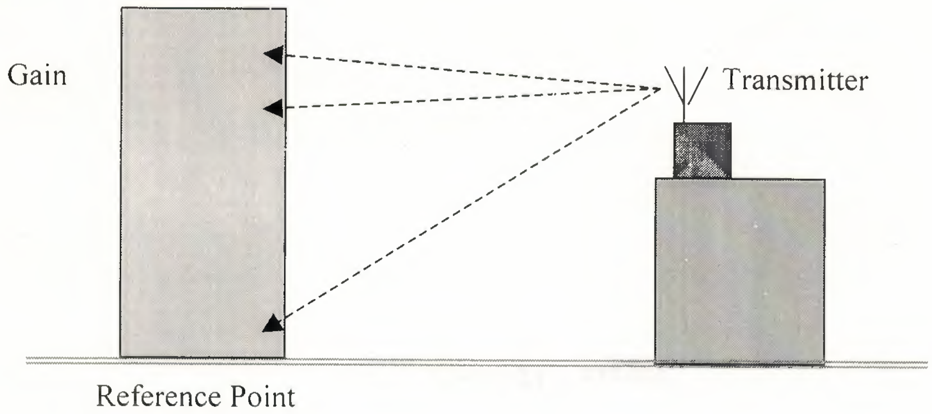


Figure 1.11.b Propagation in Buildings

1.3.5 Propagation Effects On GSM Frequencies

Frenzel Zone

The Frenzel Zone (pronounced frenzel) actually consists of several different zones, each one forming an ellipsoid around the major axis of the direct propagation path. Each zone describes a specific area depending on the wavelength of the signal frequency. If a signal from that zone is reflected of an obstacle which protrudes into the zone, it means that a reflected signal as well as the direct path signal will arrive at the receiver. Radio waves reflected in the first Frenzel Zone will arrive at the receiver out of phase with those taking the direct path and so combine destructively. This results in a very low received signal strength. It is important when planning a cell to consider all the radio paths for obstacles which may produce reflections from the first Frenzel zone because if they exist it is like planning permanent areas of no coverage in certain parts of the cell.

In order to calculate whether or not this condition exists the radius of the first Frenzel zone at the point where the object is suspected of intruding into the zone must be calculated. The equation 1.9 is as follows:

$$F_1 = \sqrt{\frac{d_1 . d_2 . \lambda}{d}} \qquad (1.9$$

Where d1 = Distance from tx antenna to the obstacle.

d2 = Distance from rx antenna to the obstacle.

λ = Wavelength of the carrier wave.

d = Total Path Length.

Once the cell coverage has been calculated the radio path can be checked for any objec intruding into the first Frenzel zone. Ideally the link should be planned for no intrusions b in some cases they are unavoidable. If that is the case then the next best clearance for t first Frenzel zone is 0.6 of the radius.

When siting a BTS on top of a building care must be taken with the positioning and heig of the antenna to ensure that the roof edge of the building does not intrude into the fi frenzel zone in figure 1.12 and with equation 1.9. Propagation effects on GSM Frequencie

Frequency = 900Mhz   Wavelength = 30cm

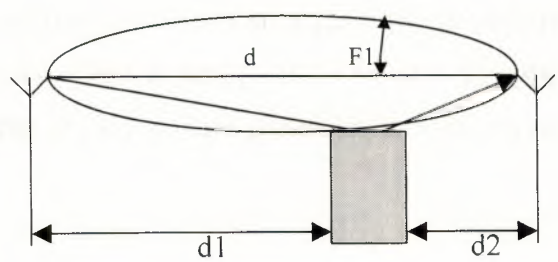


Figure 1.12 Frenzel Zone

1.3.6 Propagation-Rayleigh and Rician

As a result of the propagation effects on the transmitted signal the receiver will pick up the same signal which has been reflected from many different objects resulting in what is known as multipath reception. The signals arriving from the different paths will all have travelled different distances and will therefore arrive at the receiver at different times with different signal strengths. Because of the reception time difference the signals may or may not be in phase with each other. The result is that some will combine constructively, resulting in a gain of signal strength while others will combine destructively resulting in a loss of signal strength.

The receiving antenna does not have to be moved very far for the signal strength to vary by many tens of dBs. For GSM 900 a move of just 15cm or half a wavelength will suffice to observe a change in signal strength. This effect is known as multipath fading. It is typically experienced in urban areas where there are lots of buildings and the only signals received are from reflections and refractions of the original signal. This type of environment has been described by Rayleigh. He analysed the signal strength along a path with a moving receiver and plotted a graph of the typical signal strength measured due to multipath fading. The plot is specifically for non line of sight and is known as Rayleigh distribution. Where the signal path is predominantly line of sight with insignificant reflections of ref ractions arriving at the receiver, this is know as Rician distribution. There are still fades in signal strength but they rarely dip below the threshold below which they will not be processed by the receiver.

Fading

The largest traffic capacity requirements for a mobile system are generated in areas that can be classified as urban. This factor causes problems due to the fact that the antenna location can be below the height of the surrounding buildings (hence no line of sight) and possibly located in close proximity to these surrounding buildings. Therefore the propagation of the radio link between base site and mobile station tends to occur by means of scattering and multiple reflections from the surrounding buildings. This means that the RF signal arrives at the receiver via a multitude of paths so the RF signal at any one point in time may be high or low depending upon whether the various RF components combine constructively or destructively. When this occurs a multipath field is said to exist. The location of the receiving antenna does not have to change by much to alter the received RF signal by several tens of dB. This rapidly changing signal is basically a spatial phenomenon. When a receiver is mounted upon a vehicle and this vehicle is moving continuously through the field, the receiver not only experiences this spatial phenomenon but also experiences a time related variable signal which is created by the vehicles movement which causes a doppler shift. A convenient distinction is often made between the short-term multipath effects and the long-term variations of the median path loss. These RF signal fluctuations are known as fading. The rapid fluctuations caused by the multipath are known as fast fading. Whilst the much longer term fluctuation in the mean RF signal level received is known as slow fading. This latter effect is caused by movement over distances large enough to produce gross variations in the overall path between the base station and the mobile station.

1.3.7 Receive Signal Strength

A moving vehicle in an urban environment seldom has a direct lone-of-sight path to the base station. The propagation path contains may obstacles in the form of buildings, other structures and even other vehicles. Because there is no unique propagation path between transmitter and receiver, the instantaneous field strength that the mobile and base receivers sees exhibits a highly variable structure.

The received signal at the mobile is the net result of many waves that arrive via multiple paths formed by diffraction and scattering. The amplitudes, phase and angle of arrival of the waves are random and the short term statistics of the resultant signal envelope approximate a Rayleigh distribution.

This analysis of the multipath environment within an urban area leads to the conclusion that within the designated macro cell environment the signal amplitude emitted from the mobile exhibits fading with a Rayleigh distribution [8]. Should a micro cell be employed, where part of a cell coverage area be predominantly line of sight than Rician Distribution will be exhibited.

1.4 Summary

We discussed the GSM System Entities and specially discussed Radio Wave Propagation, Propagation in Buildings and Reflection, Diffraction, Effects of Urban and Rural Environments on Propagation.

Answer:

- We have to use suitable antenna types, output power of BTS and site location is very important for propagation.

2. CELLULAR CONCEPT

2.1 Over View

We will discussed cellular concept, umbrella cells, macro cells, micro cells, cell splitting, corporate cells, pico cells.

Question:

- Which type of cell is the best for Lefkoşa City Centre, why?

2.2 Cellular Principles

Cells can be called omni directional with equal coverage in all directions from the base station, or sectorised with the base station antennas pointing to different directions [1].

The major problems with radio distribution arise from electromagnetic wave propagation. The power of radio waves decreases with the inverse of the squared distance (d^{-2}); however, it must be remembered that this applies only in empty space. As a consequence, propagation at ground level in an urban environment with different obstacles is more difficult. A second problem is spectrum scarcity: the number of simultaneous radio communications supported by a base station is therefore limited.

Cellular coverage allows a high traffic density in a wide area despite both problems at the expense of infrastructure cost and of complexity. Because of the limited transmission range of the terminals, cellular system is based on a large number of receptions and transmission devices on the infrastructure side (the base stations), which are scattered over the area to cover a small geographical zone called a cell.

2.3 Umbrella Cells

A cell can be defined as an umbrella cell if the cell has a relatively large coverage area or the cell has a high traffic load, and inside the coverage area of the umbrella cell there are one or more cells.

When the cell-splitting technique was first applied, the operators realized that a freeway crossing within very small cells caused a large number of handovers among the different small cells. Since each handover requires additional work by the network, it is not particularly desirable to increase the number of such events. This is particularly true on European freeways, where the average speed is very high. The time a mobile on such a European freeway would stay in one cell decreases with increasing speed. Umbrella cells were introduced. Figure 2.1 to address this problem. In an umbrella cell, power is transmitted at a higher power level than it is within the underlying microcells and at a different frequency. This means that when a mobile that is travelling at a high speed is detected as a fast mover, it can be handed off to the umbrella cell rather than tie up the network with a fast series of handoffs. Such a mobile can be detected from its propagation characteristics or distinguished by its excessive handoff demans. In this cell, the mobile can stay for a longer period of time, thus reducing the workload for network.

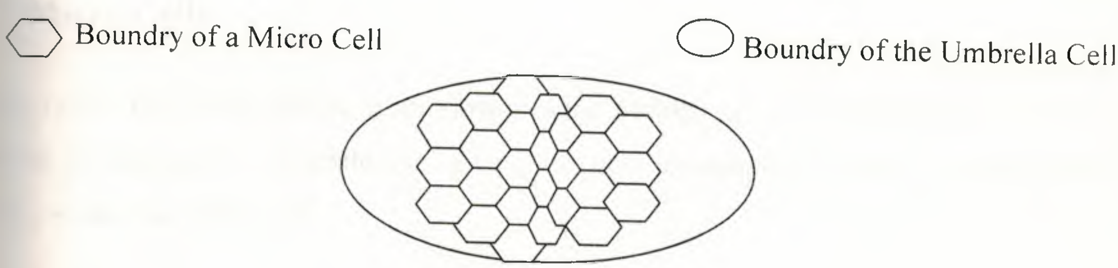


Figure 2.1 Umbrella Cells

2.4 Macro Cells

Implemented specifically to cater for the fast moving Mobile Subscribers and to provide a fall-back service in the case of coverage holes and pockets of interference in the micro cell layer. Macro cells form an umbrella over the smaller micro cells.

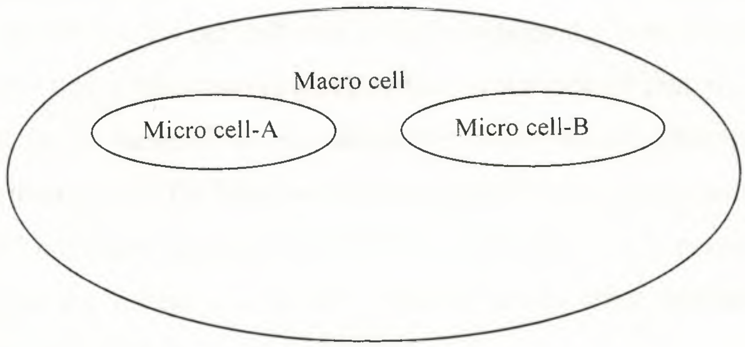


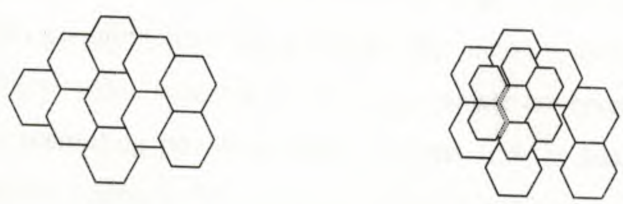
Figure 2.2 Micro Cells and Macro Cells

2.5 Micro Cells

Micro cells handle the traffic from slow-moving mobile subscribers. The micro cells, as shown in the diagram opposite, can give contiguous coverage over the required areas of heavy subscriber traffic [9].

2.6 Cell Splitting

As the number of subscribers grew larger, the density within these networks also became higher. The operators and radio engineers had to look for new capacity funds. A rather basic idea was to split the existing space into smaller portions, thus multiplying the number of channels available. A long with this simple scheme, the power levels used in these cells decreased, making it possible to reduce the size of reduce the size of batteries required for mobile stations. With the decreased power required for mobiles came decreased size and weight. This made the networks more attractive to new users. As the traffic within a particular cell increases, the cell is split into smaller cells. This is done in such a way that cell areas, or the individual component coverage areas of the cellular system, are further divided to yield yet more cell areas. The splitting of cell areas by adding new cells provides for an increasing amount of channel reuse and, hence, increasing subscriber serving capacity. Decreasing cell radii imply that cell boundaries will be crossed more often. This will result in more handoffs per call and a higher processing load for subscriber. Simple calculations show that a reduction in a cell radius by a factor of four will produce about a tenfold increase in the handoff rate per subscriber. Since the call processing load tends to increase geometrically with the increase in the number of subscribers, with cell splitting the handoff rate will increase exponentially. Therefore, it is essential to perform a cost –benefit study to compare the overal cost of cell splitting versus other available alternatives to handle increased traffic load.



Groving by Splitting Cell 4 into Cells of Small Size

Figure 2.3 Cell splitting

2.7 Corporate Cells

Corporate cell is a special cell intended to offer an extensive coverage inside a company's building. Normally it is a picocell including an antenna network. Depending on the billing system and possible IN features in the switch, phone calls made by company's phones inside the building are cheaper than the normal tariff. In that case the coverage of the corporate cell should be everywhere inside the building better than the service of the neighbouring base stations. It is impossible to guarantee that the calls will always be done using the corporate cell since in case of congestion, for example, the call can be rerouted to another cell. Therefore it is very important to monitor the traffic load in the corporate cell.

2.8 Pico Cells

Typical service areas where mobile phones are expected to operate are office buildings, parking garages, shopping centres, subway stations, department stores, factories and housing areas. Depending on the situations, the cells and antennas can be installed indoors. This is what is called a picocell. The indoor coverage requirements must be taken into consideration when planning coverage outdoors. By selecting an appropriate site for a cell outdoors, it may be possible to use it to provide adequate coverage for indoor office areas. The typical cell transmitting power is below 2 watts and the base station equipment and antennas are installed indoors. The coverage area radius varies from 10 to 100 meters, providing coverage for several floors of the building.

2.9 Summary

We discussed cellular concept, umbrella cells, macro cells, micro cells, cell splitting, corporate cells, pico cells.

Answer:

- Macro cell is the best type of cell for Lefkoşa City Centre. Because, too many buildings in City Centre and population is high. So, we need high capacity and good signal level in building.

3. BASE STATIONS AND RADIO INTERFACE

3.1 Over View

We will discuss in this chapter about base stations and radio interfaces, control cahannels, handover types, RF control strategy, radio channels and structure of the GSM Radio interface, timing advanced and frame structure, GSM Radio interface, radio frequency channels and bands for GSM, base station antennas, down tilting, diversity, power splitter, antenna configurations.

3.2 Base Transceiver Station (BTS)

A base station is normally understood as the whole station, i.e. it includes all necessary equipment and antenna installations. A Base Transceiver Station (BTS) is the base station device. A site is the location and equipment room, where the base station is placed. One site includes normally 1-3 BTSs. A cell is the service area covered with one BTS. One BTS has normally 1-6 Transceiver Units (TRX). If sectorised cells are used, we can get better coverage in the main beam direction and more capacity than by using omni directional antennas. The more the antenna directs the signal to a narrow sector, the more gain we can get to the main beam direction. Network capacity can be increased by using sectorised cells since the same frequency can be re-used closer and more often than with omni antennas as the radiation pattern of directed antennas in the back beam direction is remarkably reduced.

There are currently two main types of base station equipment racks: racks wired for Omni cell BTS only and racks for 1, 2 or even 3 sectorised cells. It is not practical to re-wire Omni cell racks to sectorised racks. The BTSs can be configured in many different ways. Nowadays a full-size sectorised rack can include up to six TRXs which can be configured for example in three cells with 2+2+2 TRXs, or for two cells, with 3+3 TRXs with an extension rack the capacity can be extended beyond six TRXs. Normal base station equipment racks are about *1,5* m high. The weight is typically approximately 150 kg. There

are also so called outdoor cabinets available which can be installed on a rooftop or on the ground. The latest technology offers integrated, very small, low-power mini base stations, that can be mounted on walls or poles together with e.g. radio minilinks. The maximum number of TRXs in the mini BTS is typically two and the size is about the same as a normal TV-set. The latest base station models are micro BTSs, only 50 cm x 30 cm x 20 cm in size and the weight is less than 20 kg. The capacity so far is only one TRX, however.
A problem with mini or micro BTSs is the capacity limitation. If more TRXs are needed it is normally possible to chain two BTSs to work as one BTS serving with double capacity. The price of this kind of solution is high.

3.3 Control Channels

In GSM 900 system one physical radio channel is divided into eight time slots. Each time slot has one or more logical channels which can be traffic or control channels. There are different types of control channels used.

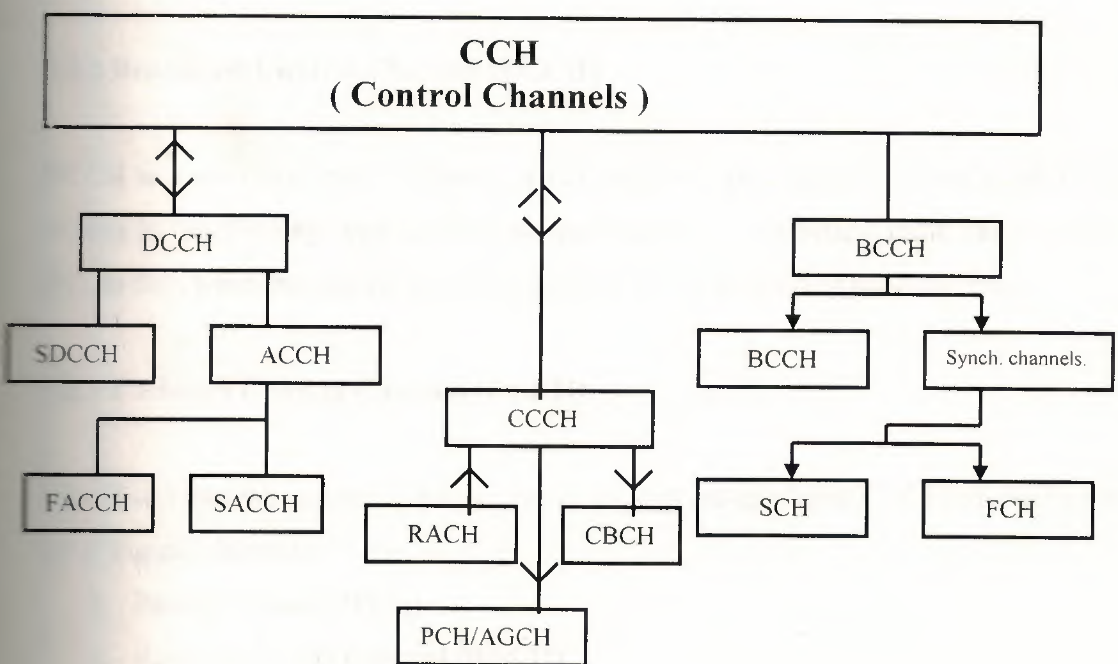


Figure 3.1 Control Channels

3.3.1 Dedicated control channels (DCCH)

Dedicated control channels are used to both directions and it is allocated for one user at once. This channel has signalling for call set-up, maintain, and call release. There are three types of dedicated control channels:

1. Stand Alone dedicated Control Channel (SDCCH)
2. Slow Associated Control Channel (SACCH)
3. Fast Associated Control Channel (FACCH)

SDCCH channel is used only for call set-up. At least one time slot must be allocated for SDCCH channel. This time slot can not be used as a speech channel.

SACCH channel transfers call related information during the call, for example power control commands and measurement results to the base station. SACCH locates on a traffic channel time slot.

FACCH channel is used to transfer information that can not be transferred on the SACCH channel. This channel locates on a traffic channel, as well.

3.3.2 Broadcast Control Channel (BCCH)

BCCH is a one-way control channel which end cell specific information to all the mobile phones in the coverage area. Mobile phones measure that physical radio channel that sends BCCH data when measuring signal strength of the neighbouring base stations.

3.3.3 Common Control Channel (CCCH)

CCCH is a two-way channel that is used in the call set-up phase. CCCH channel consists of three logical channels.

1. Paging Channel (PCH)
2. Random Access Channel (RACH)
3. Access Grant Channel (AGCH)

Paging channel is used to when someone tries to call to a mobile phone.

Random access channel is used when the mobile phone sends the first burst to the base station.

Access grant channel is used to allocate a traffic channel to a mobile phone that has responded on the RACH channel.

3.4 Location Area

The location of a mobile phone is known within an accuracy of a location area (LAC). When a call is coming to a mobile phone the call is sent through all the base stations locating in one location area. When a mobile phone moves to another location area. the phone makes a location update. Typically each BSC has its own location area. This is, however, not necessary. Several BSC areas can form one LAC. When planning location areas, it is important to know that location update causes signalling traffic, which can lead to SDDCH congestion if a LAC border situates in a place where there is a heavy traffic. During the location area change there is a short time period, during which the phone is not connected to the network for a short time. At this time the incoming calls go to the voice mail or to an announcement machine. If the location area is too big, pagings to the mobile phones cause too much load to the system.

3.5 Cell Selection

In idle state and in the beginning of call set-up mobile phone selects the base station offering the strongest signal. With rxLevAccessMin parameter we define the minimum signal level that the phone must receive from the base station before the phone can lock to the cell in question.

3.6 Handover

The handover decisions made by the BSC are based on the measurement results reported by the MS/BTS and various parameters set for each cell. The parameters control the handover in the BSC. By changing the values of the parameters it is possible to affect the handover decisions at all stages of the procedure: measurement processing, threshold comparison and decision algorithm [5]. All parameters are administered on a cell-by-cell basis by means of the O&M; that is, by using the local MMI in the BSC site or the Operation and Maintenance Centre (OMC).

3.6.1 Handover Types

The possible types of handover are the following:

1. Intra-BTS handover
2. Intra-BSC handover;
3. Inter-BSC (MSC) handover.

The handover may take place during a call from a traffic channel (TCH) to a traffic channel. An intra-BTS handover can take place either to a radio timeslot on a new carrier or to a different timeslot on the same carrier. A handover may also take place from a dedicated control channel (DCCH) to a dedicated control channel during the initial signalling period of call set-up. The parameter Enable Sdcch HO indicates whether the handover from a DCCH to a DCCH is enabled. As far as the. algorithm is concerned, the handover from a DCCH to a DCCH does not differ from the handover from a TCH to a TCH. During the call set-up phase in situations of congestion (Directed Retry Procedure) a handover can take place from a dedicated control channel (DCCH) of the serving cell to a traffic channel of an adjacent cell.

3.6.2 Handover Causes

A handover is normally caused by radio criteria, but the handover algorithm present is also able to perform handovers caused by four other reasons:

1. Due to congestion in the call set-up phase, a handover from a DCCH of the serving cell to a traffic channel (TCH) of an adjacent cell, that is, Directed Retry Procedure (DRP).
2. The MSC requests the BSC to perform a specified number of handovers from one specified cell to other specified cells, that is, Traffic Reason Handover (TRH).
4. BSC internal traffic control (for example, a handover from an umbrella cell to a microcell).
5. An order from the channel administration to empty the cell by means of the handover procedure (for example, because of changes in the radio network configuration).

The BSC uses different handover decision algorithms for handovers caused by normal radio criteria and handovers caused by other reasons than radio criteria. When an MS moves from one cell coverage area to another, the radio link measurements show low signal level (RXLEV) and/or quality (RXQUAL) on the current serving cell and a better RXLEV available from a neighbouring cell, or the neighbouring cell allows communication with a lower RF power level. The crucial principle for the BSC selecting the target cells for the handover caused by radio criteria is that the neighbouring cell must be better than the current serving cell in order for the handover to be useful. If the handover is caused by other reasons than radio criteria, it is not necessary for the target cell to be better than the serving cell. It suffices that the target cell serves the call well enough; for example, a handover from an umbrella cell to a microcell is performed whenever the call can be maintained on the neighbouring microcell.

Target Cell Evaluation

The evaluation on the preferred list of the target cells is based on:

1. The radio link measurements
2. The priority levels of the neighbouring cells;
3. The load of the neighbouring cells which belong to the local BSS.

First the BSC defines and selects those cells which meet the requirements for the radio link properties, and then it ranks the cells according to the priority levels and the load of the neighbouring cells with the exceptions of the imperative handover procedure and the traffic reason handover procedure when the BSC rinks the cells only according to radio link properties.

3.6.3 RF Power Control Strategy

The RF power control strategy employed by the BSC defines the RF power command that is signalled to the MS, and the RF power level that is used by the BTS. The RF power control optimises the RF output power of the MS and the BTS and simultaneously ensures that the signal level required at the BTS/MS is sufficient to maintain adequate speech/data quality. The RF power level to be employed in each case is based on the measurement results reported by the MS/BTS and on the various parameters set for each cell. All parameters controlling the power control procedure are administered on a cell-by-cell basis by means of the O&M. By changing the values of the parameters, it is possible to affect the RF power control at all stages of the procedure [4].

3.6.4 Interdependence of HO and PC

The Power Control (PC), for both the BTS and the MS, runs independently in parallel with the handover, but in such a way that the power control knows the status of the handover and vice versa, that is, the BSC does not try to adjust the MS/BTS power level in the current serving cell and execute a handover to a neighbouring cell simultaneously. The BSC determines which RF power level the mobile station that has been handed over will use as the initial RF power in the target cell. The default initial RF power level is the maximum RF power that an MS is permitted to use on a traffic channel in the target cell but, in the case of an intra-BSC handover, the PC/HO algorithm is also able to optimise the optimal RF power level so that the RF power level is lower if the radio link properties of the target cell are good.

Optimisation of the MS power level in a handover cuts down the probability of high RF power peaks in the uplink after HOs. This way it reduces the uplink interference in the radio network. This property is controlled by the parameter MsPwrOptLevel, which is set independently for each adjacent cell by means of the O&M. Optimisation of the MS power level in a handover is an optional feature.

With a proper choice of the PC and HO thresholds, the BSC maintains call quality by means of power control, and proposes handover only when the MS actually reaches the border of the serving cell. If both the HO and PC threshold conditions are fulfilled, the handover has greater priority than the power control. If the handover cannot be performed, power increase may be used as first aid.

[illegible] Umbrella Handover

A cell can be defined as an umbrella cell if the cell has a relatively large coverage area or the cell has a high traffic load, and inside the coverage area of the umbrella cell there are one or more cells. Since the umbrella cell offers often the best coverage, the phone calls tend to begin in that cell. However, if the cell is defined to work as an umbrella cell, BSC checks if any of the neighbours to which an umbrella handover is allowed to be done, has a sufficient signal strength level. The level can be lower than the signal from the umbrella cell, but if the underlying cell provides a signal which is good enough for a good quality connection, an umbrella handover will be executed. In this way we can transfer traffic from one dominating cell to surrounding ones.

3.6.6 Handover Priority

If two or more criteria for a handover (HO) are present simultaneously, the priority order is the following:

1. HO: Uplink quality,
2. HO: Downlink quality,
3. HO: Uplink level,
4. HO: Downlink level,
5. HO: MS-BTS distance,
6. HO: Better cell (PBGT or Umbrella),
7. PC: lower thresholds (uplink and downlink as well as quality and level),
8. PC: upper thresholds (uplink and downlink as well as quality and level).

3.7 Timing Advanced and Frame Structure

3.7.1 Timing Advanced and Power Control

To simplify the design of the mobile, the GSM Recommendations specify an offset of three time slots between the BSS and MS timing thus avoiding the necessity for the mobile to transmit and receive simultaneously. The facing diagram illustrates this.

However, the synchronisation of a TDMA system is critical because bursts have to be transmitted and received within the "real time" time slots allotted to them. The further the mobile is from the base station then, obviously, the longer it will take for the bursts to travel the distance between them. The GSM base station caters for this problem by instructing the MS to advance its timing (i.e. transmit earlier) to compensate for the increased propagation delay.

This advance is then superimposed upon the 3 time slot nominal offset, as shown figure 3.2

"Power Control" is an optional feature of the GSM air interface which allows the operator to not only compensate for the distance from mobile to base station as regards timing, but can also cause the base station and mobile to adjust their power output to take account of that distance. The closer the mobile is to the base station, the less the power it and the base station will be required to transmit [13]. This feature saves radio battery power at the mobile, and helps to reduce co-channel and adjacent channel interference.

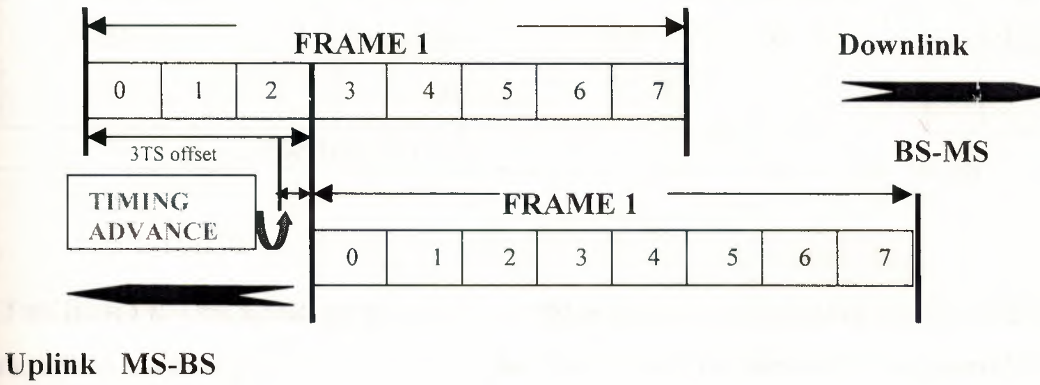


Figure 3.2 Timing Advanced

3.7.2 Frame Structure

Burst

The diagram shows the five types of burst employed in the GSM air interface and shows that all bursts, of whatever type, have to be timed so that they are received within the appropriate time slot of the TDMA frame. The "burst" is the sequence of bits transmitted by the base station or mobile the "time slot" is the discrete period of real time within which it must arrive in order to be correctly decoded by the receiver.

1. Normal Burst: The normal burst carries traffic channels (both voice and data) and all types of control channels. It is bi-directional. A normal burst is the most common burst in the GSM system and is transmitted in one time slot either from the base station or from the mobile station. There are eight time slots in a TDMA frame. The actual user data occupy only a portion of the time slot, and the remainder of the bits are reserved for a host of control functions and some demodulating aids. Shown in Table 3.1.

Table 3.1 Structure of a Normal Burst.

T	Coded Data	S	Training Sequence	S	Coded Data	T	GP
3	57	1	26	1	57	3	8.25

148 Bit =546.12μs

a) Tail Bits(T): This small group consists of three bits at the beginning and the end of each burst and is used as guard time. The tail bit time covers the periods of uncertainly during the ramping up and down of the power bursts from the mobile in accordance with the power versus time template shown. The tail bits are always set to zero. Coincidentally, the demodulation process requires some initial zero bit values.

b) Coded Data: These two times, of 57 bits each, contain the actual transmitted signaling data, or user data. Included and mixed in with the user's payload data are channel coding bits , which are used in the receiver to help recover the original data. For now, you should think of the coding bits as packing material that protects the freight [15]. Large parts of the remainder of this chapter explain channel coding, or data protection.

c) Stealing Flag (s): These two bits are an indication to the decoder (in the receiver) of whether the incoming burst is carrying signalling data, which are usually messages the radios use to maintain the link between themselves, or whether the burst is carrying user data. The indicating flag is needed because signalling data are very important and go to different places than user data go. Another word for user data is traffic.

d) Training Sequence: This is a fixed bit sequence known to both the mobile and the base station, which lets radios syncronize their receivers with the burst. Syncronization lets receivers interpret the recovered data correctly. It might not be fully clear why this bit pattern is required, since all the timing seems to be well defined so far. The reason the include the training sequence in each normal burst is to compensate for the effects of multipath fading [7]. We learned a little about multipath and its destructive influence on TDMA systems.

e) **Guard Period (GP):** It probably seems odd to specify fractions of a bit, so instead it should be considered as a defined time, rather than as actual data bits. No data are transmitted during the guard period, which is reserved for the ramping time. Taking the bit length defined in the system as 3.69μs/bit, the guard period can be calculated as 8.25 bits. 3.69μs/bit = 30.4 μs, which is appoximately the time used during power ramping. During this time, two consecutive bursts from two mobiles may overlap (i.e, the previous burst ramps down and the current burst ramps up) [2]. No data are transmitted during the ramp time (GP), and communication is not disturbed while radios are ramping their RF power outputs.

2. Frequency Correction Burst: This burst carries FCCH downlink to correct the frequency of the mobile's local oscillator, effectively locking it to that of the base station. Since timing is a critical need in the system, the base station has to provide the means for a mobile station to synchronize with the master frequency of the system. To achive this, the base station transmits, during the certain known intervals, a pure sine wave signal for the period of exactly one time slot. What a comfort this must be for the mobile. Due to the nature of the type of modulation used in GSM, this can be accomplished by simply sending a fixed sequence of zeros (000...) in the time slot.

3. Synchronisation Burst: So called because its function is to carry SCH downlink, synchronising the timing of the mobile to that of the base station. When a mobile station starts to synchronize with the network, it first looks for and detects only the frequency where the base channel is located. The mobile does not yet have a key with which to demodulate and decode the information provided in the forward base channel, which is information that contains some valuable system parameters. As was explained previously, the key is one of the eight defined training sequences.

Table 3.2 Structure of the Frequency Correction Burst.

T	**Fixed bit sequnce**	**T**	**GP**
3	**142**	**3**	**8.25**

148 Bit = 546μs

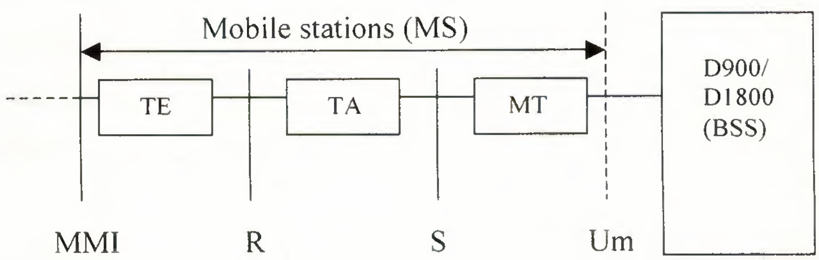
4. Dummy Burst: Timeslot 0 of the BCCH carrier will always contain control channel information but depending on configuration the remaining seven timeslots may be used to support additional control channel information or a traffic channel. If any of the remaining seven timeslots are idle then Dummy bursts must be inserted as all eight timeslots on the BCCH carrier must always be active.

5. Access Burst: This burst is of much shorter duration than the other types. The increased guard period is necessary because the timing of its transmission is unknown this is due to the unknown quantity of the mobile's location and the lack of timing advance information at this point during the call set up process.

3.8 GSM Radio Interface

The GSM radio interface Um is required for supporting universal use of any compatible mobile station (MS) in any GSM compatible PLMN.

Figure 3.3 shows the reference configuration according to GSM specifications at the radio interface Um [3]. The reference configuration for a mobile station shows the reference points (R;S) of interfaces (MMI,Um) and function groups (TE ,TA , MT).



R, S Reference points

Um Radio interface

TE Terminal adapter

MT Mobile termination

MMI Man Machine Interface (user interface)

Figure 3.3 Reference Configuration at the GSM Radio Interface.

3.8.1 Interface Functions

The following functions are executed by the mobile termination (MT):

terminal capabilities.

Provision of the MMI (for subscriber controlled input, SCI)

Radio link termination

Channel adaption and user data rate adaption

Channel management

Flow control of signalling and user data

User data encryption

Mobility management

Error protection

The following functions are executed by D900/D1800 (BSS): data link layer functions for signalling over the radio link.

Call setup functions between MS and BSS

Radio Link Termination

User Data Rate Adaption

Radio Link Management

Speech Transcoding

Handover Functions

Error Protection

3.8.2 Structure of the GSM Radio Interface

PLMNs use the Frequency Division Multiple Access (FDMA) procedure in which each traffic channel or control channel is assigned a Radio Frequency Channel (RFCH). The radio frequency channels are separated from one another by analog filters. D900/D1800 operates with a combination of FDMA and Time Division Multiple Access (TDMA) with eight time division traffic channels or control channels transmitted over one radio frequency channel. This means that one transmitter and one receiver support 8 physical traffic channel pairs in the case of half rate channels. This reduces the space and energy requirements in the base transceiver stations (BTS) compared with analog radio networks. A physical traffic channel is defined by the frequency range of an RFCH pair and a time slot in the TDMA frame.

3.8.3 Radio Frequency Channels and Bands For D900

According to the GSM standards the Um interface is used between the BTS antenna and the MS. The D900 provides the GSM primary band (890-915 MHz for uplink, 935-960 MHz for downlink) as well as the GSM extended band (880-915 MHz for uplink, 925-960 MHz for downlink). With FDMA 124 (174 for extended band) discrete duplex radio frequency channels are available: 124 (174) downlink channels for transmission from the MS to the BSS and 124 (174) downlink channels for transmission from the BSS to the MS. With TDMA the number of channels is increased by a factor of 8 to 992 (1392 for GSM extended band) physical duplex traffic channels in the case of full rate channels [9]. With pure half rate operation, twice the number of physical duplex traffic channels available for a TDMA system. With dual rate operation (full rate and half rate), a value which is practically between a pure full rate and a pure half rate operation is produced for a TDMA system. The specifications of the radio frequency bands are as follows:

GSM primary band (P-GSM 900)

- Carrier frequencies of the BSS receivers (uplink): fup(n) = (890+0,2xn) MHz

with Absolute Radio Frequency Channel, ARFCN 1<=n<=124)

- Carrier frequencies of the BSS transmitters (downlink): Fdown (n)=fup(n)+45MHz

Radio frequency channel spacing: 200 kHz

Duplex spacing: 45 MHz

- GSM extended band (E-GSM 900)

Carrier frequencies of the BSS receivers (uplink):

Fup(n)=(890+0.2 x n)MHz+

with ARFCN 0<=n<124)

[890+0.2 x (n-1024)] MHz

with ARFCN $975 <= n <= 1023$)

- Carrier frequencies of the BSS transmitters (downlink):

$f_{down}(n) = f_{up}(n) + 45$ MHz

Radio frequency channel spacing: 200 kHz

Duplex spacing: 45 MHz

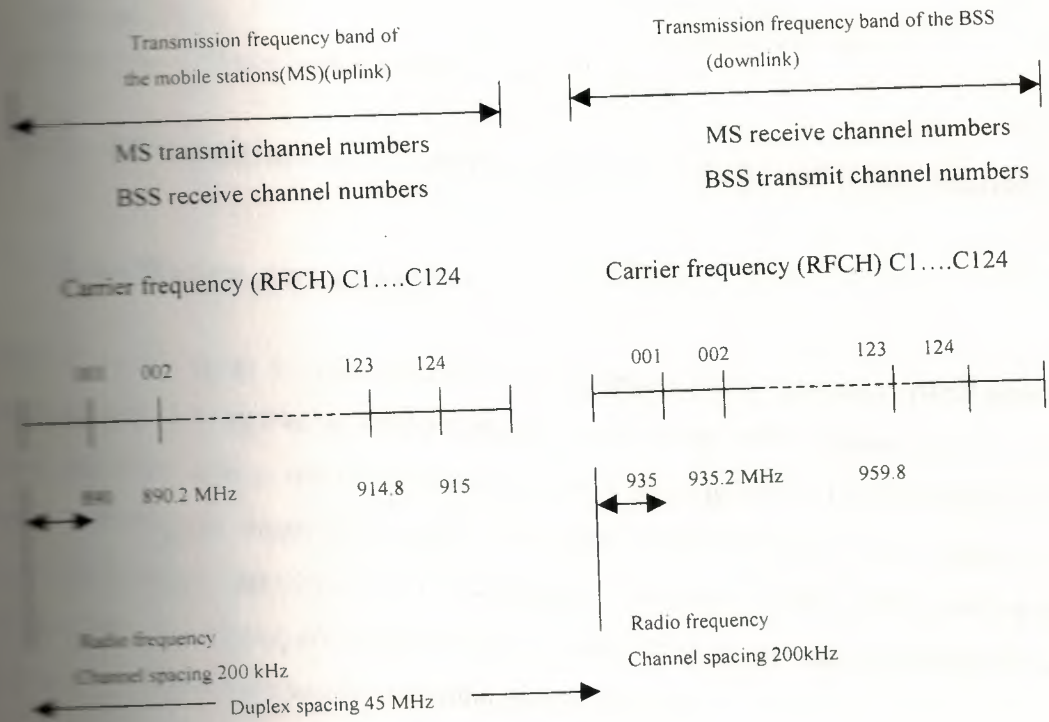
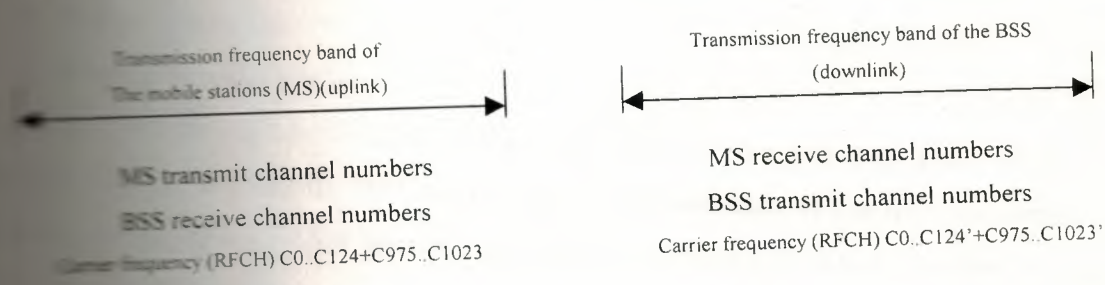


Figure 3.4 Radio Frequency Channel Distribution For D900 BSS (GSM Primary Band)



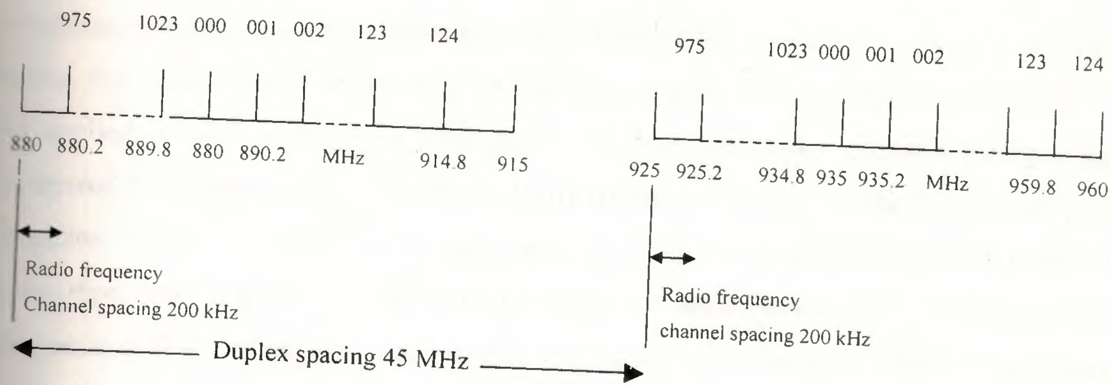


Figure 3.5 Radio Frequency Channel Distribution For D900 BSS (GSM Extended Band)

3.9 Base Station Antennas

There is a wide range of base station antenna types available. Nowadays panel antennas are most popular. The size of an antenna increases according to the antenna gain. In city areas especially, the physical size of an antenna can be a limiting factor. For GSM 900 the largest panel antennas are about 2,5m high fibre-glass covered boxes. In city areas diversity improves receiver sensitivity and interference tolerance. If only one antenna can be installed, the transmitter and receiver can be connected to one single antenna by using a duplex filter. The most important antenna parameters are:

1. Horizontal beam width
2. Vertical beam width
3. Antenna gain
4. Front to back ratio
5. Side lobe characteristics

Horizontal -3dB beam width (lobe) defines the width of the coverage area. Normally, antennas with 60, 90, 120. or 360° (omni) beam width are used. It has to be remembered that the coverage area of a cell does not end at the -3 dB point, it describes rather the area with a maximum coverage.

Vertical beam width depends on the gain of the antenna. The greater the gain, the narrower the vertical beam. In a cells with relatively low antenna height (<100 m) compared to the area altitude to be covered this is not a problem. But, if the antennas are on a top of a mountain, the radiation of the antenna may go beyond the area to be covered. If such a risk exists, the vertical beam width must be considered. Electrical or mechanical down tilt can be applied in such a case. Antenna gain describes how many decibels stronger signal compared to a dipole (dBd) or isotropic (dBi) antenna is radiated to the main beam (-3 dB) direction. 0 dBd =2.1 dBi. Front to back ratio describes the gain between the main and back beam directions. A great (> 25 dB) value is desired. Also important is the front/back ratio of the antenna. It describes how many decibels difference is in the gain between the directions 0° & 180°. The greater the separation, the better the antenna is since back beam radiation is normally not a desired phenomenon.

There are different ways to install the base station antennas. Typically antennas are installed on a mast, rooftop or on a wall. Figure 3.6 shows typical antenna installation configurations. Configuration B is the best solution because sufficient attenuation between the Transmitter (TX) and Receiver (RX) antennas is guaranteed. In configuration A there may be a small risk that the TX signal leaks to the RX antennas. This configuration can be used if the horizontal beam width of the antennas is < 12O°. If diversity is not necessary or possible, installation according to configuration C is recommended. When a place for two antennas is available as in configuration D, it is possible, by using a duplex filter to connect one antenna both for transmitting and receiving and the second antenna is used for diversity. If only a very limited space is available, installation E can be used. In this case diversity is not possible.

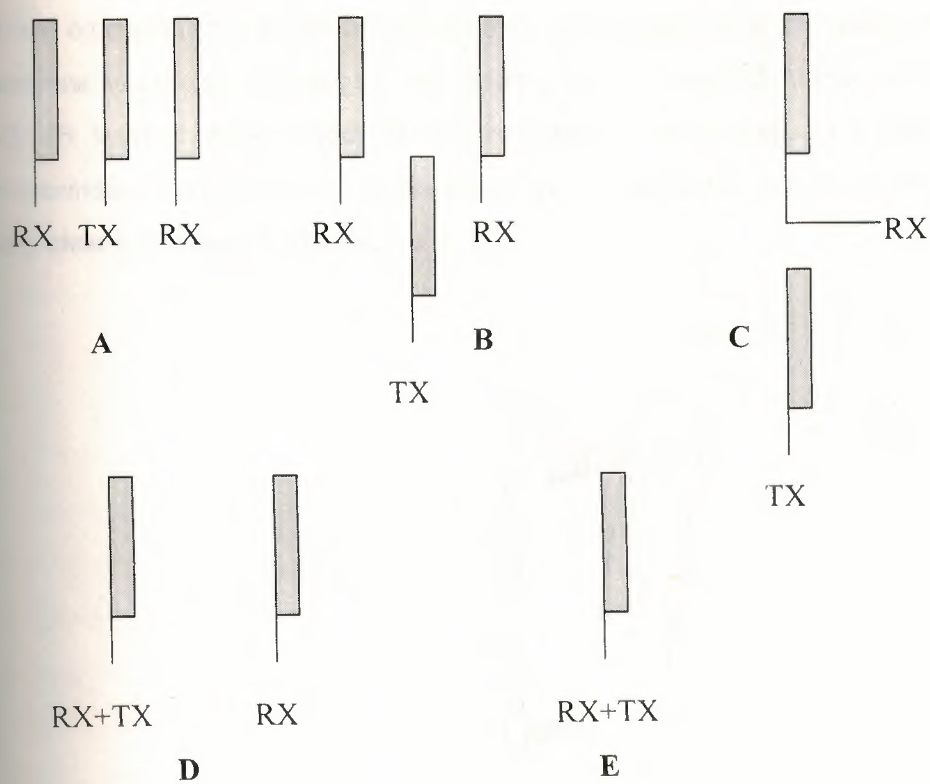


Figure 3.6 Different Antenna Installation Configuration.

3.9.1 Down Tilting

By down tilting a base station antenna coverage and interference area can be reduced. In addition to that, field strength increases near the antenna. For example, when the cell size has to be reduced and new cells will be built around the existing one, down tilting may be a suitable solution. Also, for totally new cells, if the antennas must be installed in a position which would offer too large coverage area, down tilting can be useful.

Antenna can be tilted either mechanically or electrically. Special mounting brackets are needed for mechanical down tilting. This should be noticed when planning the antenna installation. An advantage of electrical down tilting is that also the back lobe and side lobes are down tilted. In mechanical down tilting the back lobe will be up tilted. By up tilting an electrically down tilted antenna the same amount as the tilt angle, back beam will be down tilted considerably. The advantage of down tilting depends on the vertical beam width of the antenna and the surroundings of the antenna. The tilt angle should be at least as great as the -3 dB vertical beam width of the antenna. In micro cells, the reflections from the surrounding buildings affect to the coverage area so much that down tilting does not have any clear advantage. In figure 3.7.

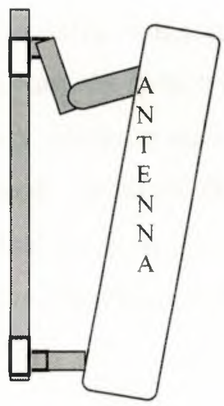


Figure 3.7 Down Tilting

3.9.2 Diversity

Space diversity enhances the receiving sensitivity of the base station by receiving uplink signal with two antennas. The diversity gain depends on the height of base station antennas, frequency range and the distance between the receiving antennas. Diversity antennas should be installed on the same vertical height with a distance from each other calculated according to the following formula:

Where $d>h/10$, **d** = horizontal distance between receiving antennas,
h = hight of the antennas

In the case of a GSM 900 network, the space should be at least 4 m. The advantage of the space diversity is greatest in city areas where radio signals reflect from many surfaces. In the countryside, especially when building a base station on a top of a mountain or big hill or on a high tower, the gain is very small unless the space between receiving antennas is increased. A typical minimum value for diversity gain is 2 dB.

In city areas and indoor solutions a polarisation diversity can be useful because the radio signal is not purely vertically polarised due to reflections. There are also cross polarised antennas available. The gain of a polarisation diversity is some 2 to 5 dB in a case of a micro cell.

A so called pseudo diversity is a cell configuration for power splitter solution where a power splitter is used in transmitting, but the two receiving antennas are connected to diversity receivers, in this way one power splitter in the receiving branch can be omitted and the receiving sensitivity will be increased. Therefore the transmitting power can be raised approximately 2 dB compared to a normal power splitter configuration. Frequency diversity is obtained when a slow frequency hopping function is used.

3.9.3 Power Splitter

A power splitter is a device which divides the radio signal into two parts. In mobile communication, splitters dividing the power 1:1 are normally used, giving half the power level (3 dB attenuation) in two antenna branches. The loss in the receiver branch is also three decibels due to an impedance matching in the splitter.

Figure 3.8 presents a normal power splitter configuration (A) and a pseudo diversity (B) structure. By using a pseudo diversity arrangement the loss of the received power can be reduced to some 1 dB when compared to a two-cell solution without diversity. This enables to increase the TX power by 2 dB.

With a power splitter it is possible to save one TRX at one site in low-traffic areas when instead of building two separate cells, only one cell with antennas directed in two directions is built. When more capacity is needed only one additional Transceiver (TRX) has to be installed to provide more capacity. This two TRX configuration gives 40 % more capacity than a two-cell solution where one TRX is installed in each cell. Use of a power splitter may cause some problems with coverage. Naturally 3 dB power loss reduces the coverage area a little, in the side beam areas of the cell where two signals received from both antennas are at an equal field strength level, the received signal level can vary rapidly when the two signal with slightly different phases are summed. This problem will not arise close to the base station.

With power splitters it is possible to reduce the investments to a network especially in rural areas when not only TRXs, but also BSC capacity can be saved. A typical place for a cell with power splitter is a base station covering a road going close by the site and located in a place where neighbouring base stations are close enough to give continuous coverage.

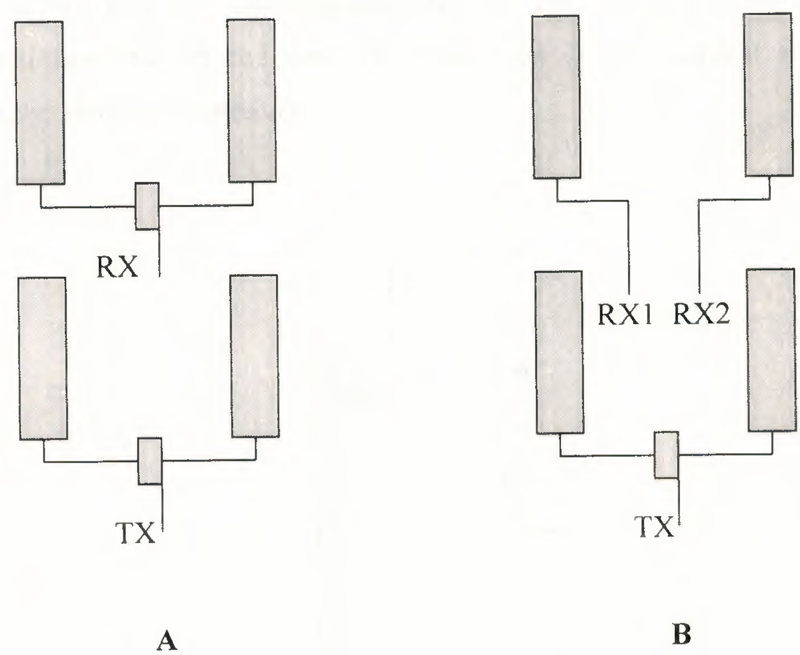


Figure 3.8 Power Splitter Configuration.

3.9.4 Antenna Configurations

Configuration of Omnidirectional Antennas

Seperation requirements for isolation.

a) **Vertical Separation**

Requirements: Tx-Tx and Tx-Rx: 30 dB

Pre-condition: No influence from tower structure, ie. more than 2m between antennas and tower. (a in fugure 3.9)

Vertical seperation: Tx-Tx and Tx-Rx : Minimum 0.2 m (k in figure 3.9)

Additional information

Antennas on the same axist with a separation of 0.2 m will actually have more than 40 dB isolation but 0.2 m is a practical separation to use. This value is valid for all types of omnidirectional antennas as the near field radiation in the vertical direction is not dependent on the gain of the antenna.

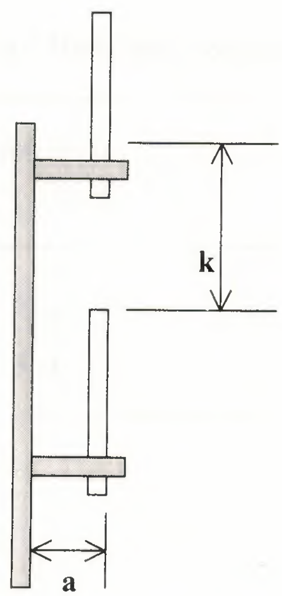


Figure 3.9 Vertical Separation

b) Horizontal Separation

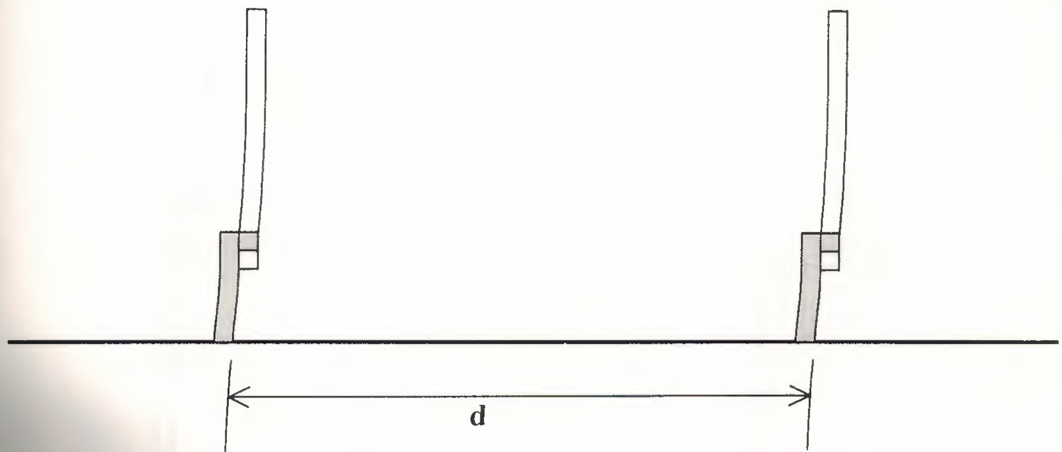


Figure 3.10 Horizontal Separation

Requirements: Tx-Tx and Tx-Rx: 30 dB

Horizontal separation: see table 3.3 below

Table 3.3 Horizontal Separation

Omni antenna Gain dBi	900 MHz	1800 / 1900 MHz
<10	3 m	1,5 m
>10	5 m	2,5 m

Additional Information

The horizontal distance between a Tx antenna and RX antenna or between two Tx antennas is dependent on the gain of the antennas.

The horizontal separation distance is considerably higher compared to vertical separation, as the antennas are in the main radiation fields.

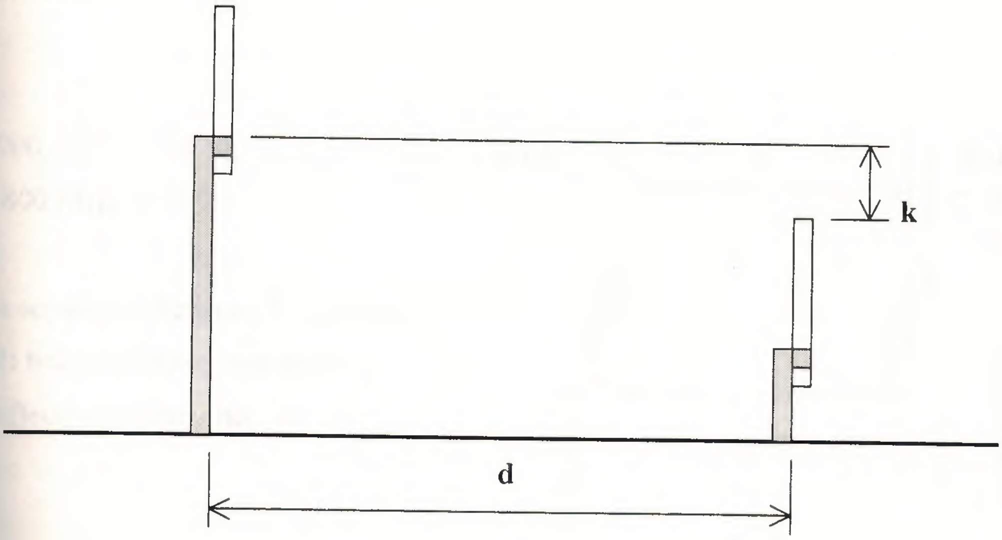


Figure 3.11 Combined Vertical / Horizontal Separation.

The following is valid for 900 MHz and 1800/1900 MHz

Requirements: Tx-Tx and Tx-Rx:30 dB

Combined separation*:* Vertical (k): minimum 0.5 m

Horizontal (d): no limitation

Additional information

The combined vertical/horizontal separation is common in systems with two receiver antennas for diversity if the Rx antennas are horizontally separated. The required 30 dB isolation will be achieved, if 0.5m vertical separation, k, is maintained, irrespective of horizontal separation, d. see figure 3.11.

b) Diversity Separation and Antenna Height

The relationship between the desirable diversity separation and the antenna height is shown in figure 3.12

900 MHz a>H/10
1800 MHz a>H/20

a: separation between Rx antennas
H: height of mast plus building
(effective antenna height)

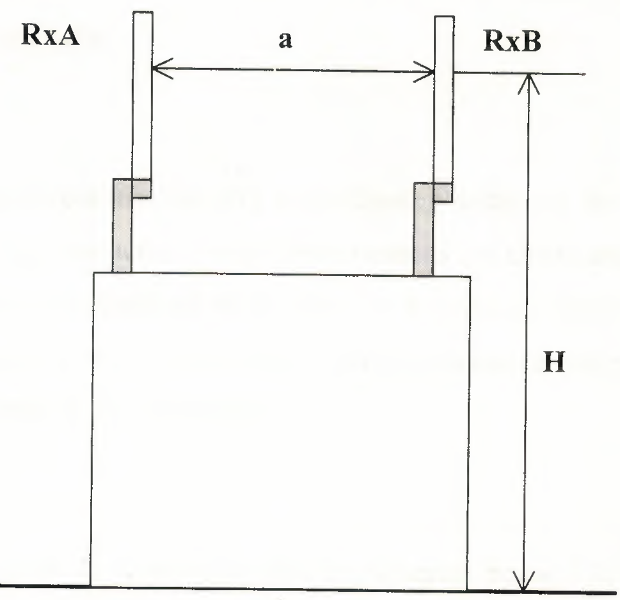


Figure 3.12 Diversity and Antenna Height.

d) Horizontal Separation for Diversity

The horizontal separation between the antennas shall be as stated in table 3.4 below

Table 3.4 Horizontal Separation for Space Diversity

	900 MHz	1800/1900 MHz
Minimum:	4m	2m
Recommended:	6m	3m

e) Vertical Separation for Diversity

Diversity improvement is also achieved by vertical separation of the antennas. For the same improvement as for the horizontal separation the vertical separation should be appoximately 5 times the horizontal value. This is valid for medium and large cells. For small cells in built up areas, a lower value can be acceptable, in extreme cases down to the same value as for horizontal separation. In other words, 4-6m (900MHz) or 2-3m (1800/1900 MHz) vertical separation can be sufficient for very small cells.

f) Nearby Obstacles

Nearby obstacles are defined in this document as reflecting or shadowing materials that can obstruct the beam in a negative way. Only obstacles within 30m distances are considered in reality the building if the antennas are to be installed on the roof of a building. Obstacles further away e.g. surrounding buildings close to the base station. Can also act as reflecting or shadowing obstacles but are not considered in this document.

g) Roof Mounting

The dominating obstacle is the roof itself. It is possible that the antenna beam will be distorted, if the antenna is too close to the roof. In other words, the antenna must be installed at a minimum height above the roof or other obstacles. In figure 3.13

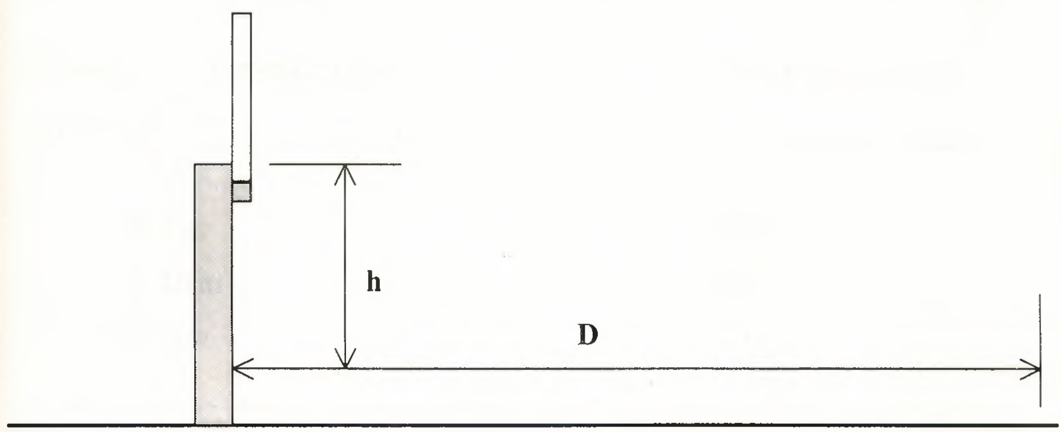


Figure 3.13 Height of Antenna Above Roof.

A practical planning rule is to keep the first fresnel zone free. For 900MHz the minimum recommended height above the roof is given by table 3.5 for 1800/1900 MHz the minimum height is given by table 3.6 these values are valid irrespective of antenna tilt.

Table 3.5 900 MHz Height of Antenna Above Roof

Distance (d) to obstacle edge (obstacle)	Height (h) above roof
0-1m	0.5m
1-10m	2m
10-30m	3m
>30m	3.5m

If possible, use 2m as the minimum height if there is a risk that people can walk close to the antenna.

Table 3.6 1800/1900 MHz Height of Antenna Above Roof.

Distance (d) to obstacle edge (obstacle)	Height (h) above roof
0-2 m	0.5 m
2-10 m	1m
>10 m	2 m

If possible, use 2m as the minimum height if there is a risk that people can walk close to the antenna.

3.10 Summary

We discussed in this chapter about base stations and radio interfaces, control cahannels, handover types, RF control strategy, radio channels and structure of the GSM Radio interface, timing advanced and frame structure, GSM Radio interface, radio frequency channels and bands for GSM, base station antennas, down tilting, diversity, power splitter, antenna configurations. We selected panel antenna type. This antenna type is suitable for cellular network planning of Lefkoşa City Centre. Poropagation of panel antenna is the best, because; we can change direction, tilting and different antenna configuration.

4. CELLULAR RADIO NETWORK PLANNING

4.1 Over View

We will mention about cellular radio network planning, coverage planning, micro cell planning, capacity planning, frequency planning, parameter planning, optimisation and network measurements.

4.2 Planning Principles

Cellular radio network planning is devided in to four major parts:

1. Coverage Planning
2. Capacity Planning
3. Frequency Planning
4. Parameter Planning

Different theoretical models for cell site locations have been introduced in books. The models suit, however, only for capacity calculations, not for cell plan. The models have some restrictions: Terrain is assumed to be totally flat, traffic either evenly distributed or there is only one small area with very high traffic [11]. All the cells should be of the same size and antenna heights should be equal. In practice, this is not possible. The real plan should take into account the local conditions and capacity demand.

When planning a new cell or a new cell site certain things have to be considered because a new cell site is a very expensive investment. The new cell should cover the area what needs to be covered. The interference area of the cell should be very limited. In fact, the difference between the coverage and interference area should be as small as possible. When deciding the cell size the future capacity demand must be considered. Unnecessary overlapping coverage should be avoided. However, when building good indoor coverage, coverage will be overlapping outdoors.

*The antenna heights in the countryside can be even 70-80m. In the city areas height of 20-*40 m is sufficient. When microcells will be built microcell antennas will be installed below the level of the rooftops.

If good indoor coverage is a target, a line of sight between the base station and the area to be covered is desired to ensure sufficient coverage. Different ways to get information of areas which have a lack of coverage are:

1. Customer feedback
2. Marketing Department
3. Traffic and quality reports
4. Knowledge of the topography and residential, business etc. areas
5. Network testing, field strength measurements
6. Competitors` cells

According to that information a list of new cells and sites can be generated. Normally there are lost of cells more in the list than what can be implemented in the near future. The possible new cell locations should be ranked according to the importance of the cell in question. When a decision of a new cell is made the following issues must be considered:

1. Is a new cell site needed?
2. Planned coverage area
3. Is it possible to cover the whole area with one site only?
4. How much traffic is estimated for the new cell?

It is important that we don`t try to cover two rather closely from each other situating areas with one cell if it seems to be a compromise that doesn`t give coverage to either of the areas. If a compromise cell is built, possibly two additional cells are needed to cover the two areas. In that case the first cell site in the middle is totally unnecessary. Too much overlapping coverage between the cells should be avoided. In order to quarantee properly working handovers, a certain amount of overlapping coverage must be between the neighbouring cells. By adjusting handover parameters the location where the handover takes place can be controlled. Problems can arise in a microcellular network in places where the signal strength can drop rapidly. For example, when going out of a building or a tunnel.

4.3 Coverage Planning

The aim of coverage planning is to create a sufficient coverage area, to achieve the required capacity within the frequency range available, to reach good quality and to minimise the costs of the network.

As a starting point, we have:

1. The preliminary number of base stations and channels needed (derived from the capacity plan)
2. The topology of the service area
3. Propagation models
4. System and equipment specifications
5. Service quality requirements

4.3.1 Planning Assumptions

All the areas to be covered should have a continuous coverage in order to avoid "coverage islands". Service will be offered to hand mobiles indoors in city and residential areas and continuous car phone coverage on the roads.

The network roll out strategy is based on marketing studies.

4.3.2 Cell Size Hierarchy

The cell size structure of a network varies according to the local circumstances, in rural areas maximum coverage can be the main target, but in city areas the capacity normally limits the possible cell size. Typical cell size radius for 3-6 km. for small cells 1-3 km and for microcells a couple of hundred meters. A BTS antenna gain of 13 dBi (8 dBd) for GSM and 16 dBi (14 dBd) for DCS is used. Especially in the countryside, larger antennas can be used to extend the coverage. Also, by using thick antenna cables (7/8" used in the calculations) the coverage area can be increased.

4.3.3 Indoor Coverage

Implementation of coverage depends on each situation. If the area is considered sparsely built and its buildings include multi-story condominiums, row houses or single family dwellings, it is worth planning indoor coverage using macrocells and microcells. Indoor coverage for commercial and office buildings will be supplemented by customer request and depending on the growth of traffic and number of subscribers.

The propagation effect of buildings has been examined extensively. There have been measurements of the coverage effect of placing a transmitting antenna on the neighbouring building`s wall or roof. In the latest studies the transmitting antenna has been placed indoors and the field strengths have been measured in different types of rooms.

The methods of research have been statistical. Most of the results of these measurements have been used to determine a model for the measured type of building so that these results can be applied to other similar types of buildings. The buildings are classified according to their type, function, and their surrounding environments.

4.3.4 Indoor Coverage Special Requirements

When planning a network for hand mobiles one of the most difficult issues is indoor coverage. A compromise has to be made. When planning a base station in the country side it is preferable to build it as close as possible (less than one km) from a town or a village if good site alternatives are available. This is to maximise the indoor coverage with a site giving general coverage to a certain area. Although the coverage predictions show good indoor coverage for the planned region, it will never be perfect. If the site is built some kilometres away from a town, reasonable outdoor coverage can be achieved but the indoor coverage may be insufficient. The received signal is very good in case there are no obstacles between the base station and the mobile phone, but if anything comes between the base station and the mobile phone, the received power will decrease very rapidly. After some time a new base station has to be built in the centre of the town. With one good site it may be possible to cover both important indoor and outdoor areas. As a planning value 10 dB building attenuation can be assumed in rural areas and 15 or 20 dB in urban areas.

To improve indoor coverage in a certain area it is useful to have several base stations around it giving coverage from different directions. In that way the probability that a signal comes from at least one direction at sufficient level increases. Radio signals pass through windows much better than through walls and better indoor coverage can be achieved in this way in all parts of buildings.

When a large office building has to be covered the base station should be located on the top of the building, or at least very close to it. Even an indoor antenna network may be necessary to cover holes in the coverage, especially if a complete coverage is needed.

Very difficult buildings to be covered are metal coated industrial halls. Although the base station would stand very close to that building, the indoor coverage may be on an unsatisfactory level. The attenuation of that type of building is high because it is like a Faraday's cage.

4.3.5 Indoor Antenna Network

If a really good indoor coverage is needed for example in a shopping centre, one single antenna may not be enough. An antenna network has to be built. The source of radio signal can be a BTS or a repeater.

If the signal to indoor antenna network will be taken from a BTS covering outdoor areas, the signal to the indoor antennas will be taken by using a (1:2) power splitter. In that case signal to the outdoor antenna will be attenuated 3 dB. After that, depending on the number of antennas needed for the indoor coverage, the signal will be divided further by using (1:2) or (1:3) power splitters. Typically the actual signal strength required to cover a room is very weak if the antenna is located in the same room. This means that one antenna may be necessary at least in every second floor in the building, but the obtained signal power, especially when using an BTS, is not a problem. If a repeater is used as the signal source, the number of antennas required may be higher due to a weaker output signal. All antenna locations, directions, types, cable lengths etc. must be properly documented so that someone else can also understand the antenna network plan.

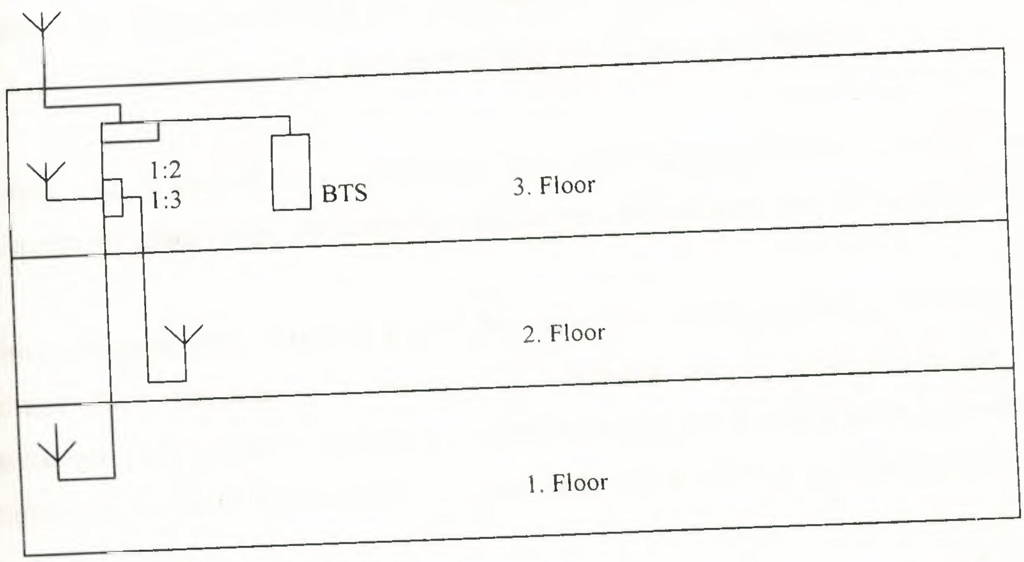


Figure 4.1 Example of Branching an Indoor Antenna Network.

4.3.6 Planning Tools

In modern, computer-aided coverage planning, the coverage prediction is calculated with different propagation models, digital maps, and possible measurement data. For the planning of micro and picocells we cannot use the same propagation models that we use for the planning of macrocells. It is difficult to develop prediction methods producing results that are precise enough for city environment, and thus, the network planner's insight into propagation problems and empirical experience is of very great importance. A coverage prediction calculated by a computer does not describe field strength at a single location but gives a general view of average coverage and interference areas. Apart from predictions, measurements are performed to check the real field strength in certain areas. By comparing the measurement results to the forecasts, the preciseness of the propagation models can be improved.

Computer-aided planning functions fairly well in rural and sparsely populated areas but in cities its accuracy is usually not satisfactory. When planning microcells, the size, form, and material of the buildings should be known. Also the width of the streets affects propagation. This necessitates very detailed digital maps in the planning tool. When modelling picocells, the material and thickness of walls, size of windows and width of corridors must be considered as examples of factors affecting propagation.

Coverage area is defined as an area where a certain minimum level of service is offered with a certain probability. Service coverage area is usually defined according to the weaker

minimum requirement. A typical probability value in cellular networks is 95% inside the coverage area. The scope of coverage area is usually defined according to the weaker transmission path and the interference area according to the stronger path. In practice, the disturbances caused by mobile phones are not taken into account in planning programs.

The path loss between a mobile phone and a base station is not constant as a function of distance but its average depends on distance. Both so-called fast and slow fading occurs in it. Several propagation models for different conditions have been developed to predict the radio path loss. These prediction models are adjusted to the measurement data. The best known are the Okumura-Hata model and, for urban areas the COST 231 Walfish-Ikegami model.

Different network planning software have different approach to how for multi-user environment, too. In every network planning software there are certain basic features available. Coverage and interference calculation, and automatic frequency planning are the most important for coverage and frequency planning and that is the main purpose of the planning software. The basic price of the software does not necessarily contain for example automatic frequency planning function, but for some extra price it is available. Depending on the software there may be an extensive data base for storing all the parameter data and possibility to transfer traffic and/or coverage measurement results into the planning tool. For observing traffic and other network measurements we have normally some other software available, if the traffic measurements can be imported to the planning tool we can utilise that information in the capacity planning.

When making interference calculations, the planning software calculates first the coverage and interference area of all the cells in a selected region and composes a so called composite coverage. This means that the most probable serving cell in each region is calculated. In some areas we have several cells with sufficient field strength for a successful call. In that case the planning tool estimates the most probable serving cell and estimates the amount of interference for that particular cell. The other cells may have interference, but it is assumed that the best cell is used in that area and the interference level is calculated for that cell. The intelligence of the automatic frequency planning tools varies. A basis for a good frequency plan is the accuracy of the coverage calculations. In addition to that, the actual service area, neighbouring cells, handover criteria, estimated subscriber number in the interfered area, for example, are information that can be utilised when allocating frequencies to the cells and trying to minimise the amount of interference. The frequency plan generated by a planning software should always be verified because sometimes it can do some obviously stupid channel allocations. If the network planner has a good knowledge of the real coverage and interference areas of the cells, it helps a lot when evaluating the frequency plan. The quality of the digital map is one of the most important factors determining the accuracy of the coverage predictions. In the countryside, a map with a raster size of 50-100 m is sufficient. In large cities the raster size should be not more than 12 m. Height data is the most important, in addition to that the land type is divided into several classes, like forest, water, suburban area etc. In accurate city area maps we should have information of building heights. The propagation models for city areas are different than the models for the rural areas. If very accurate predictions are needed we should use a vector map instead of a raster map. In a vector map we can have more precisely the shapes of the buildings, for example.

4.3.7 Coverage Planning For The Countryside

In the countryside, capacity is normally not a limiting factor, when planning cells. The required signal to noise ratio depends only on the received signal strength. In such a case a maximum coverage area is the main target in the coverage planning. This can be achieved by using high gain antennas, high antenna heights, and high transmitting power. High gain antennas are normally large in size, but in a mast there should be enough space for the antennas. If sectorised antennas are used, the coverage area can be formed according to the demand, and high signal level can be reached rather far from the base station. Very high cell site places (top of a mountain) must be avoided. Multipath propagation can be a problem if the signal reflects from many places with a big difference in distance. In addition to that, especially when using high gain antennas, the radio signal can travel over the area to be covered.

4.3.8 Coverage Planning For The City Areas

In city areas capacity is typically limiting the maximum cell size. The coverage area of the cell is determined many times by the interferences in the network. A serv-sign in the phone`s display does not necessarily mean a high quality connection. The achieved C/I ratio is essential. Although the level of interferences would be rather high, it is possible to have a good quality connection if the field strength of the serving cell exceeds the interference signal by more than 9 dB.

The main principles in the coverage planning for the big cities are:

1. Sites are placed close to important areas (shopping centres, business offices, main roads etc.) to maximise the indoor coverage and offer very good quality.
2. Continuous good quality service on the main main streets.
3. Antennas point outwards from high-traffic area (city centre) in macrocells.
4. When traffic grows in a certain area, small and microcells will be built in those areas.

In the city centre three sector cell site is suitable to maximise the coverage and capacity in the heavy traffic area. In the surrounding cells antennas should be directed outwards from the centre. This is to avoid interferences. In this way the same frequencies can be used rather close in the other site of the centre. In practice, the cell locations must be planned to meet the local coverage and capacity needs. The capacity plan for city areas gives the number of new cells needed to carry the predicted traffic in the future. In traffic hot spot areas there may be a need to build some microcells almost only for capacity purposes. The idea is to take the most of the traffic from one macrocells, the principle that antennas should point of the cell is very limited.

Of great importance is to try to minimise the interference areas of the cells. Unnecessary overlapping coverage should be avoided, but, when offering good indoor coverage the outdoor coverage will become overlapping. If it is necessary to build a new base station for capacity reasons, the new one should be built close to a traffic hot spot, if possible.

4.3.9 Microcell Planning

Microcells are an effective way to increase capacity and indoor coverage in the network. Microcellular network requires expensive investments and therefore it should be built only when macrocellular network can not offer sufficient capacity. Depending on the available frequency band and traffic forecast it may be reasonable to start to build a microcellular network already in the beginning of the network rollout.

Microcell is acell where the base station antennas are installed below rooftop level. In microcells the radio signal propagates in street canyons where it is easier to control the coverage and especically interference areas. Microcells will be installed to traffic hot spot areas where capacity demand is highest.

Microcell antennas can be installed along a street or perpendecular to the street pointing to the building on the opposite side of the street. The first position gives good outdoor coverage along the street but the problem is that the coverage and especially interference area extends easily too far away from the cell site. However, indoor coverage extends only very close to the antennas. In the latter installation very good indoor coverage is offered to the near locating buildings, and the interference area is very limiting as well.

A microcellular network can be built under macrocell layer gradually according to the capasity demand. At certain moment some large cells can be changed in to microcells when the microcellular network coverage extends all over the coverage area of the macrocell. Several microcells are needed to replace one macrocell. Typically 4-6 microcells are needed. Transition from a macrocellular network to a microcellular one takes relatively long time. Therefore it is very difficult to change a macrocellular network to a continuous microcellular coverage at once.

4.3.10 Rf Repeaters

The RF repeater is a bi-directional amplifier that amplifies a radio signal coming from a base station and transmits the signal forwards to mobile phones. Similarly, it boosts the signal transmitted by a mobile phone and sends it to a base station. Figure 4.2 shows the principle of a repeater.

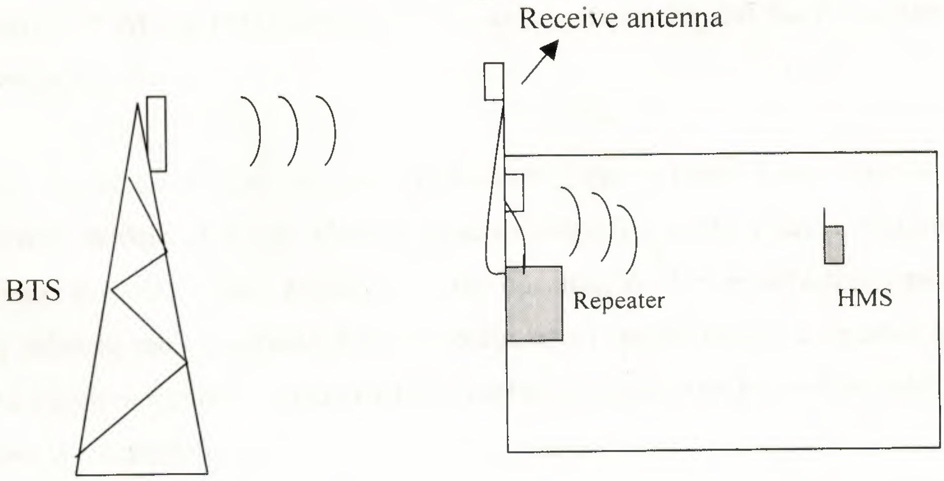


Figure 4.2 RF Repeater is Used to Improve Indoor Coverage.

Pros and Cons of a repeater;

+ Less expensive than a base station
+ No need for a transmission line
+ Easy to install
+ Small size

- No capacity increase
- No traffic measurements Risk of a feedback loop
- Risk of a feed back loop
- Only simple alarms available
- Coverage area not well defined
- Small output power

Repeaters do not normally make any frequency conversion. They only amplify the received signal and send it forward. This necessitates that the attenuation between the receiving and transmitting antenna should be at least 15 dB more than the gain of the repeater. This issue can be critical especially in outdoor solutions. When taking the base station signal from outside a building arid covering indoor areas, sufficient attenuation can normally be achieved. A typical maximum gain of a repeater is 80 dB and the maximum transmitting power is 25 dBm

There are different types of repeaters available, the so-called band selective and channel selective models. A band selective repeater amplifies a pre-defined frequency band, for example the whole band available for the operator. A channel selective repeater transmits only selected radio channels. The advantage of a channel selective repeater compared to a band selective repeater is that possible interference can better be avoided when only desired channels are amplified.

Attenuation between the receiving and transmitting antenna must be at least 15 dB more than the gain of the repeater. This issue can be critical especially in outdoor solutions and this one major reason for that why repeaters should be used only for building indoor coverage. When taking the base station signal from outside a building and covering indoor areas, sufficient attenuation can normally be achieved. A typical maximum gain of a repeater is 80 dB and the maximum transmitting power is 25 dBm. In order to ensure a proper operation of a repeater the signal strength from the base station in the repeater's input connector must be at least -8O dBm.

A repeater is not a substitute for a real base station. It does not increase capacity and the coverage area is not as well defined as the area served by a BTS. The amplification per channel depends on the number of radio channels to be amplified. In addition to that, an AGC (Automatic Gain Control) may limit the amplification if a mobile phone gets too close to a repeater. At the same time the coverage area will get smaller. The newest repeater models include a mobile phone that is used to remote control the repeater and to send alarms to a maintenance centre. A repeater cannot measure the carried traffic.

There are also so called fibre optic repeaters available on the market. They convert an RF signal with a laser diode to light and transfer the signal to a remote head where a conversion from light to RF-signal is done. The remote head includes also an amplifier. The advantage of this system is that the radio signal can be delivered to a rather long distance (approx. 12 km) due to low loss of fibre optic cable. Otherwise it is like a normal RF-repeater. The price of a fibre optic repeater is much higher than the price of a normal repeater.

A repeater is remarkably less expensive than a base station and it does not need a transmission line. It is recommended to use repeaters to cover indoor areas and tunnels. An extensive use of repeaters can cause problems because possible changes in the network can affect the operation of repeaters and, if a feedback loop arises between the receiving and transmitting antennas, the repeater can also block the serving base station.

In order to ensure a proper coverage from the repeater, a relative strong signal, >-80 dBm should be obtained from the base station to the input connector of the repeater. This means that a repeater cannot be used in areas with bad outdoor coverage. It is comparatively easy to replace a repeater with a new base station when more capacity is needed, since the antennas are installed and the equipment room is already available. The site has to be upgraded and new transmission lines are needed to the new base station, however.

4.4 Capacity Planning

The network can be dimensioned to meet the estimated capacity demand in different ways. It is a question of how easy and how expensive it will be to expand the capacity. The network can be dimensioned so that to get more capacity only new channels have to be added to existing base stations and some new cells will be built in traffic hot spot areas [19]. The capacity growth has to be taken into account in all network plans, and it must be possible to add capacity rapidly and economically in response to future capacity demands. In a network dimensioned just to fulfil the capacity needed in the near future, without a possibility to add more channels to the existing base stations, we have to build new base stations and change the cell size hierarchy if the capacity requirements are higher than estimated. The network capacity is defined to be the maximum number of simultaneous calls that would be possible in a certain area. Capacity planning is divided into regional planning and cell specific planning. Regional capacity planning should be done following long-term predictions (1-3 years). Individual cells are planned for shorter time periods, e.g. one year ahead at one month accuracy. The theoretical capacity cannot be reached in a real network. This is because the traffic is not equally distributed between the base stations. There are always cells which carry only a small part of their maximum traffic capacity and the capacity of a cell is normally added for example in two or four channel steps. In a new network there will be lots of extra capacity because many cells will be built to give coverage while the subscriber number is still low. Capacity planning may be divided into two parts, design by areas or by cells. At first, the capacity for the each area is determined. These areas are sub-divided according to the needs of each cell. The basic criteria for the design of each area is based on the selected coverage area strategy.

4.4.1 Erlang

Erlang (Erl) is the unit of traffic in telecommunication networks. Traffic is typically measured during one hour time period. One Erlang equals one reserved channel on average during the measurement time. The maximum possible level of traffic is the same as the number of channels.

4.4.2 Capacity by Area

The total number of channels, and the method of calculating the capacity, depends whether a new system is being designed or an existing one is being expanded. When an entirely new area is being designed, having no existing mobile telephone network of the same system, it is possible to use those parameters which are familiar through experience in other networks: subscribers/channel, traffic/channel and traffic/subscriber. Based on the experiences with existing networks from earlier years, statistical information such as the number of subscribers and traffic allocation, it is possible to predict the growth in the number of subscribers and required capacities to an accuracy of 1/2 to 2 years. The predicted number of subscribers is quite dependent on the operator's business actions, which are taken into consideration when making these forecasts. In urban areas with large cells and microcells, the forecasts are based on daily traffic measurements, which can be used to calculate the traffic disbursement by area. By observing figures for a long time, it is evident that the traffic distribution changes gradually. The capacity for the planning area can be defined as follows: From the subscriber number forecasts we derive the number of subscribers. Using the measured traffic it is possible to calculate the area's typical specific traffic. If the traffic measurements are not available, figures can be taken from the other mobile telephone networks, which represent the actual specific traffic's collected data. The planning area's proposed traffic is equation 4.1.

$$A=Su.Au \tag{4.1}$$

Su: is the number of subscribers

Au: specific traffic (mErl/subs.)

4.4.3 Capacities of The Cells

1. Initial Capacity

The initial capacity usually depends whether the cell is being built to increase the coverage area or capacity. Quite often both reasons apply. When the cell is built to increase the capacity, the traffic of the surrounding cells and the needed capacity is taken into consideration. These criteria are used to calculate the cell's initial capacity, which in urban areas is preferably made slightly larger than the initial capacity. In the countryside, the coverage area usually meant to increase so the calculated capacity is often left unchanged. If the cell coverage area is close to busy roads, factories, hotels of other busy places, it is advisable to take this into consideration while determining the capacity.

2. Number of Channels/Cell

As capacities of cells are increased, two principles are followed. in the first, the channels are equally divided to the different cells. This way, each cell has the same number of channels by the area they cover and the amount of traffic they handle, although their geographical sizes may vary. In practice, this means that cells with less traffic are joined and cells with more traffic are divided into new cells. The other method of approach is to observe the "natural" distribution of traffic. Then it makes no difference if any cell handles more or less traffic. Instead, channels are added at the same rate as the traffic increases. This leads to the division of individual cells. Whereas the previous method affects the planning area design, the later method requires the redesign of the entire channel separation.

Small cells are always constructed in the lower network layers, when the basic network is ready. In the designing the capacities for picocells, it is possible to use the results of the given area's traffic measurements right from the beginning. The most important for these being the area's traffic/subscriber. The total traffic volume is counted. The number of channels may be calculated by Erlang's equation B, when the total traffic and desired restriction rate is known.

Likewise, it is useful to estimate how much the coverage area has increased compared to the earlier, and how much it affects the added traffic. The missing indoor coverage has sometimes appeared to have caused the surrounding cell traffic to remain the same and the traffic through the recently built cell is entirely new.

3. System Final Capacity

The factors which affect the final capacity of the system are available frequency band's width and the mobile telephone's minimum transmitting power. The frequency band's width is the natural factor restricting the capacity. The capacity may be increased by decreasing the size of the cell. The smaller the cells, the more frequently the frequency groups may be used and the more capacities are useful for proportion to the area.

The final restricting factor is the small transmitting power of the mobile telephones, since the operators cannot do anything about it.

4. Observing Traffic

The development of traffic levels is observed by weekly traffic reports. The planners may observe the traffic through the cells by morning and afternoon measurements, as necessary, or they may obtain measurements from the OMC for any time interval since the peak hour is not the same for all cells. The peak hour is defined so that the greater portion of the traffic occurs during the measuring interval.

Mother way to define the peak hour is to measure the traffic in 15-minute periods and take the sum of the four busiest traffic intervals. This way we can determine the actual traffic flow through those cells which peak hour does not occur during the current time interval. A properly sized system depends on the accuracy and reliability of traffic measurements. The traffic measurements will prove their worth with the increase of microcells and picocells.

In order to maintain the radio network cost effective, the number of TRXs should be according to the real capacity demand. In practice, 100 % utilisation level is impossible to achieve, but 50-60 % level is a realistic target. By applying capacity enhancing radio network features the efficiency can be improved by equalising the traffic load between different cells. Naturally, in the beginning of the network operation, the traffic and utilisation is very low.

4.5 Frequency Planning

Frequency planning by using theoretical hexagonal cells and frequency re-use patterns is not feasible in practice. In theory the cells should be of the same size and antenna directions should be fixed, for example, to 0°, 120° and 240°. In practice, the size and shape of coverage and interference area differ at each cell. In theoretical models the land topography is assumed to be totally flat. Also, the capacity distribution between the cells should be equal, but in practice, each cell has its individual number of channels.

In one cell the channel separation must be at least 3 channels (600 kHz). For example frequencies 100 and 103 can be used in the same cell. In adjacent cells 2 channels (400 kHz) separation is sufficient to enable successful handovers, so cells which are defined as neighbours should have one channel in between.
Frequency planning can be done in the beginning with a large safe margin. It is important to guarantee that the S/I-ratio is more than 12 dB on the service area of one cell. Later on, when there are not suitable free channels available and the prediction models are fine-tuned by comparing the actual coverage and interference areas of the cells to the predictions, the frequency plan can be revised and changed.

Modern network planning tools can make the frequency allocation automatically. It can be done also manually, especially in the beginning of the roll-out, when there are lots of free frequencies available. When planning frequencies for the countryside, proper channel allocation can be done manually. In large city areas manual frequency plan is not a simple task to do. With a network planning tool the frequency allocation can be done, if certain conditions are fulfilled. The coverage and interference predictions should be rather reliable. In city areas the information of the most probable serving cell at each location is an important information if an optimised plan is the target. Actually, the accuracy of the coverage calculations limits the possibilities, how 'tight' frequency plan can be done without the risk of interference. When allocating channels for microcells, planning tool predictions are often not precise enough. The interference prediction of a microcell in the planning tool is typically much larger than the real interference area.

If intelligent overlay-underlay function will be used, the frequency band available should be divided into two parts. Most of the earner frequencies will be reserved for regular frequencies, and some frequencies for super-reuse TRXs. In this way it is possible to keep frequency planning under control with IOU since the frequency allocation principles are different for the two layers. When making a frequency plan for a large city, it is recommended to start the channel allocation from the centre of the city. After that, planning will be continued from the centre to outside of the city. This is because the city centre is normally the most difficult district for frequency planning. If it seems to be impossible to fully avoid interferences in the network, the frequency plan should be done in that way, that the possible interferences are limited to nonimportant areas. If it is foreseen that new cells will be built at certain places in the near future, channels can be allocated for those cells. It is, however, not needed to reserve certain amount of channels for all the future cells. Instead of that, the whole available frequency band can be used in the network. Later on, we can reduce the coverage and interference area of the existing cells, if needed. In addition to that, by using microcells, the frequency planning will be much easier than with high capacity large cells.

4.5.1 Frequency Re-Use

Network capacity can be increased by using sectorised cells since the same frequency can be re-used closer and more often than with omni antennas as the radiation pattern of directed antennas in the back beam direction is remarkably reduced.

Most commercial radio and television systems are designed to cover as much area as possible. These systemstypically operate at the maximum power and with the highest antennas allowed by the FCC. The frequency used by the transnmitter can not be reused until there is enough geographical separation so that one station does not interfere significantly with another station assigned to that frequency.

The cellular system takes the opposite approach. It seeks to make and efficient use of available channels by using low power transmitters to allow frequency reuse at much smaller distances. Maximizing the number of times each channel may be reused in a given geographic area is the key to an efficient cellular system design. Cellular systems are designed to operate with groups of low power radios spread out over the geographical service area. Each group of radios serve mobile units presently located near them. The area served by each group of radios is called a cell. Each cell has an appropriate number of low power radios for communications within itself. The power transmitted is chosen to be large enough to communicate with mobile units located near the edges of the cell. The radius of each cell may be chosen to be perhaps 26 km (about 16 miles) in a start-up system with relatively few subscribers, down to less 2 km (about 1 mile) for a mature system requiring considerable frequency reuse. As the traffic grows, new cells and channels are added to the system. If an irregular cell pattern is selected, it would lead to an inefficient use of the spectrum due to its inability to reuse frequencies on account of co channel interference. In addition, it would also result in an uneconomical deployment of equipment, requiring relocation from one cell site to another. Therefore, a great deal of engineering effort would be required to readjust the transmission, switching, and control resources every time the system goes through its development phase.

All these difficulties lead to the use of a regular cell pattern in a cellular system designed. In reality, the cell coverage is an irregularly shaped circle. The exact coverage of the cell will depend on the terrain and other factors, as described in the previous chapter. For design convenience and as a first order approximation, we assume that the coverage areas are regular polygons. For example for an omnidirectional antenna with constant signal power, each cell site coverage area would be circular. To achieve full coverage without dead spots, a series of regular polygons for cell sites are required. Any regular polygon, such as an equilateral triangle, a square, or a hexagon, can be used for cell design. The hexagon is used for two reasons: First, a hexagonal layout requires fewer cells and therefor, fewer transmitter sites and second, a hexagonal cell layout is less expensive compared to square and triangular cells. In practice, after the polygons are drawn on a map of the coverage area, radial lines are drawn and the SNR ratio calculated for various directions using propagation models from the previous chapter or computer programs. We will assume regular polygons for the coverage areas even though in practice that is only an approximation.

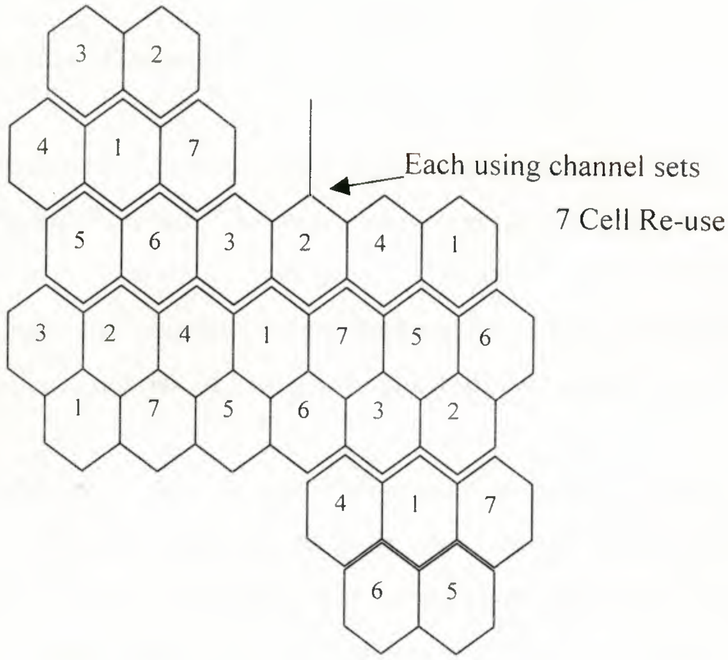


Figure 4.3 Frequency Re-use Pattern (Omni-Cell Pattern)

When a channel is re-used there is a risk of co-channel interference which is where other base stations are transmitting on the same frequency.

As the number of channel sets increases the number of available channels per cell reduces and therefor capacity reduces. But the interference level will also reduce, increasing the quality of services.

The capacity of any one cell is limited by the interference that can be tolerated for a given grade of service. A number of other factors, apart from the capacity, effect the interference level:

1. Power Control (Both BTS and MS)
2. Hardware Techniques
3. Frequency Hopping (if applied)
4. Sectorisation
5. Discontinuous Transmission(DTX)

4.5.2 Frequency Hopping

By using frequency-hopping, the average received signal is improved, since the deepest fade valleys are flattened. This improves receiver sensitivity in a normal GSM900 network by round 1 or 2 dB and the useful range of the cell is enlarged by a corresponding amount [14]. The larger the distance between hopping frequencies, the greater the effect. Frequency hopping reduces the risk of losing several subsequent speech bursts, thus improving speech quality.

Frequency-hopping also improves frequency economy. Theoretically calculating, the frequency-hopping will give round 2 dB improvement on the C/I-ratio in a typical GSM 900 network. The benefit of frequency hopping depends on the number of carriers per cell. The more carriers there are, the better the effect. According to different studies the improvement is in decibels approximately the same as the number of TRXs per cell. The effect varies, however, depending on the situation.

Frequency-hopping enlarges the RF link budget and reduces interference. This decreases the distance between the coverage limit and the interference limit of a cell. In very dense areas where even 2 dB is significant, this will provide more flexibility in matching the carrier frequency allocations to the actual traffic demand, and thereby improve the frequency economy.

In order to benefit most from the frequency hopping it is recommended to set the carrier frequencies in a minimum separation of 600 kHz in cells covering the countryside, 200 kHz in large cells in city areas and 1.6 MHz in microcells in order to lower the correlation between the carriers. As a new feature is a so called synthesised frequency hopping. The BCCH carrier can not use hopping. In baseband hopping each TRX has its own fixed frequency and the hopping is actually swapping timeslots between the TRXs. This means that the number of hopping frequencies is same as the number of hopping TRXs. In synthesised hopping the hopping TRX changes the frequency for each timeslot, and the frequency can be selected randomly and there can be more hopping frequencies than TRXs.

4.6 Parameter Planning

Carefully selected base station parameters are an essential part of a well functioning cellular network. The most essential parameters are power and handover controlling parameters. Especially, a dense network like in the Nicosia area requires an experienced network planner to fine-tune the radio network parameters in order to minimise the number of dropped calls. With the power control functions adjusting mobile and base station transmitting power it is possible to reduce the risk of interference and also extend the operating time of mobile phones. The up link and down link transmission paths should be balanced. Typically, the low transmitting power of mobile phones is the limiting factor. There are different thresholds which can cause a handover. Other handover algorithms are also available depending on the network supplier. For example, in a multilayer network some large cells can be defined as umbrella cells. A call begins in a normal way in an umbrella cell, but if there is an other cell with a sufficient field strength level available, the call will be directed to that one. Typically, when a new cell will be planned, more or less default values will be set. When the cell is on air, based on BSC and field test measurements values will be optimised. Especially handover parameters will be adjusted.

4.7 Network Optimisation

Network optimisation means different measures to improve the functionality of the radio network. Methods to optimise the network include all the four major parts of radio network planning: parameter planning, coverage planning, capacity planning and frequency planning. Here are couple of examples of problem situations and possible ways to solve the problems.

4.7.1 Parameter Planning

Many times only by tuning the network parameters we can improve the quality remarkably. Number of dropped calls depends much on the handover parameters. If a phone call remains a too long time in one cell and the handover procedure starts too late, the call may drop. By adjusting the handover parameters, the calls can be handed over to the next base station exactly at the right place. Especially in a micro cellular network, when a phone moves around a corner, the signal strength can drop very rapidly [18]. Also, when moving from the coverage area of an indoor cell to outdoors, a risk for a dropped call exists. If congestion is a problem in the network, when having overlapping coverage, by changing handover parameters we can move traffic from one congested cell to another cell which has free capacity.

4.7.2 Coverage Planning

By means of coverage planning we can remove some coverage gaps in the network. Either we can change the antenna type, direction, and antenna height, or, add a new cell to an existing cell site. Sometimes, if interferences are the problem, we can reduce the interference area of a cell remarkably by relocating the antenna placement, adjusting the tilt angle, and at the same time the coverage area will reduce only a little.

4.7.3 Capacity Planning

Capacity planning can be done to optimise the traffic capacity of each base station cell in the network. If unnecessary extra capacity is noticed at some cells, we can reduce the number of TRXs and take them to another cells where additional capacity is needed. In that way the total number of TRXs can remain almost the same, but the congestion problems can be solved.

4.7.4 Frequency Planning

If interferences are the problem, by making changes to the frequency plan the quality can be improved. Either the whole frequency plan can be redone, or, only some interfered frequencies will be changed.

In many cases, not only one of the four major parts of the radio network planning is sufficient to solve the problems. A combination of all the planning steps is usually necessary. For example, to solve a capacity problem, some new cells are needed, but at the same time by changing frequency and capacity plan, an optimised result can be achieved.

Important information for network optimisation are network performance statistical measurements and tests. When a new cell site is planned, typically some basic parameter values are set for the cell. When the cell is on air, by measuring the real coverage and functionality of handovers, fine-tuning of the parameter settings may improve the situation even further. In some cases, the antenna type and/or direction can be changed in order to cover exactly the desired area. Typically, time and planning resources limit the amount of network optimisation.

4.8 Network Measurements

BSC measurements are one of the most important source of information considering the state of the radio network. By observing different measurement counters we can notice possible problems or faults in the network. Also for observing the network quality we need measurements. The BSC measurements are statistical, we can't get information where possible problems arise. That information we can get by doing field test measurements.

From BSC we can get a wide range of different measurement reports in one hour time interval, for example. This data is so called raw data which can be processed in an other software. Because the amount of data is large, only selected measurement reports can be stored for long time period, for example one year. For a short time all the measurements can be stored in the OMC, but after one or two weeks, typically, the data will be deleted. From a large number of measurements some average values can also be calculated and stored in a long-term storage [17]. Since the amount of measurement data is huge, the problem is how to notice the essential changes and development trends in the network. That is why the data must be filtered. If the size of the network is rather small the measurement data can be processed in Excel, for example. When the number of cells increases, a dedicated measurement processing software which can handle large data bases quickly is necessary. Also the possibilities to get versatile reports and graphs are better.

For capacity planning we need measurements of traffic and blocking in order to plan the capacity expansions in the base stations. In this work it helps a lot if we have long-term traffic data available. From only a couple of measurements it is difficult to forecast the trend for one year ahead. If we have busy hour traffic available from a time period of two months, for example, we can predict quite accurately, assuming that the growth will continue in a similar way, the lime when capacity of each cell must expanded. If the growth is linear, it is straightforward to estimate the month when congestion will exceed our limit. If growth is exponential, we can try to estimate the trend according to that trend. From the basic counters like traffic, blocking, handover measurements, call success rate etc. we can also calculate certain new values, different ratios [6]. By observing these values for a long term time period we can get information of the quality trends in our network. For example, if we look only the number of unsuccessful handovers, the trend can look bad. But if we divide that number by the number of handover attempts, we may notice, that the quality is actually getting better. Explanation for this is that the absolute number of unsuccessful handovers increases if the traffic is growing.

Field test measurements can be done by using special hand mobile phones with a test display, or by using an automatic test system. Typically such system consists of a mobile phone, GPS receiver, and a PC. The PC will make automatic test calls and collect measurement data. When coverage area of a cell is to be compared with predicted coverage, we can use a special field strength measurement receiver. The measurement data can be stored together with a GPS position data and it can be transferred to a planning tool. In that way it is easy to see the difference between measurement and prediction on the same screen. By utilising this data it is possible to tune the propagation model parameters [16].

To evaluate the development of network quality and coverage, the network performance can be investigated by placing hundreds of test calls on pre-defined test routes in cities and on main roads. The route will be marked on a map and clearly defined in the driver's instructions. The route should be the same every time the area is tested, because the results are compared with earlier results on the same route. Drive tests can be done also to compare the network's performance to the competitors' networks. Regular drive tests should reflect the trend of network quality and coverage.

4.9 Summary

We discussed about cellular radio network planning, coverage planning, micro cell planning, capacity planning, frequency planning, parameter planning, optimisation and network measurements.

5. CELL PLANNING FOR THE 20.000 SUBSCRIBERS

5.1 Over View

We will mention about in this chapter cell planning for the 20.000 subscribers in Lefkoşa City Centre. The number of sites will be calculated carriers, cells for this scenario. We will prepare database of Lefkoşa City network, network configuration and transmission plans will be designed. We will calculate for number of BSC, BTS, sites, cells and TRX.

5.2 Details and Calculations

The GSM 900 band is divided by 2 operators and each one will have 60 carriers. We assumed our operator's frequencies are from 1 to 60.

This is a brief example of capacity issues for a system in Lefkoşa City where we expect 20.000 subscribers.

Available Spectrum : 60x200 KHz carriers in the GSM 900 band .

Usage of the Carriers: 2 time slots for BCCH+SDCCH.

Traffic: 25 mE per subscriber.

Blocking Rate : 2 % (erlang table)

Type of Sites: All sites are sectorized with maximum configuration S4/4/4.

We will use only sectorized sites because, our area is city centre. We will need optimization. For example; Down Tilt or Up Tilt etc.

The above calculations are based in a uniform geographical traffic distribution. A more realistic situation may look like: **Total 20.000 subscribers;**

Table 5.1 Carriers, TCH, Erlang, Subscribers.

CARRIERS	TCH	ERLANG	SUBSCRIBERS
2	14	8.20	328
3	22	14.90	596
4	30	21.93	887

10.000 subscribers for area A :

Number of BTS (S4/4/4) = 10.000/(887x3) ≅ 4

8.000 subscribers for area B:

Number of BTS (S3/3/3) = 8.000/(596x3) ≅ 5

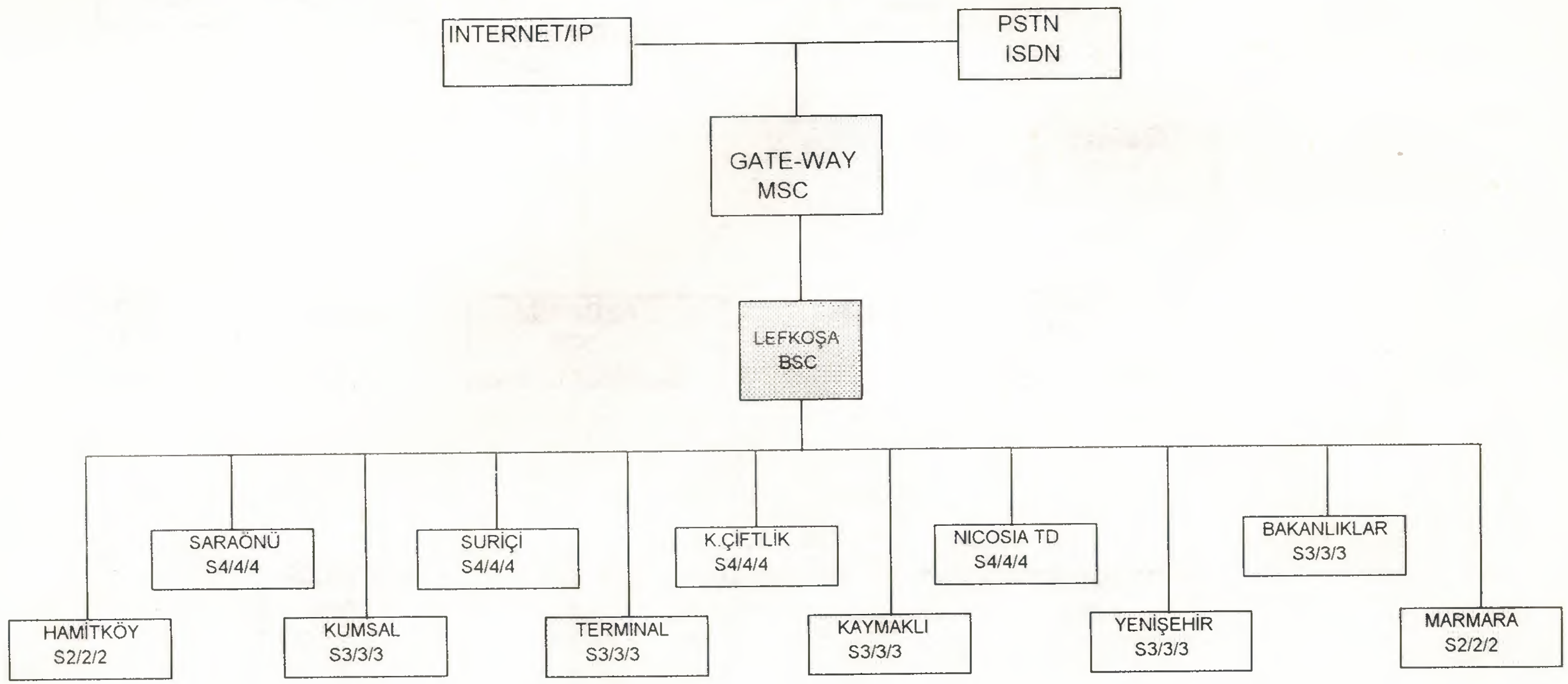
2.000 subscribers for area C:

Number of BTS (S2/2/2) = 2.000/(328x3) ≅ 2

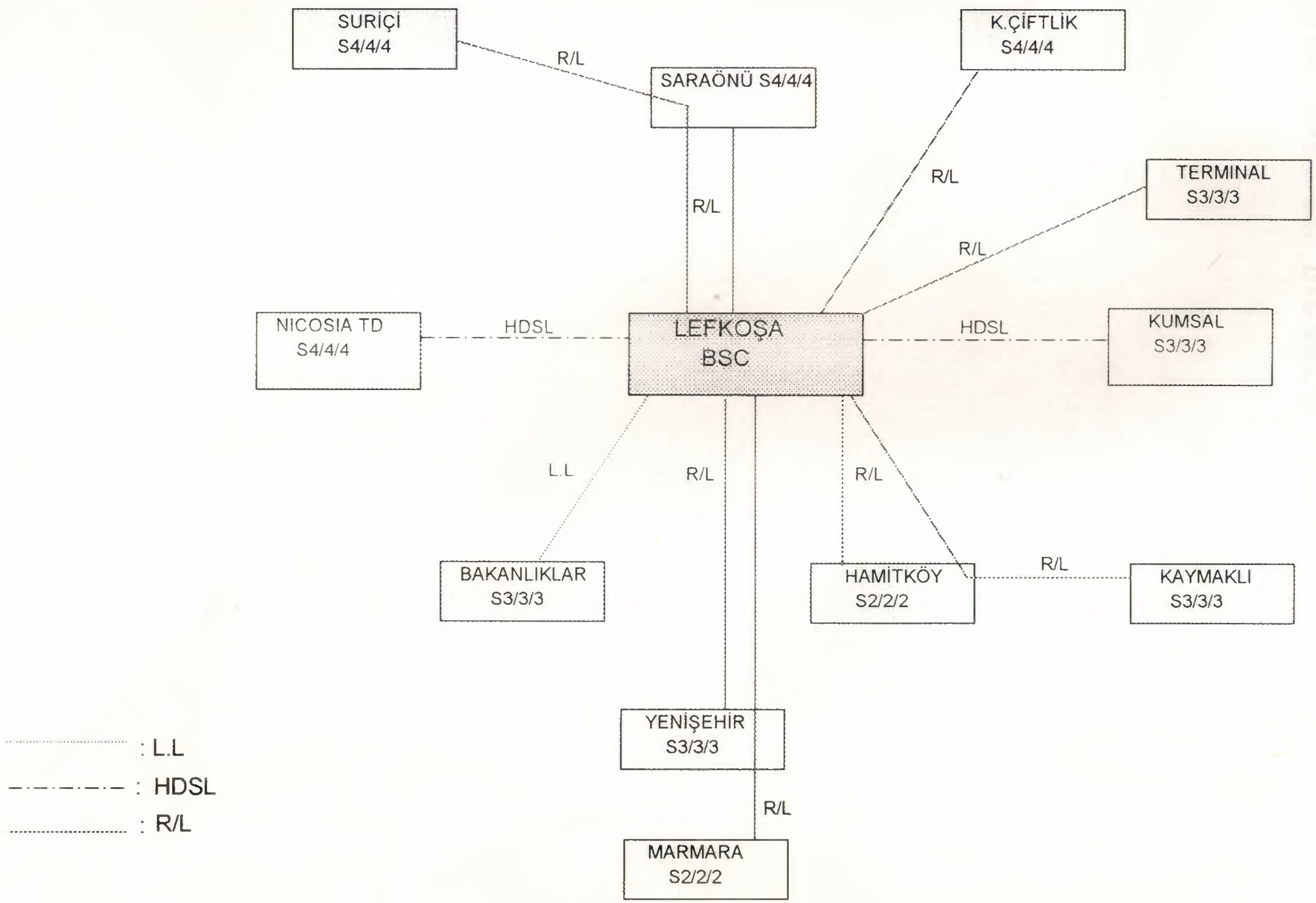
DATABASE OF LEFKOŞA CITY NETWORK

NO	SITE NAME	CELL NAME	CONFIGURATION	CELL ID.	LACOD	BSC NAME	BSIC	BCCH ARFCN-1	ARFCN-2	ARFCN-3	ARFCN-4	ANGLES	TILTS	Neighbour-1	Neighbour-2	Neighbour-3	Neighbour-4	Neighbour-5	Neighbour-6	Neighbour-7
1	SURİÇİ	SURİÇİ-1	S4	XXX11	12345	LEFKOŞA	10	56	59	2	5	5°	10°	SURİÇİ-2	SURİÇİ-3	NICOSIATD-2	TERMINAL-1			
2	SURİÇİ	SURİÇİ-2	S4	XXX12	12345	LEFKOŞA	10	45	48	51	54	110°	0°	SURİÇİ-1	SURİÇİ-3	SARAYÖNÜ-1				
3	SURİÇİ	SURİÇİ-3	S4	XXX13	12345	LEFKOŞA	10	34	37	40	43	280°	6°	SURİÇİ-1	SURİÇİ-2	SARAYÖNÜ-3	K.ÇIFTLIK-2	SARAYÖNÜ-1	NICOSIATD-2	
4	SARAYÖNÜ	SARAYÖNÜ-1	S4	XXX21	12345	LEFKOŞA	11	12	15	18	21	70°	0°	SARAYÖNÜ-2	SARAYÖNÜ-3	SURİÇİ-2	SURİÇİ-3			
5	SARAYÖNÜ	SARAYÖNÜ-2	S4	XXX22	12345	LEFKOŞA	11	1	4	7	10	270°	0°	SARAYÖNÜ-1	SARAYÖNÜ-3	K.ÇIFTLIK-2				
6	SARAYÖNÜ	SARAYÖNÜ-3	S4	XXX23	12345	LEFKOŞA	11	23	26	29	32	345°	8°	SARAYÖNÜ-1	SARAYÖNÜ-2	SURİÇİ-3	NICOSIATD-2			
7	NICOSIATD	NICOSIATD-1	S4	XXX31	12345	LEFKOŞA	12	1	4	7	10	50°	10°	NICOSIATD-2	NICOSIATD-3	TERMINAL-1	TERMINAL-2	KAYMAKLI-2		
8	NICOSIATD	NICOSIATD-2	S4	XXX32	12345	LEFKOŞA	12	46	49	52	24	165°	10°	NICOSIATD-1	NICOSIATD-3	SURİÇİ-1	SURİÇİ-3	SARAYÖNÜ-3	K.ÇIFTLIK-1	KUMSAL-1
9	NICOSIATD	NICOSIATD-3	S4	XXX33	12345	LEFKOŞA	12	35	38	41	44	285°	10°	NICOSIATD-1	NICOSIATD-2	K.ÇIFTLIK-1	KAYMAKLI-2	KUMSAL-1		
10	TERMINAL	TERMINAL-1	S3	XXX41	12345	LEFKOŞA	10	54	57	60		175°	0°	TERMINAL-2	TERMINAL-3	NICOSIATD-1				
11	TERMINAL	TERMINAL-2	S3	XXX42	12345	LEFKOŞA	10	14	17	20		280°	8°	TERMINAL-1	TERMINAL-3	NICOSIATD-1	KAYMAKLI-1	KAYMAKLI-2	SURİÇİ-1	
12	TERMINAL	TERMINAL-3	S3	XXX43	12345	LEFKOŞA	10	23	26	29		355°	0°	TERMINAL-1	TERMINAL-2	HAMİTKÖY-2	HAMİTKÖY-3	KAYMAKLI-1		
13	K.ÇIFTLIK	K.ÇIFTLIK-1	S4	XXX51	12345	LEFKOŞA	14	12	15	18	21	40°	12°	K.ÇIFTLIK-2	K.ÇIFTLIK-3	NICOSIATD-2	NICOSIATD-3	KUMSAL-1		
14	K.ÇIFTLIK	K.ÇIFTLIK-2	S4	XXX52	12345	LEFKOŞA	14	60	57	41	38	175°	0°	K.ÇIFTLIK-1	K.ÇIFTLIK-3	SARAYÖNÜ-2	SURİÇİ-3			
15	K.ÇIFTLIK	K.ÇIFTLIK-3	S4	XXX53	12345	LEFKOŞA	14	45	48	51	54	320°	5°	K.ÇIFTLIK-1	K.ÇIFTLIK-2	KUMSAL-2				
16	BAKANLIK	BAKANLIK-1	S3	XXX61	12345	LEFKOŞA	11	14	17	20		50°	15°	BAKANLIK-2	BAKANLIK-3	Y.ŞEHİR-2	Y.ŞEHIR-3	KUMSAL-3		
17	BAKANLIK	BAKANLIK-2	S3	XXX62	12345	LEFKOŞA	11	2	5	8		150°	10°	BAKANLIK-1	BAKANLIK-3	KUMSAL-2	KUMSAL-3	Y.ŞEHİR-2		
18	BAKANLIK	BAKANLIK-3	S3	XXX63	12345	LEFKOŞA	11	54	57	60		300°	0°	BAKANLIK-1	BAKANLIK-2	MARMARA-2				
19	KUMSAL	KUMSAL-1	S3	XXX71	12345	LEFKOŞA	13	22	25	28		130°	15°	KUMSAL-2	KUMSAL-3	NICOSIATD-2	NICOSIATD-3	K.ÇIFTLIK-1		
20	KUMSAL	KUMSAL-2	S3	XXX72	12345	LEFKOŞA	13	30	33	36		240°	5°	KUMSAL-1	KUMSAL-3	K.ÇIFTLIK-3	BAKANLIK-2			
21	KUMSAL	KUMSAL-3	S3	XXX73	12345	LEFKOŞA	13	46	49	52		345°	10°	KUMSAL-1	KUMSAL-2	Y.ŞEHİR-2	BAKANLIK-1	BAKANLIK-2		
22	KAYMAKLI	KAYMAKLI-1	S3	XXX81	12345	LEFKOŞA	12	2	5	8		55°	4°	KAYMAKLI-2	KAYMAKLI-3	HAMİTKÖY-2	HAMİTKÖY-3	TERMINAL-2	TERMINAL-3	
23	KAYMAKLI	KAYMAKLI-2	S3	XXX82	12345	LEFKOŞA	12	12	15	18		190°	12°	KAYMAKLI-1	KAYMAKLI-3	NICOSIATD-1	NICOSIATD-3	TERMINAL-2	Y.ŞEHİR-2	
24	KAYMAKLI	KAYMAKLI-3	S3	XXX83	12345	LEFKOŞA	12	54	57	60		320°	15°	KAYMAKLI-1	KAYMAKLI-2	Y.ŞEHİR-1	Y.ŞEHİR-2	HAMİTKÖY-3		
25	Y.ŞEHİR	Y.ŞEHİR-1	S3	XXX91	12345	LEFKOŞA	11	1	4	7	10	50°	0°	Y.ŞEHİR-2	Y.ŞEHİR-3	HAMİTKÖY-3	KAYMAKLI-3	HAMİTKÖY-1	MARMARA-1	
26	Y.ŞEHİR	Y.ŞEHİR-2	S3	XXX92	12345	LEFKOŞA	11	23	26	29		160°	15°	Y.ŞEHİR-1	Y.ŞEHİR-3	KAYMAKLI-3	BAKANLIK-1	KUMSAL-3	KAYMAKLI-2	BAKANLIK-2
27	Y.ŞEHİR	Y.ŞEHİR-3	S3	XXX93	12345	LEFKOŞA	11	38	41	44		300°	15°	Y.ŞEHİR-1	Y.ŞEHİR-2	MARMARA-1	MARMARA-2	BAKANLIK-1		
28	MARMARA	MARMARA-1	S2	XX111	12345	LEFKOŞA	10	25	28			120°	12°	MARMARA-2	MARMARA-3	Y.ŞEHİR-1	Y.ŞEHİR-3			
29	MARMARA	MARMARA-2	S2	XX112	12345	LEFKOŞA	10	30	33			220°	12°	MARMARA-1	MARMARA-3	BAKANLIK-3	Y.ŞEHİR-3			
30	MARMARA	MARMARA-3	S2	XX113	12345	LEFKOŞA	10	20	23			350°	0°	MARMARA-1	MARMARA-2					
31	HAMİTKÖY	HAMİTKÖY-1	S2	XX121	12345	LEFKOŞA	13	30	33			0°	0°	HAMİTKÖY-2	HAMİTKÖY-3	Y.ŞEHİR-1				
32	HAMİTKÖY	HAMİTKÖY-2	S2	XX122	12345	LEFKOŞA	13	41	44			140°	0°	HAMİTKÖY-1	HAMİTKÖY-3	TERMINAL-3	KAYMAKLI-1			
33	HAMİTKÖY	HAMİTKÖY-3	S2	XX123	12345	LEFKOŞA	13	35	38			230°	12°	HAMİTKÖY-1	HAMİTKÖY-2	KAYMAKLI-1	KAYMAKLI-3	Y.ŞEHİR-1	TERMINAL-3	

NETWORK CONFIGURATION



LEFKOŞA BSC TRANSMISSION PLAN



5.3 Summary

We discussed about cell planning for the 20.000 subscribers in Lefkoşa City Centre. The number of sites calculated carriers, cells for this scenario. We prepared database of Lefkoşa City network, network configuration and transmission plans are designed. We calculated for number of BSC, BTS, sites, cells and TRX.

CONCLUSION

Basis of GSM architecture MSC, BSS, MS and OMC were presented principle of operation of Base Station Controller (BSC), and transceiver (TRX), Mobile Switching Centre, Home Location Register (HLR) and Mobile Station (MS) were described. Mobility management and mobile authentication procedure were provided.

Chapter 1 We analysed fundamental of mobile communication system and GSM entities, radio wave propagation effect of urban and environment area on propagation were considered. The effects such as shadowing, fading, reflection, diffraction and scattering, that yield multipath propagations were analysed.

Chapter 2 We decided that use only sektor cell type. Because we planned for city centre area. We could not omni cell, micro cell, cell splitting corporate cell, pico cell.

Chapter 3 Description of GSM frames, channels structures traffic, control and signalling channels were discussed. GSM encryption methods, authentication privacy were examined.

Chapter 4 is very important chapter. This chapter is given information about cellular radio network planning, coverage planning, capacity planning, micro cell planningi frequency planning parameter planning, optimisation and network measurements.

Chapter 5 Cell planning procedure is performed for 20.000 subscribers using real map of Lefkoşa City. Planning is based on GSM 900. Using available spectrum (60x200KHz), traffic load (0,025 Erlang), blocking rate (0,02), sectorized type sites (S444) configurations, BSC transmission plan, database and network architecture were developed.

Analysis of the cell planning results was recommended for Lefkoşa having 20.000 subscribers. We need 33 cells, 11 sites, 105 TRX.

- We calculated number of BSC, BTS, Sites, Cells and TRX. These results are enough for good coverage and capacity.
- We used sektör cells. This type is the best for city areas. We could not use omni cell in city centre. We decided sektör angles and configurations of cells.

- This network is achived good coverage (specially indoor), capacity and good quality of service.
- Our network is the cheapest. Because, we could cover all of Lefkoşa City with 11 sites, 33 cells and 105 TRX. We used suitable high gain antennas and mounting equipments. We used 20W power of BTS's combiner output. So, we don't need more number of sites, cells and TRX.
- We made a ideal plan for transmission.
- Good frequency planning in this network. There is no interference area.
- We selected suitable sites locations on the Lefkoşa City Centre map.

Calculations presents the significant results, my contribution and future investigations.

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SITE LOCATIONS ON THE LEFKOŞA CITY MAP