DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

WCDMA (WIDEBAND CODE DIVISION MULTIPLE ACCESS) RADIO NETWORK

by
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June, 2009
İZMİR

WCDMA (WIDEBAND CODE DIVISION MULTIPLE ACCESS) RADIO NETWORK

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"WCDMA (WIDEBAND CODE DIVISION MULTIPLE ACCESS) RADIO NETWORK"** completed by **EMRE BAŞARAN** under supervision of **ASST. PROF. DR. ZAFER DİCLE** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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I would like to thank to my family and my friends for their never ending support throughout my life.

Emre BAŞARAN

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ABSTRACT

With the mobile technologies getting in our lives, the humans have not only sent voice with their mobile phone but also have wanted to benefit from the multimedia applications as receiving data services with their mobile phone.

Data rate level per user supplied by radio network has also increased in proportion to the user's desires. By getting the third generation communication system, the data in high speeds can be downloaded and inter active multimedia applications will also start to be used efficiently.

For the radio networks behind the mobile technologies planned well is the most important factor effect the coverage, capacity, and quality. It can be provided for the users to access network with high speeds wherever they are under coverage of a well planned radio network. While planning radio network, it is important to reach the demanded capacity, coverage and quality values with the possible minimum base station.

In this study, number of the stations needed for the radio network should be specified with the determined target coverage, capacity and quality values, and in order to place the points in holding the maximum level of radio network quality of these specified base stations about third generetion radio network city planing sample is done.

Keywords: WCDMA, third generation, radio network desing

WCDMA (GENİŞ BAND BÖLMELİ ÇOKLU ERİŞİM) RADYO ŞEBEKESİ

ÖZ

Mobil teknolojilerin hayatımıza girmesi ile insanların telefonları ile sadece ses iletimi yapmayıp telefonları aracılığı ile data hizmetlerini alıp çoklu ortam uygulamalarından faydalanma istekleri ortaya çıkmıştır.

Kullanıcıların istekleri ile orantılı olarak radyo şebekesinin kullanıcı başına sağladığı hız seviyesi de artmaktadır. 3. nesil haberleşme sistemlerinin hayatımıza girmesi ile yüksek hızlarda data indirilebilmekte ve inter aktif çoklu ortam uygulamalarıda etkin bir biçimde kulanılmaya başlanacaktır.

Mobil teknolojilerin arkasında bulunan radyo şebekelerinin iyi planlanmış olması kullanıcıların kapasite, kapsama ve kalitesini etkileyen en önemli faktördür. İyi planlanmış bir radyo şebeke ile kullanıcıların yüksek hızlarda her bulundukları ortamda şebekeye erişimleri sağlanabilir. Radyo şebekesini planlarken hedeflenen kapsama, kalite ve kapasite değerlerine mümkün olan en az istayon ile ulaşabilmek önemlidir.

Bu çalışmada, hedef olarak belirlenen kapsama, kalite ve kapasite değerleri ışığında oluşturulan radyo şebekesi için gerekli olan istasyon sayıları belirlenip, bu belirlenen istasyonların radyo şebeke kalitesini en üst düzeyde tutacak noktalara yerleştirilmesi konusunda teorik 3. nesil radyo şebeke şehir planlama örneği yapılmıştır.

Anahtar sözcükler: WCDMA, üçüncü nesil, radyo şebeke dizayn

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CHAPTER ONE

INTRODUCTION

1.1 The Growth Of Mobile Communications

Today wireless voice service is one of the most convenient and flexible means of modern communications. GSM technology has been at the leading edge of this wireless revolution. It is the technology of choice in over 120 countries and for more than 200 operators worldwide. Current estimates are that by the year 2001 there will be around 600 million wireless subscribers (e.g. mobile telephone users), out of which more than 50% will depend on GSM technology. As the wireless revolution has been unfolding, the Internet has also shown a phenomenal growth simultaneously. The advent of the World Wide Web and web browsers has propelled TCP/IP protocols into the main stream, and the Internet is widespread not only in the corporate environment but also in households. Large number of consumers have embraced the Internet and use it today to access information online, for interactive business transactions, and e-commerce as well as electronic mail. Figure 1.1 illustrates the growth in mobile and Internet subscribers.

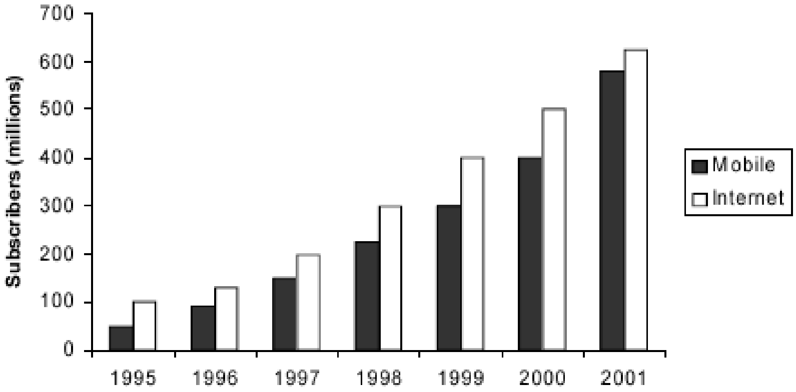


Figure 1.1 The growth of mobile and internet services.

The success of mobile communications, i.e. the ubiquitous presence it has established and the emergence of the Internet point towards a tremendous opportunity to offer integrated services through a wireless network. One of the main market segments for wireless services besides corporate intranet / internet access is the consumer sector. The availability of intelligent terminals or multipurpose wireless telephones is already ushering a new era of the information age, where subscribers can receive directly through GSM-SMS: news, sport updates, stock quotes, etc. However, the progress of audiovisual techniques and the support for a Weblike interface in a new generation of terminals, will push consumers to a new era of multimedia communications with a focus on services rather than technology. To support the growth of Internet type services and future demands for wireless services, ETSI SMG and other standards bodies have completed or are now completing specifications to provide a transition platform or evolution path for wireless Networks like GSM.

The technology options in Figure 1.2 can be summarized as follows:

- 14.4 kbits/s allows GSM data calls with a rate of 14.4 kbits/s per time slot, resulting in a 50% higher data throughput compared to the current maximum speed of 9.6 kbits/s.
- High Speed Circuit Switched Data (HSCSD) aggregates symmetrically or asymmetrically several circuit channels, e.g. 28,8 kbits/s for two time slots (2 + 2) or 43,2 kbits/s for three time slots (3 + 1).
- General Packet Radio Service (GPRS) enables GSM with Internet access at high spectrum efficiency by sharing time slots between different users. It affords data rates of over 100 kbits/s to a single user while offering direct IP connectivity. Enhanced Data Rate for GSM Evolution (EDGE) modifies the radio link modulation scheme from GMSK to 8QPSK. There by increasing by three times the GSM throughput using the same bandwidth. EDGE in combination with GPRS (EGPRS) will deliver single user data rates of over 300 kbits/s.
- UMTS as 3rd generation wireless technology utilizes a Wideband CDMA or TD/CDMA transceiver. Starting with channel bandwidths of 5 MHz it will offer data rates up to 2 Mbits/s. UMTS will use new spectrum and new radio network configurations while using the GSM core infrastructure.

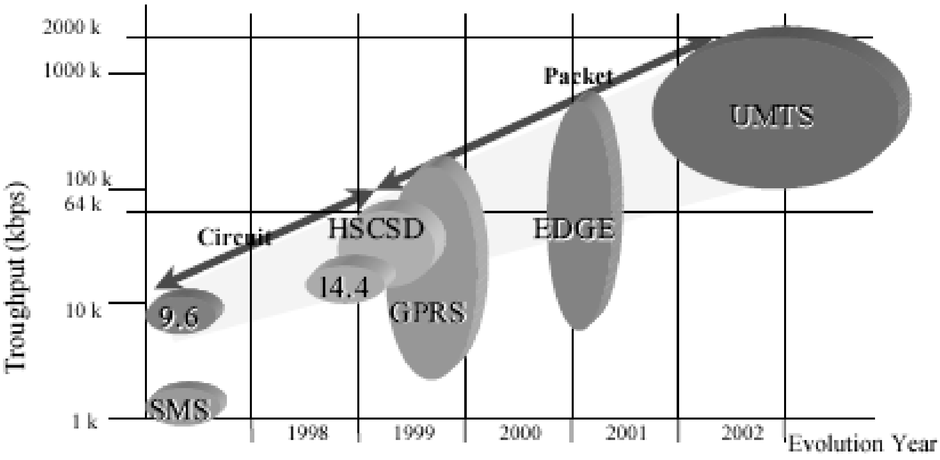


Figure 1.2 Evolution for wireless networks, e.g. GSM.

Although the circuit switched enhancements such as HSCSD will increase transmission rates, it is packet switched enhancements, which will meet the challenges or demands posed on current wireless networks. Thus, GPRS and UMTS with EDGE as an intermediate solution will provide the platform to support integrated services of voice and data including multimedia.

While GPRS and UMTS meet the demands for Internet (IP) features and higher bandwidths in mobile networks, another evolution step is taking place in the network infrastructure. This is the convergence of single networks into a multi-purpose backbone network.

1.2 WCDMA in Third Generation Systems

Analog cellular systems are commonly referred to as first generation systems. The digital systems currently in use, such as GSM, PDC, cdmaOne (IS–95) and US-TDMA (IS-136), are second generation systems. These systems have enabled voice communications to go wireless in many of the leading markets, and customers are increasingly finding value also in other services, such as text messaging and access to data networks, which are starting to grow rapidly.

Third generation systems are designed for multimedia communication: with them person to person communication can be enhanced with high quality images and video, and access to information and services on public and private networks will be enhanced by the higher data rates and new flexible communication capabilities of third generation systems. This, together with the continuing evolution of the second generation systems, will create new business opportunities not only for manufacturers and operators, but also for the providers of content and applications using these networks.

In the standardisation forums, WCDMA technology has emerged as the most widely adopted third generation air interface. Its specification has been created in 3GPP (the 3rd Generation Partnership Project), which is the joint standardisation project of the standardisation bodies from Europe, Japan, Korea, the USA and China. Within 3GPP, WCDMA is called UTRA (Universal Terrestrial Radio Access) FDD (Frequency Division Duplex) and TDD (Time Division Duplex), the name WCDMA being used to cover both FDD and TDD operation. Throughout this book, the chapters related to specifications use the 3GPP terms UTRA FDD and TDD, the others using the term WCDMA. This book focuses on the WCDMA FDD technology.

1.3 Air Interfaces and Spectrum Allocations for Third Generation Systems

Work to develop third generation mobile systems started when the World Administrative Radio Conference (WARC) of the ITU (International Telecommunications Union), at its 1992 meeting, identified the frequencies around 2 GHz that were available for use by future third generation mobile systems, both terrestrial and satellite. Within the ITU these third generation systems are called International Mobile Telephony 2000 (IMT–2000). Within the IMT–2000 framework, several different air interfaces are defined for third generation systems, based on either CDMA or TDMA technology. The original target of the third generation process was a single common global IMT–2000 air interface. Third generation systems are closer to this target than were second generation systems: the same air interface – WCDMA – is to be used in Europe and Asia, including Japan and Korea, using the frequency bands that WARC–92 allocated for the third generation IMT–2000 system at around 2 GHz. In North America, however, that spectrum has already been auctioned for operators using second generation systems, and no new spectrum is available for IMT–2000. Thus, third generation services there must be implemented within the existing bands, and also WCDMA can be deployed in the existing band in North America. The global IMT–2000 spectrum is not available in countries that follow the US PCS spectrum allocation. Some of the Latin American countries, like Brazil, plan to follow the European spectrum allocation at 2 GHz. In addition to WCDMA, the other air interfaces that can be used to provide third generation services are EDGE and cdma2000. EDGE (Enhanced Data Rates for GSM Evolution) can provide third generation services with bit rates up to 500 kbps within a GSM carrier spacing of 200 kHz. EDGE includes advanced features that are not part of GSM to improve spectrum efficiency and to support the new services. cdma2000 can be used as an upgrade solution for the existing IS–95 operators and will be presented. The expected frequency bands and geographical areas where these different air interfaces are likely to be applied are shown in Figure 1.3. Within each region there are local exceptions in places where multiple technologies are already being deployed.

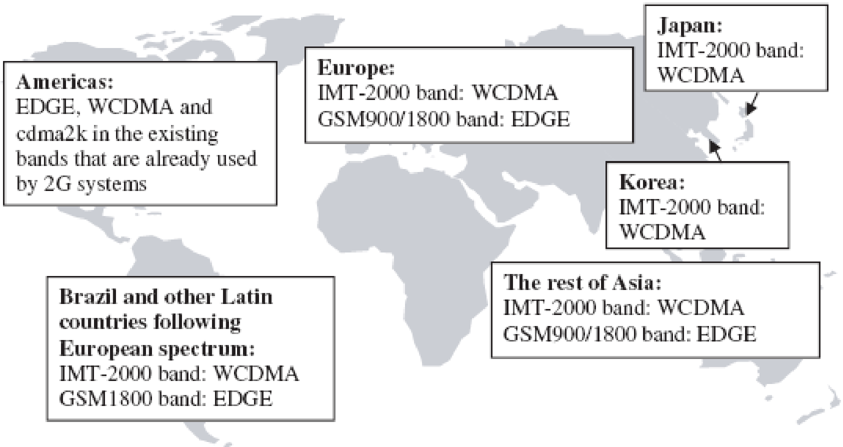


Figure 1.3 Expected air interfaces and spectrums for providing third generation services

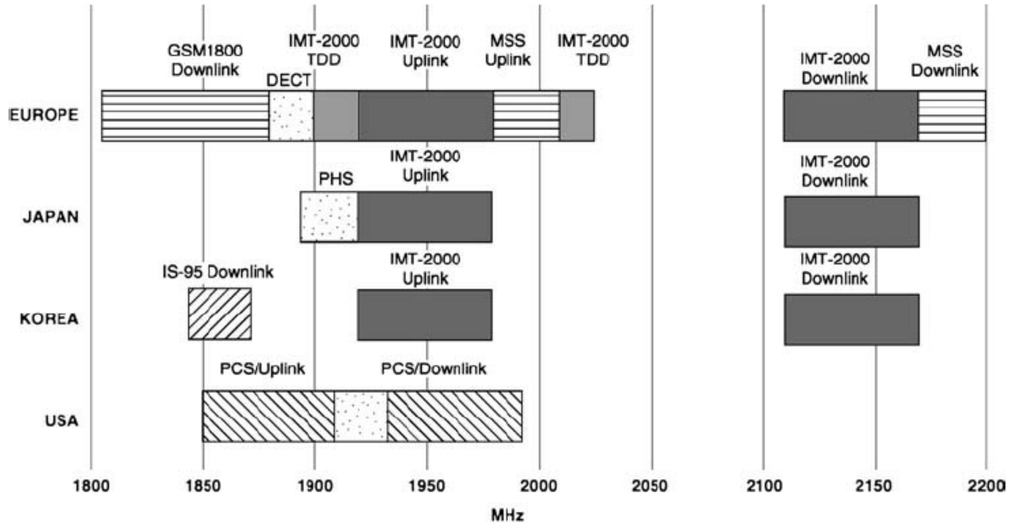


Figure 1.4 2 GHz band spectrum allocation in Europe, Japan, Korea and USA (MSS ¼ mobile satellite spectrum)

The spectrum allocation in Europe, Japan, Korea and the USA is shown in Figure 1.4 and in Table 1.1. In Europe and in most of Asia the IMT–2000 (or WARC–92) bands of 2 _ 60 MHz (1920–1980 MHz plus 2110–2170 MHz) will be available for WCDMA FDD. The availability of the TDD spectrum varies: in Europe it is expected that 25 MHz will be available for licensed TDD use in the 1900–1920 MHz and 2020–2025 MHz bands. The rest of the unpaired spectrum is expected to be used for unlicensed TDD applications (SPA: Self Provided Applications) in the 2010–2020 MHz band. FDD systems use different frequency bands for uplink and for downlink, separated by the duplex distance, while TDD systems utilise the same frequency for both uplink and downlink.

Table 1.1 Existing frequency allocations around 2 GHz

	Uplink	Downlink	Total
GSM 1800	1710-1785	1805-1880	2x75 MHz
UMTS-FDD	1920-1980	2110-2170	2x60 MHz
UMTS-TDD	1900-1920	2010-2025	20+15 MHz
Americas PCS	1850-1910	1930-1990	2x60 MHz

Also in Japan and Korea, as in the rest of Asia, the WARC–92 bands will be made available for IMT–2000. Japan has deployed PDC as a second generation system, while in Korea, IS–95 is used for both cellular and PCS operation. The PCS spectrum allocation in Korea is different from the US PCS spectrum allocation, leaving the IMT–2000 spectrum fully available in Korea. In Japan, part of the IMT–2000 TDD spectrum is used by PHS, the cordless telephone system. In China, there are reservations for PCS or WLL (Wireless Local Loop) use on one part of the IMT–2000 spectrum, though these have not been assigned to any operators. Depending on the regulation decisions, up to 2 _ 60 MHz of the IMT–2000 spectrum will be available for WCDMA FDD use in China. The TDD spectrum will also be made available in China. In the USA no new spectrum has yet been made available for third generation systems. Third generation services can be implemented within the existing PCS spectrum. For the US PCS band, all third generation alternatives can be considered: EDGE, WCDMA and cdma2k. EDGE can be deployed within the existing GSM900 and GSM1800 frequencies where those frequencies are in use. These GSM frequencies are not available in Korea and Japan. The total band available for GSM900 operation is 2 _ 25 MHz plus EGSM 2 _ 10 MHz, and for GSM1800 operation, 2 _ 75 MHz. EGSM refers to the extension of the GSM900 band. The total GSM band is not available in all countries using the GSM system. The first IMT–2000 licences were granted in Finland in March 1999, and followed by Spain in March 2000. No auction was conducted in Finland or in Spain. Also, Sweden granted the licenses without auction in December 2000. However, in other countries, such as the UK, Germany and Italy, an auction similar to the US PCS spectrum auctions was conducted.

1.4 Differences between WCDMA and Second Generation Air Interfaces

GSM and IS–95 (the standard for cdmaOne systems) are the second generation air interfaces considered here. Other second generation air interfaces are PDC in Japan and US-TDMA mainly in the Americas; these are based on TDMA (time division multiple access) and have more similarities with GSM than with IS–95. The second generation systems were built mainly to provide speech services in macro cells. To understand the background to the differences between second and third generation systems, we need to look at the new requirements of the third generation systems which are listed below:

- Bit rates up to 2 Mbps;
- Variable bit rate to offer bandwidth on demand;
- Multiplexing of services with different quality requirements on a single connection, e.g. speech, video and packet data;
- Delay requirements from delay-sensitive real time traffic to flexible best-effort packe data;
- Quality requirements from 10 % frame error rate to 10^{-6} bit error rate;
- Coexistence of second and third generation systems and inter system handovers for coverage enhancements and load balancing;
- Support of asymmetric uplink and downlink traffic, e.g. web browsing causes more loading to downlink than to uplink;
- High spectrum efficiency;
- Co-existence of FDD and TDD modes.

Table 1.2 lists the main differences between WCDMA and GSM. In this comparison only the air interface is considered. GSM also covers services and core network aspects, and this GSM platform will be used together with the WCDMA air interface.

Table 1.2 Main differences between WCDMA and GSM air interfaces

	WCDMA	GSM
Carrier Spacing	5 MHz	200 kHz
Frequency reuse factor	1	1-18
Power control frequency	1500Hz	2 Hz
Quality Control	Radio resource management algorithms	Network planning
Frequency diversity	5MHz bandwidth gives multipath diversity with rake receiver	Frequency hopping
Packet data	Load-based packet scheduling	Time slot based scheduling with GPRS
Downlink transmit diversity	Supported for improving downlink capacity	Not supported by the standart, but can be applied

CHAPTER TWO
MULTIPLE ACCESS TECHNOLOGIES OVERVIEW

In modern mobile communication systems coordination of simultaneous multiple access to the same or different frequency band and different radio access technology is necessary.

- FDMA (Frequency Division Multiple Access), users are separated by frequency.
- TDMA (Time Division Multiple Access), users are separated by time.
- CDMA (Code Division Multiple Access), users are separated by codes.

2.1 Frequency Division Multiple Access (FDMA)

Frequency Division Multiple Access (FDMA) is common in the first generation of mobile communication systems, so called analogue systems. The available spectrum in FDMA is divided into physical channels of equal bandwidth.

- Orthogonal in frequency within cell
- Narrow bandwidth per carrier
- Continuous transmission and reception
- No synchronization in time

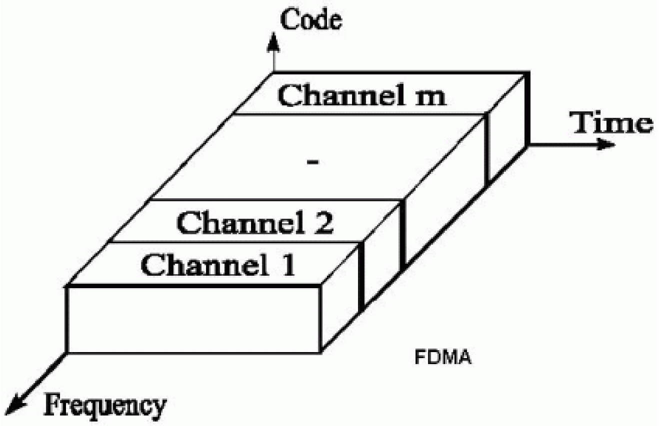


Figure 2.1 Frequency Division Multiple Access (FDMA)

One physical channel is allocated per subscriber. In pure FDMA systems, different speech/data/signaling (per subscriber) transmissions may be transmitted at the same time on different frequencies. The physical channel allocated to the subscriber is used during the entire duration of the call and is unavailable for other subscribers during that time. The physical channel is released at the end of the call and is then available for the next subscriber. In summary, in FDMA, narrow bandwidth is used for continuous transmission and reception, there is orthogonality in frequency within the cell, and no synchronization in time is needed.

2.2 Time Division Multiple Access (TDMA)

In TDMA, the available frequency is divided into units, which correspond to units of time, known as time slots. Each subscriber requiring resources is allocated a unit of time (time slot) during which they can transmit or receive data. The TDMA system is used in many second generation (2G) systems such as GSM and TDMA/D-AMPS.

Note: When discussing Time Division Multiple Access (TDMA) in this section, it is the access technique that is discussed and not the standard. TDMA that is used in for example GSM and TDMA/DAMPS. In TDMA, the available spectrum is divided in time into Time Slots (TSs).

- Orthogonal in time within cell
- Increased bandwidth per carrier
- Discontinuous transmission and reception
- Synchronization in time

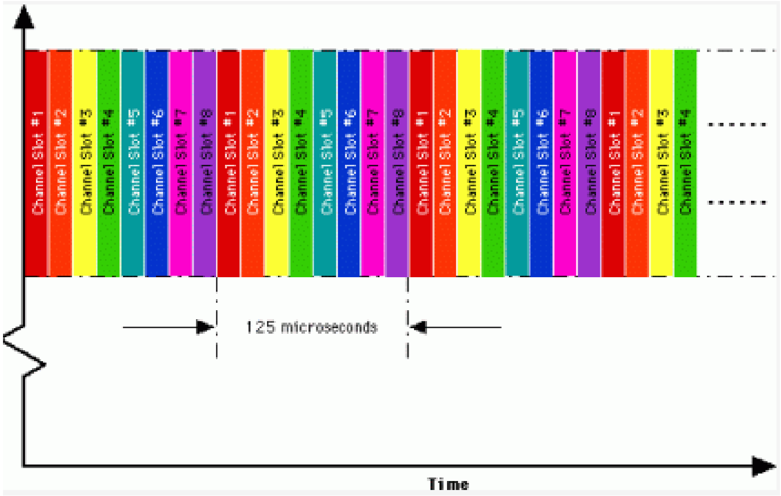


Figure 2.2 Time Division Multiple Access (TDMA)

The subscriber is allocated a TS and only that TS can be used during the time that is assigned to that subscriber. A physical channel in TDMA is defined as one TS and the subscriber has cyclical access to it. The subscriber information (speech, data or signaling) is divided up and transmitted, bit by bit, via the assigned TS. The high frequency transmission of each TS is called a burst. A TS is typically in the order of a millisecond. TDMA requires strict timing of the burst transmission in order to avoid overlapping of adjacent TSs. The time delay caused by the transmission of bursts is a problem in cellular systems with large cells. A very precise synchronization between the UE and the BS is required. ‘Timing Advance’ information and ‘Guard Periods’ between adjacent time slots prevent interference between bursts of adjacent TSs. In summary, in TDMA there is synchronization, increased bandwidth and increased peak power. The transmission and reception is discontinuous and there is also orthogonality in time within the cell.

2.3 Code Division Multiple Access (CDMA)

CDMA is a digital technique for sharing the frequency spectrum. It is a spread-spectrum technology that employs codes to separate users in the same frequency spectrum. CDMA is based on proven spread spectrum communications technology. The first commercial and most widely deployed CDMA implementation is cdmaOne CDMA systems based on the IS–95 standard. In CDMA, all subscribers share the same frequency at the same time within a cell, so there is a need to distinguish between the different calls or sessions. Direct Sequence Spread Spectrum (DSSS) technology is used to spread the spectrum, and in Direct Sequence CDMA (DS-CDMA), the information for each user is spread across the spectrum band using a unique code. Spreading means that the information is multiplied by codes. CDMA technology offers operators an answer to the capacity demands on their networks. Central to CDMA's capacity gains is its use of spread spectrum technology, which codes and spreads all conversations across a broad band of spectrum (1.25 MHz). This scheme allows a large number of users to simultaneously share the same 1.25 MHz carrier. This technique differs from that used to transmit voice and data over TDMA networks, which assigns each user a time slot in a narrow band of spectrum.

- Separate users through different codes
- Large bandwidth
- Continuous transmission and reception

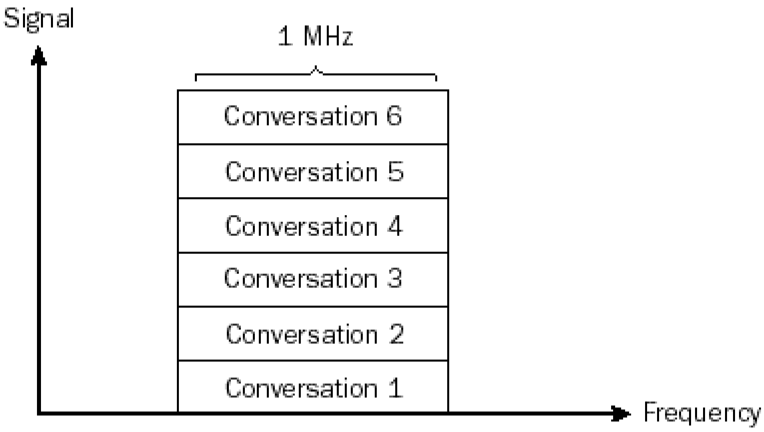


Figure 2.3 Direct Sequence Code-Division Multiple Access (DS-CDMA)

In DS-CDMA the carrier is modulated or spread using a digital code. Each primary information bit is coded with a chip sequence. The chip rate is much higher than the bit rate. The ratio between the bit rate and the chip rate is called the Spreading Factor (SF). The receiver must know the correct code sequence in order to extract a specific transmission from the signal sent within the used frequency range. This technology allows a narrowband signal to be spread several times creating a widebandsignal.

CHAPTER THREE

WIDEBAND CDMA (WCDMA)

WCDMA is based on DS-CDMA technology. Apart from high-bit rate services, (384 kbps wide area coverage and 2 Mbps local coverage) the WCDMA radio interface offers significant improvements over second-generation narrow band CDMA.

WCMDA offers:

- Improved coverage and capacity, thanks to greater bandwidth and improved coherent uplink detection. (5MHz bandwidth);
- Support for inter-frequency handover, which is necessary for large-capacity hierarchical cell structures (HCS);
- Support for capacity-enhancing technologies, such as adaptive antennas and multi-user detection;
- A fast and efficient packet-access protocol.

3.1 Advantages and Disadvantages of Spread Spectrum

There are advantages and disadvantages of using the spread spectrum technology in WCDMA.

Some of the many advantages are as follows:

- The wideband transmission has the advantage of being less sensitive to frequency selective interference and fading.
- The power density of the spectrum is decreased several times and the transfer of information is still possible even below background noise.
- CDMA is very spectrum efficient due to the possibility of reusing each carrier in each cell.
- There is no fixed capacity limit (number of users at the same time). The main limit is the increase in the level of interference from other subscribers, which reduces the quality of service.

- Soft handover is required in WCDMA. It is explained in more detail in the section on ‘Handover’. Some of the disadvantages associated with WCDMA are:
- The power levels of all UE’s transmissions received at the BS must be equal if the bit rates are equal and therefore fast power control is necessary.
- As UEs in soft handover mode require resources of more than one cell, the system capacity may be reduced.

3.2 Spreading Principles

Spreading in the WCDMA experimental system involes the use of short and long codes.

3.2.1 Spreading With Short and Long Codes

In advance of outlining the process of spreading , some basic terms will be reviewed as follows.

- A bit of information is a ‘1’ or a ‘0’ (binary) or a ‘-1’, ‘+1’ (bipolar).
- The user information bits are spread into a number of chips when it is “multiplied” with the spreading code. The chip rate for the system is constant 3.84 Mchip/s and the signal is spread into a bandwidth of approximately 5 MHz.
- The Spreading Factor (SF) is the ratio between the chip rate and the symbol rate. This is equal to the spreading gain (that is, the protection against interference).
- The same code is used for de-spreading the information after it is sent over the air interface, that is, both the UE and the BS use the same codes.

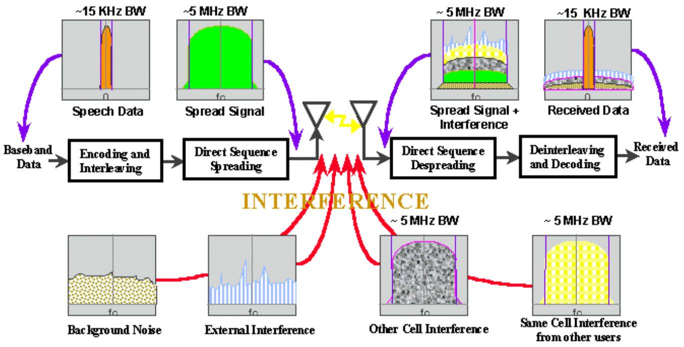


Figure 3.1 Overview of Spreading Process

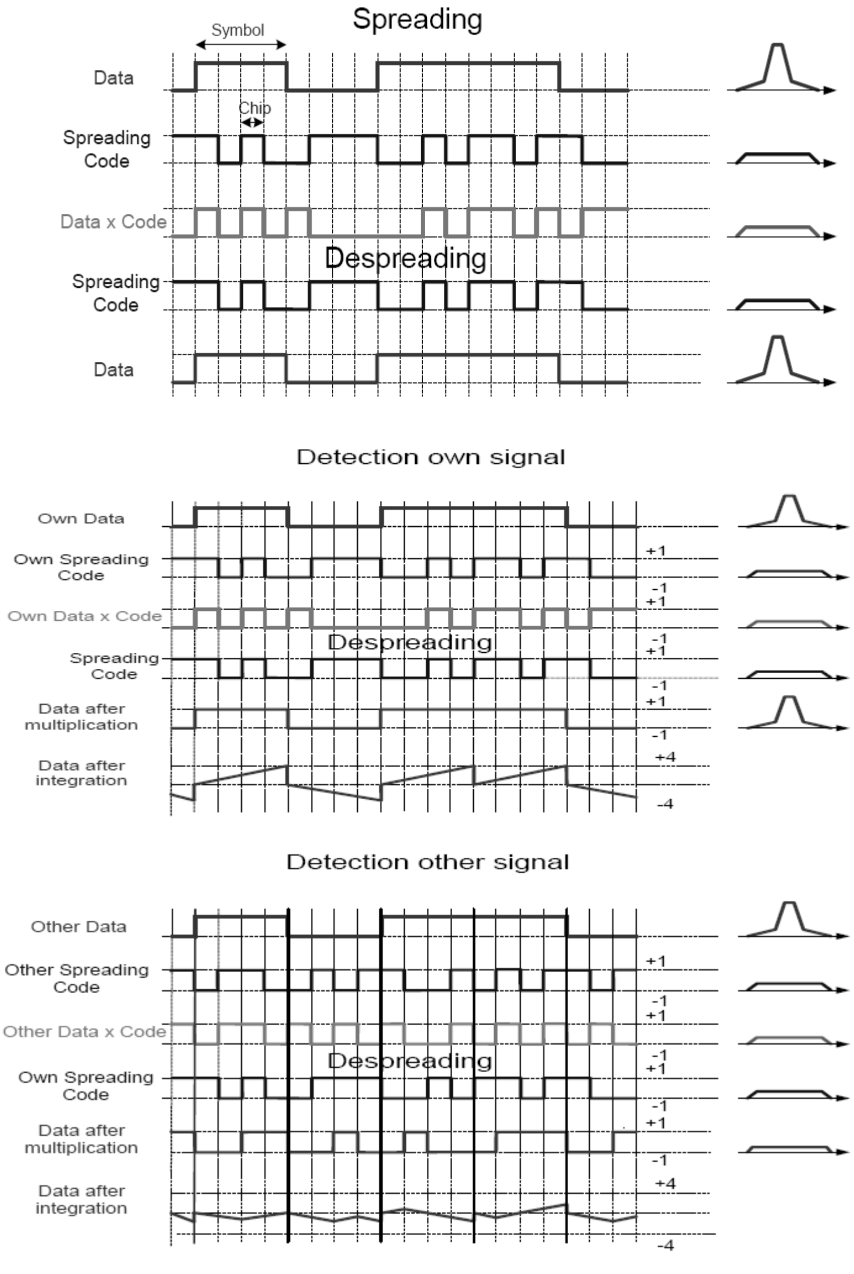


Figure 3.2 Spreading Process

3.2.2 Channelization Codes and Scrambling Codes

Scrambling codes are allocaded in UL and DL Gold seguences of diffirent lengths. All Node B and all UE have unique scrambling codes.

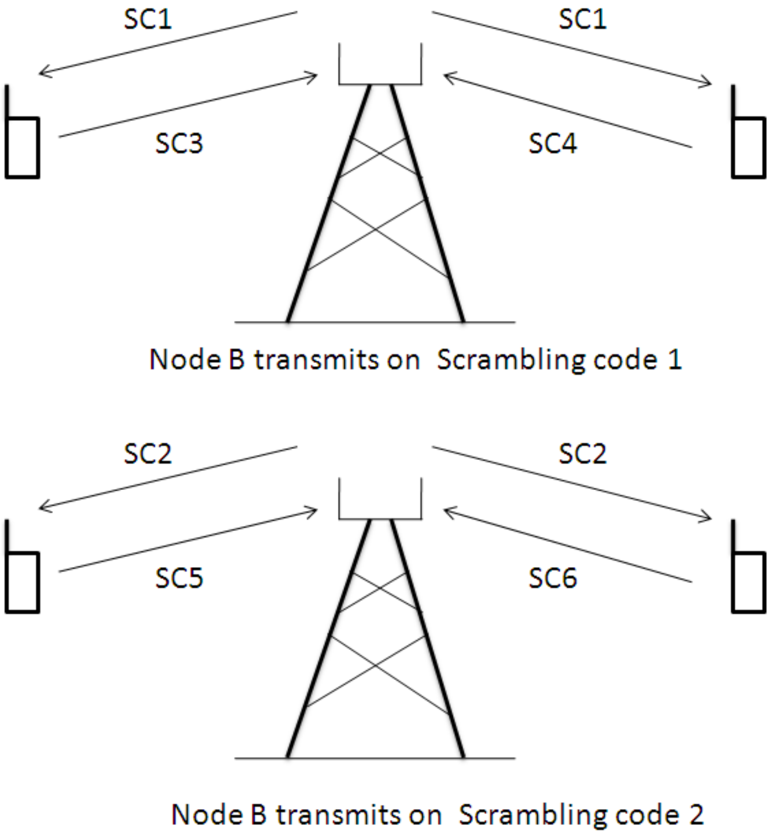
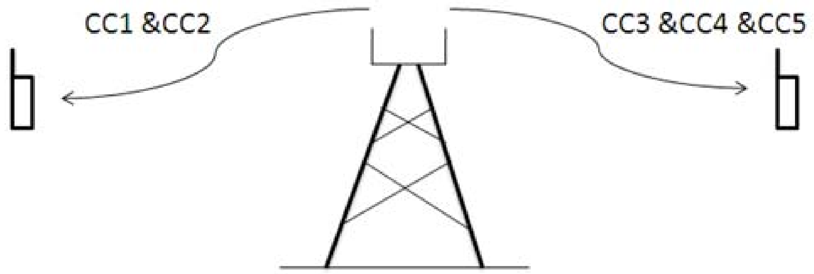


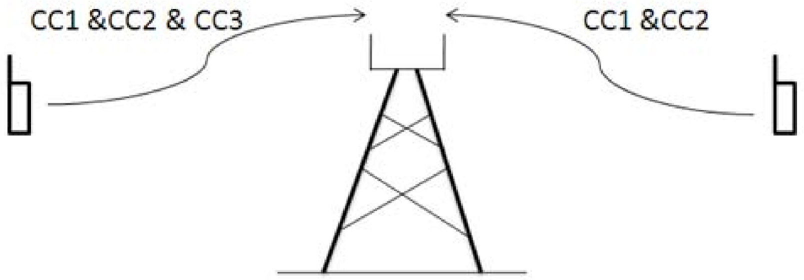
Figure 3.3 Scrambling Codes

The primary function of the scrambling codes in the WCDMA experimental system is to distinguish between all Node B and all UE. Good long codes shold have low out of phase autocorrelation peaks to maximize the probability of correct synchronization. The scrambling codes should also have low crosscorrelation peaks in order to minimize the interference different Node B and different UEs.

The channelization codes are used for the seperate diffirent logical channels that are using the same channelization code.



In the downlink orthoganal codes are used to distinguish between data channels from the base station



In the uplink orthoganal codes are used to distinguish between data channels from the same mobile

Figure 3.4 Channelization Codes (CC)

These channelization codes are mutually ortogonal which means that it is theoretically possible to seperate the logical channels at the receiver. Unfortunately due to multipath propagation it is not possible to do this fully Orthogonal code tree is shown below.

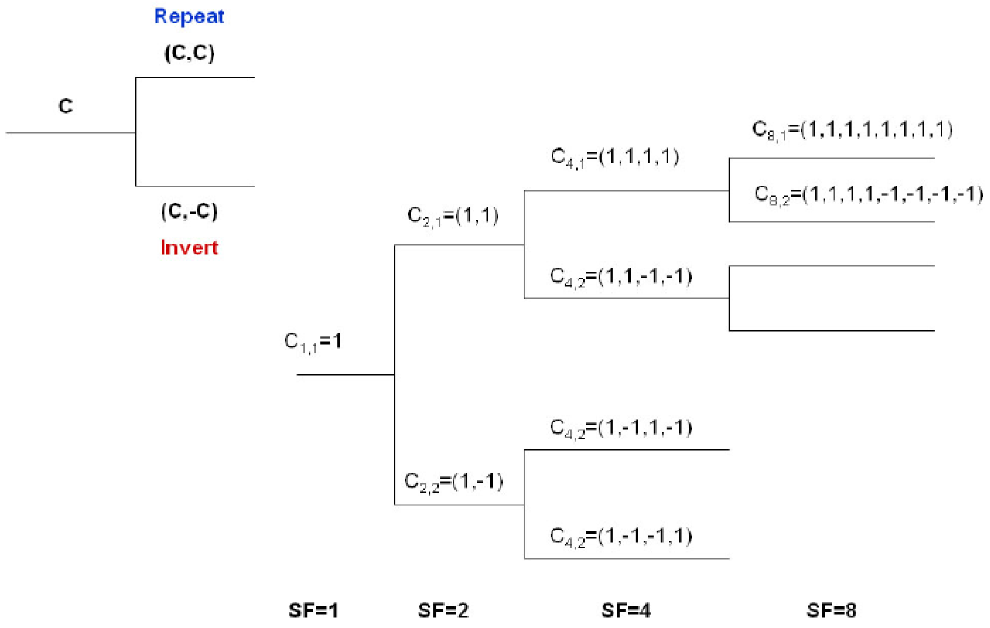


Figure 3.5 Generation of OVSF codes for different Spreading Factors.

Chanelization and scrambling codes are combined in the WCDMAexperimental system and are there used to spread the user data.

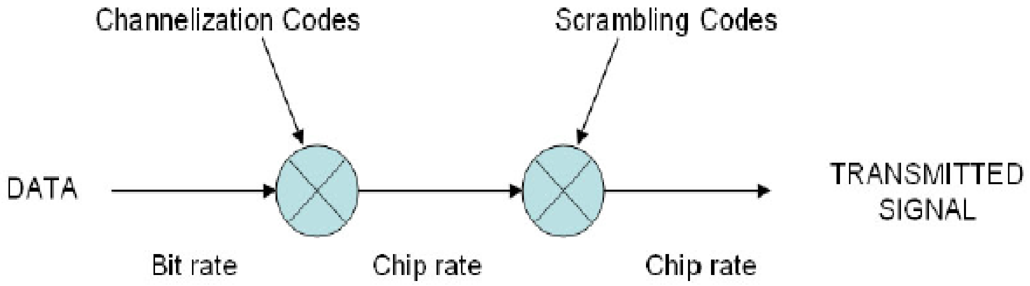


Figure 3.6 Relationship between spreading and scrambling.

The rate of both the chanelization and scrambling codes generators is 3.84 Mchips/s while thr rate of the data varies between 16 ksps and 256 ksps.

Table 3.1 User Bit-rate and Spreading Factors

User Bitrake Uplink	SF	Chiprate Mchips/s
15	256	3,84
30	128	3,84
60	64	3,84
120	32	3,84
240	16	3,84
480	8	3,84
960	4	3,84
1920	2	3,84
3840	1	3,84

3.2.3 Code Correlation

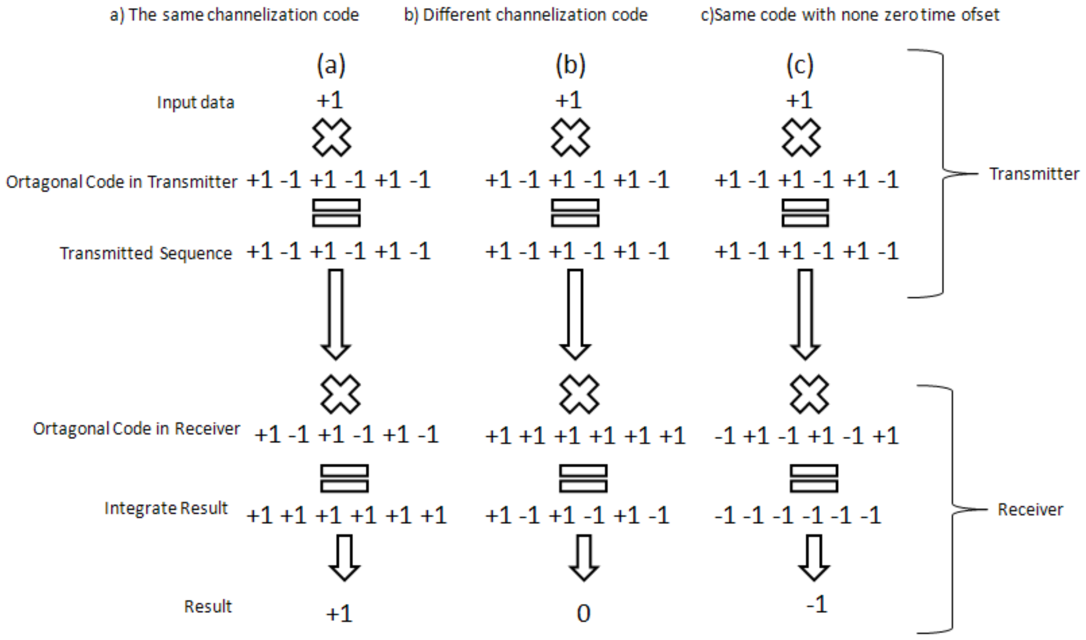


Figure 3.7 Code correlation using channelization codes

In the first scenario (a), the same channelization code is used in both the receiver and the transmitter (autocorrelation). This results in a maximum correlation result (100%) and the same information that was sent is received.

In the second scenario (b), different channelization codes are used (cross correlation). Because of the orthogonal properties this results in minimum correlation or zero output.

In the third scenario (c), the same channelization code is used, but time shifted. Here it can be seen that these codes are sensitive to time shift and the result is unpredictable. It is therefore necessary to have perfect synchronization of the codes.

CHAPTER FOUR
MATHEMATICAL BACKGROUND OF SPREAD SPECTRUM CDMA SYSTEMS

4.1 Spread Spectrum Modulation

The general concept of spread spectrum modulation is presented in Figure 4.1 Formally the operation of both transmitter and receiver can be partitioned into two steps. At the transmitter site, the first step is modulation where the narrow-band signal Sn, which occupies frequency band Wi, is formed. In modulation process bit sequences of length n are mapped to 2^n different narrow-band symbols constituting the narrow-band signal Sn. In the second step the signal spreading is carried out. In the signal spreading the narrow-band signal Sn is spread in a large frequency band W_c. The spread signal is denoted S_w, and the spreading function is expressed as ε( ).

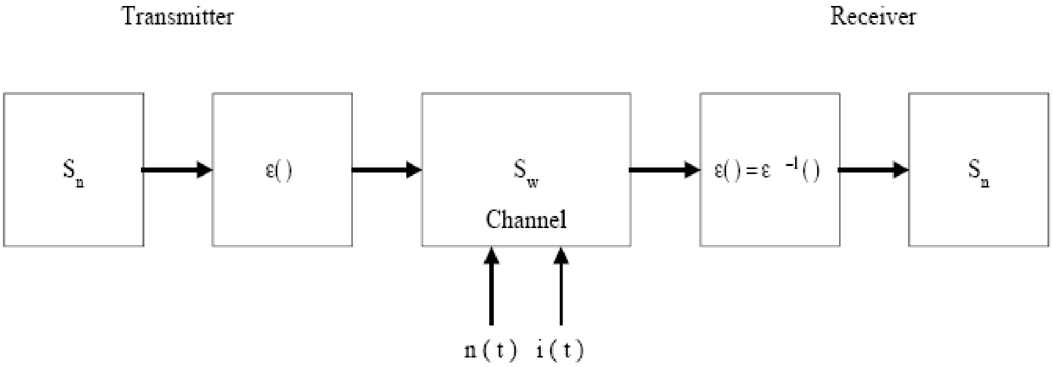


Figure 4.1 Spread spectrum system concept.

At the receiver site the first step is despreading, which can be formally presented by the function $\varepsilon^{-1}(\ ) = \varepsilon(\ )$. In despreading, the wideband signal Sw is converted back to a narrow-band signal Sn. The narrow-band signal can then be demodulated using standard digital demodulation schemes.

4.2 Tolerance of Narrow-Band Interference

A spread spectrum system is tolerant to narrow-band interference. This is demonstrated in Figure 4.2 and Figure 4.3.

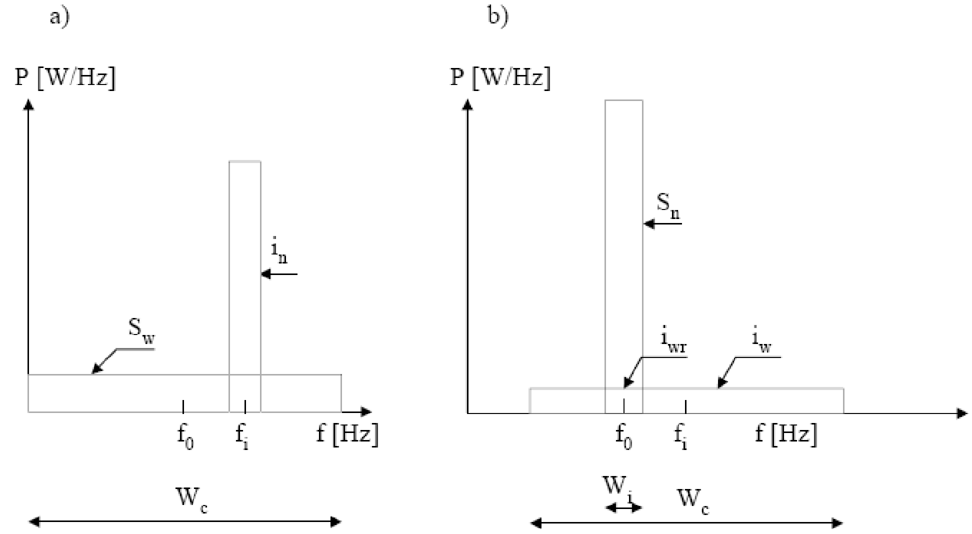


Figure 4.2 Despreading process in the presence of interference.

Lets assume that a signal Sw is received in the presence of a narrow-band interference signal i_n , see Figure 4.2 a and b. The despreading process can be presented as follows.

$$\varepsilon^{-1}(S_w + i_n) = \varepsilon^{-1}(\varepsilon(S_n)) + \varepsilon^{-1}(i_n) = S_n + i_w \tag{4.1}$$

The despreading operation converts the input signal into a sum of the narrow-band useful and a wideband interfering signal. After despreading operation a narrow-band filtering (operation F( )) is applied with the bandpass filter of bandwidth B_n equal to the bandwidth W_i of S_n. This results in

$$F(S_n + i_w) = S_n + F(i_w) = S_n + i_{wr} \tag{4.2}$$

Only a small portion of the interfering signal energy passes the filter and remains as residual interference because the bandwidth W_c of iw is much larger than W_i, Figure 4.3.

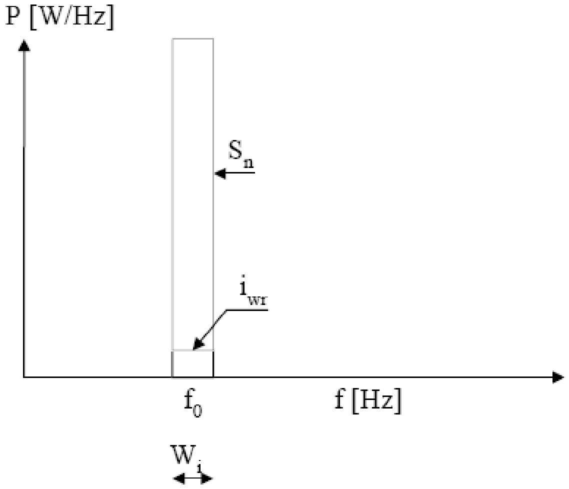


Figure 4.3 Result of filtering operation.

The ratio between transmitted modulation bandwidth and the information signal bandwidth is called processing gain.

$$G_p = \frac{W_c}{Wi} \qquad (4.3)$$

As the purpose of this subchapter is to show fundamental properties of Spread Spectrum Modulation. Thus, lets consider the system without error correction coding overhead etc. In the case, the gain defined by the equation (4.3) is given by just spectrum spreading operation (i.e. in linear scale is equal how many times has the spectrum been expanded). Such a gain has strong narrow interference suppression properties as is shown below. Important is to note however, that Processing gain as is used by 3GPP could be defined according equation (4.3) as well, but due to additional signal manipulation processing (error control coding, overhead etc.) included, resulting processing gain is composed from spreading part and from coding part.

In figure 4.2 and figure 4.3 the effect of processing gain can be clearly seen. equation (4.4) shows that the larger processing gain the system has, the more the power of uncorrelated interfering signals is suppressed in the despreading process. Thus processing gain can be seen as an improvement factor in the SNR (Signal to Noise Ratio) of the signal.

$$P(i_{wr}) = \frac{W_i}{W_c} P(i_w) = \frac{1}{G_p} P(i_w) \tag{4.4}$$

The trade-off is the transmission bandwidth W_c. In order to have a large processing gain giving a high interference suppression, a large transmission bandwidth is needed.

CHAPTER FIVE

WCDMA ASPECTS

As spreading and modulation have been explained, the following basic aspects of Direct Sequence Code Division Multiple Access (DS-CDMA) are discussed below:

- Power Control
- RAKE Receiver
- Handover (Hard, Soft, and Softer)
- Cell Breathing

5.1 Power Control

Power control is the most important element in WCDMA. Because many users access and uses the same frequency and bandwith at the same time, there is a high possibility of interference between the users. In the case where there is no power control, if an UE is close to the Node B the signal could be stronger from that UE then from the Node B which is furthest from the Node B. This is know as the near far problem.

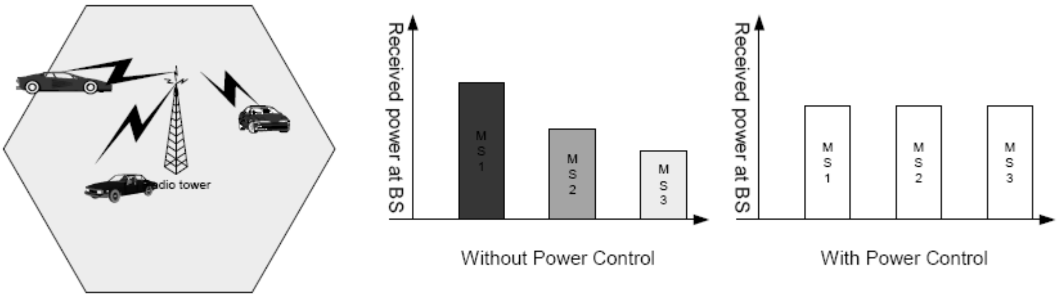


Figure 5.1 Power control

In order to maintain good capacity levels in the network, the signals received by the Node B, no matter where the UEs are transmitting from (that is near or far) should be of equal power assuming that all UEs are transmitting at the same users bit rate.

There are three types of power control:

- Open-Loop power control
- Inner-Loop (fast) power control
- Outer-Loop (slow) power control

5.1.1 Open-Loop Power Control

Open-loop power control is used for initial power setting of the UE at the beginning of a connection and for the common channel data transmission. When the mobile requires access to the network, rather than transmit at full power, as is the case in GSM, it uses the following steps to avoid causing interference to other users in the cell:

1. The mobile measures the received power from the Base Station.
2. The mobile reads the Base Station transmit power of the common pilot from the broadcast channel.
3. The mobile estimates (calculates) the minimums transmit power necessary to access the cell and makes an attempt at a slightly lower power.
4. If this attempt is unsuccessful, that is, there is no response from the Base Station, it will increase the power in steps and re-try.

5.1.2 Inner-Loop (Fast) Power Control

Power control is also required to avoid mobiles transmitting too high a power level as they move towards the Base Station. The system must ensure that the mobile transmits only sufficient power levels to be received and avoid unnecessary interference to other users. This means that the inner-loop power control must have a large dynamic range.

The inner-loop power control must also be fast enough to compensate for a phenomenon known as fast (or Rayleigh) fading, whereby the received signal strength experiences fades that depend on the radio frequency and the speed of the object. These fades exist because the received signal is composed of several copies (reflections from different objects in the environment) that add constructively or destructively.

Once a connection is established, the mobile (uplink) power, can be controlled by the Base Station by sending power control messages, TPC bits (are used for the downlink power control as well). The power can be adjusted in steps of less than 1 dB at a rate of 1500 times per second.

5.1.3 Outer - Loop (Slow) Power Control

The outer loop power control is needed to keep the quality of communication at the required level by setting a target, the socalled SIR (Signal-to-Interference Ratio) target for the fast power control. The SIR target for fast control is set by the RNC and it is based on the Bit Error Rate (BER) or the Block Error Rate (BLER). The outer loop aims at providing the required quality, no worse, no better, since too high a quality would waste the capacity of the system. If the received quality in UL is better than the required quality, the SIR target is decreased. If not, the SIR target is increased.

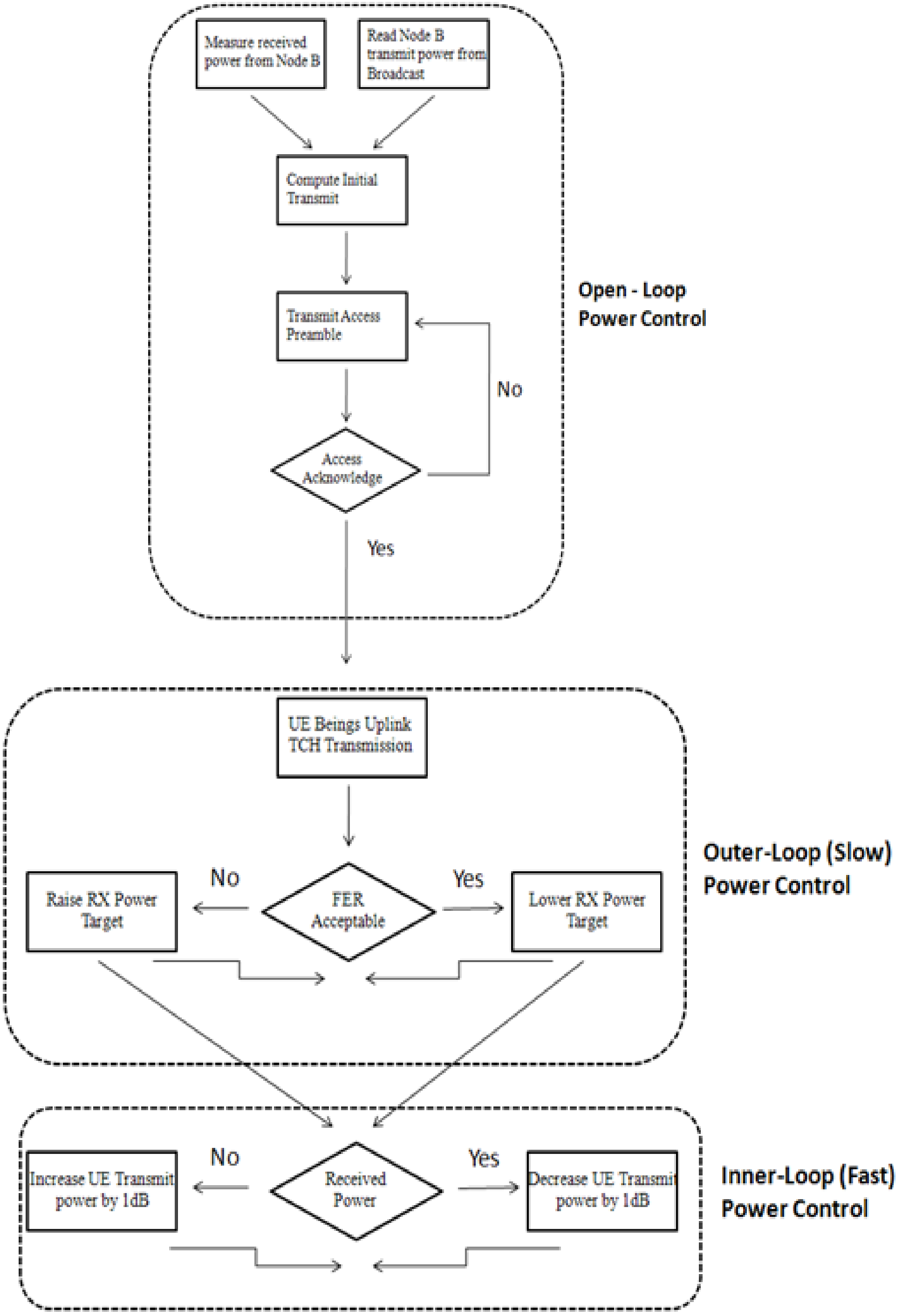


Figure 5.2 Power control algorithms

5.2 Rake Receiver

The purpose of the rake receiver is to rake together multiple replicas of the same signal received from the UE in order to receive a stronger combined signal. When the signal is sent from the UE it hits off diffirent objects and these objects reflect the signal towards the receiving antenna at the Node B.

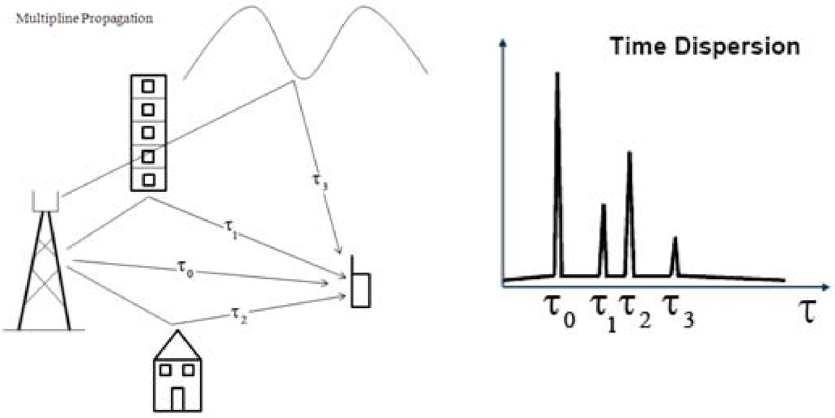


Figure 5.3 Multi-path fading

At the antenna the same signal arrives from the UE with diffirent delays due to the differences in path distance as shown in the figure 5.3.The rake receiver needs to find out what the delays fort he strongest replicas of signal are.

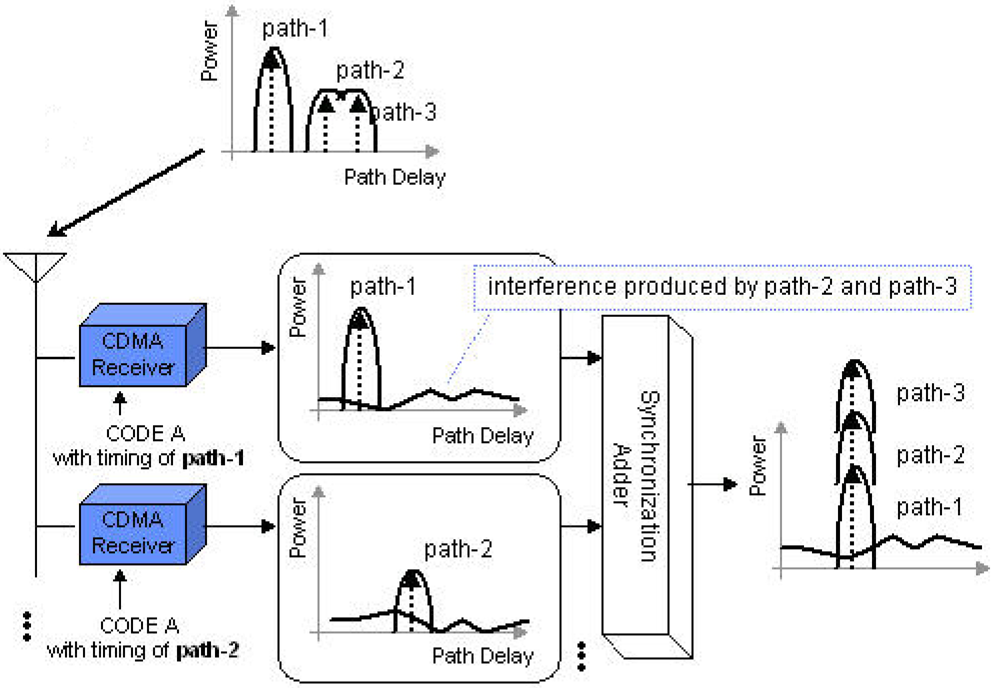


Figure 5.4 The rake receiver

5.3 Handover Scenarios

The main reasons for handover are connectivity continuation and UE mode changes. Due to the movements of the MS, radio links and connections need to be changed from one or several sectors or BSs to another or several others, without dropping the call. Regarding mode changes, a change of a connection from a common channel to a dedicated channel and vice versa is required. The handover procudure is defined as the change of a physical channel dring an existing connection.

There are two main types of handover in WCDMA:

- Intra system handover
  - Intra-frequency handovers.
    - MS handover within one cell between different sectors: softer
    - MS handover between different BS:soft
  - Inter-frequency handovers.
    - Hard
- Inter system handover
  - Handover between WCDMA <--> GSM900/1800: Hard

Softer handover is the special case of a soft handover between sectors/cells belonging to the same base station site.

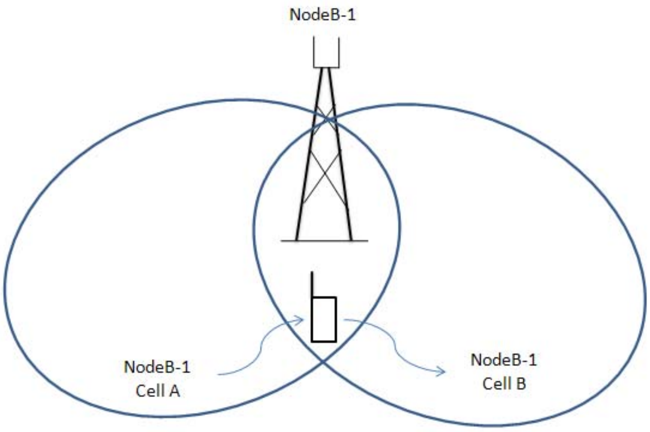


Figure 5.5 Softer handover

In the soft handover an MS is connected to two or more BSs at the same time.

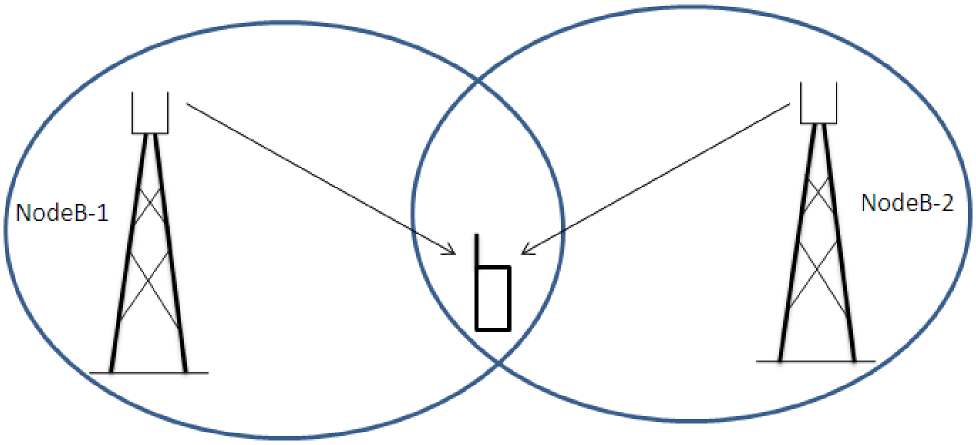


Figure 5.6 Soft handover

Inter frequency hard handovers between cells to which different carriers have been allocated.

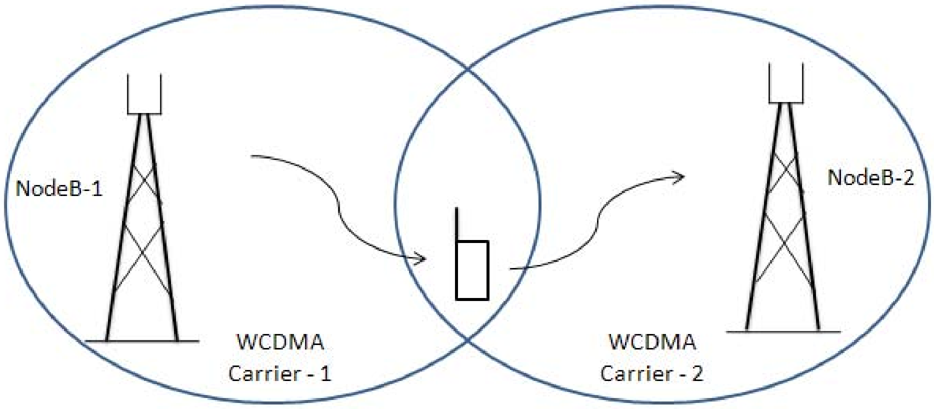


Figure 5.7 Inter frequency hard handover

Inter system hard handover between different operators/systems using different carrier frequencies including handover to GSM.

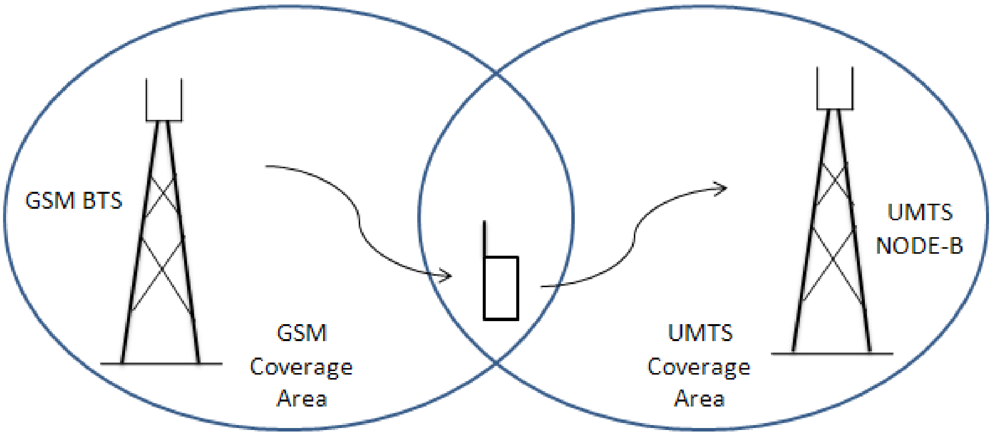


Figure 5.8 Inter system hard handover

Handover procedure is following below in Figure 5.9.

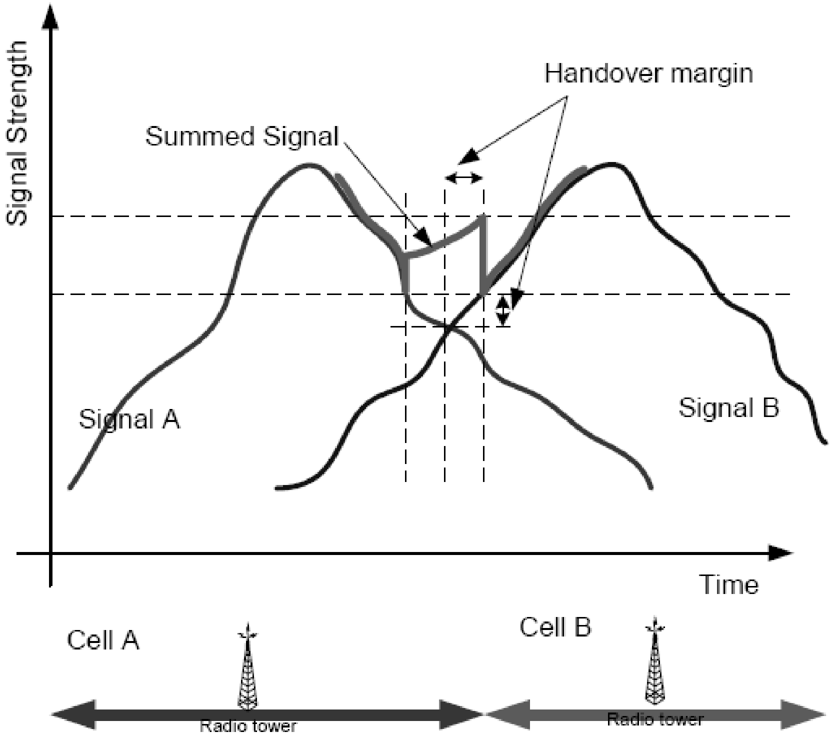


Figure 5.9 Handover procedure

Strength of the A becomes equal to defined lower threshold. The neighbouring signal has adequate strength. B is added to active set.

Quality of signal B starts to become better than signal A. The RNC keeps that point as starting point for handover margin calculation.

The strength of signal B becomes equal or better than the defined lower threshold. Thus its strength is adequate to satisfy the required QoS of the connection. The strength of the summed signal exceeds the predefined upper threshold, causing additional interference to the system. As a result, RNC deletes signal A from the active set.

5.4 Cell Breathing

In comparison to a traditional TDMA system the coverage of WCDMA depends on the load in the cells. As traffic increases, interference increases and the distance between the BS and the UE for effective data transfer becomes shorter. In a system where the traffic load changes this will effectively cause the cells to grow and shrink with time. This effect is often referred to as cell breathing.

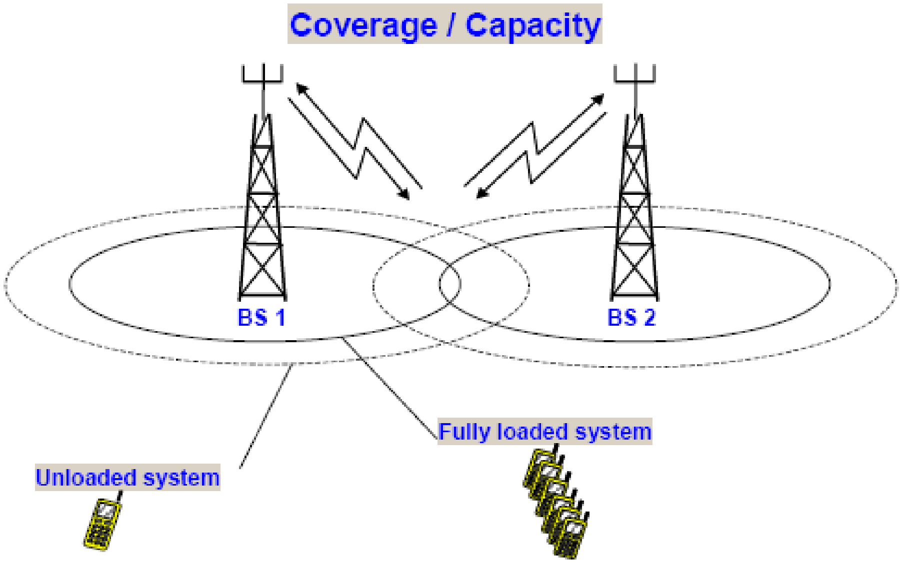
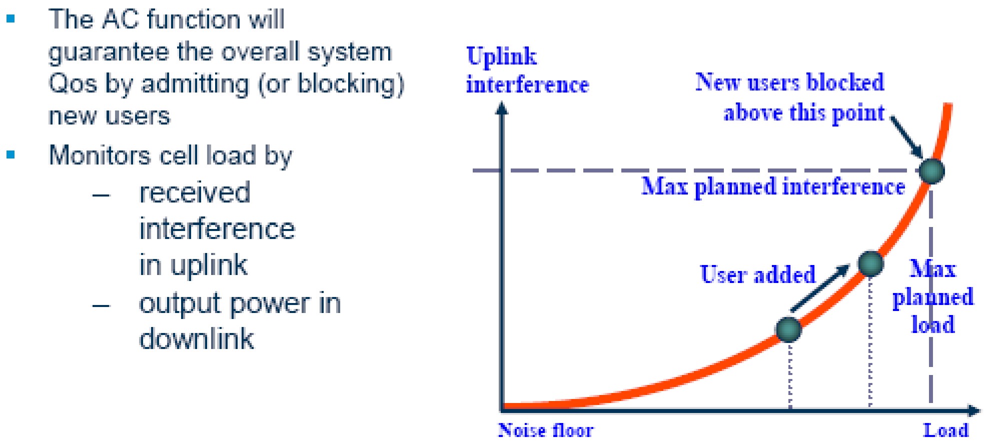


Figure 5.10 Cell breathing

In the DL all connections on a certain carrier share the same power amplifier. If at one moment the load is low, a particular UE will have the opportunity to connect to the BS even if it is very far away from it. On the other hand, if the traffic load is high, the UE will not be able to connect unless it is close to the BS. This effect makes it somewhat difficult to use the term coverage for the DL.

The plain receiver sensitivity depends on the required Carrier to Noise (C/N) ratio. However, the received Carrier (C) power must be large enough to combat both Noise (N) and Interference (I), that is, the C/(N+I) must exceed the receiver threshold. In order to get an accurate coverage prediction in a busy system, a magrin accounting for the noise rise on the UL is needed, as the interference increases with system.

The cell is planned for a certain capacity. The Radio Resource Management with admission control will guarantee the overall system QoS by admitting or blocking new users as illustrated in Figure 5.11.



- The AC function will guarantee the overall system Qos by admitting (or blocking) new users
- Monitors cell load by
  - received interference in uplink
  - output power in downlink

Figure 5.11 AC admission control

CHAPTER SIX

RADIO NETWORK DESIGN PROCESS

The basic radio network design process is shown in Figure 6.1 below.

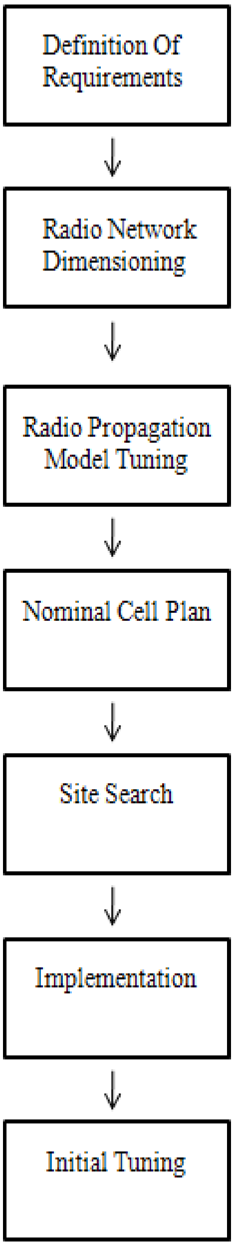


Figure 6.1 Radio network design process

This process is made up of the following steps:

Definition Of The Requirements : At the beginning, it is necessary to define the performance requirements of the WCDMA network to be implemented.

Radio Network Dimensioning : Calculations must be performed in order to obtain a rough estimation of the minimum equipment needed to meet the defined Network requirement. The result of these calculations is used to create the Bill of Quantity (BoQ). If the operator is planning to use existing Base Stations, this stage could be skipped.

Radio Propagation Model Tuning : In order to obtain more reliable radio propagation predictions, it is appropriate to tune the models implemented in TEMS Cell planner Universal (or similar radio planning tool) for the most important and critical areas to be covered.

Nominal Cell Planning : TEMS Cell planner, or a similar tool, is used to produce a nominal cell plan. Various coverage plots and analysis can be made to ensure this plan meets the requirements. The result of the Site Search and survey phase may require this cell plan to be modified.

Site Search And Survey : The cell planner, with the support of the site hunters, finds the most appropriate sites to achieve the radio coverage, according to the general criteria. The construction aspects and the possibility of obtaining the site installation permission license are also taken into account by the site hunters. For the most critical sites in terms of coverage/capacity requirements, the cell planner decides to perform a survey and, if necessary, RF measurements.

Implementation : This phase covers the various sub-phases of implementing the nominal cell plan. TEMS cell planner universal, or another similar tool, could be used to evaluate cell parameters, handover candidates etc. The best location from site search, RBS type, antenna, feeders etc are chosen. After the site is built the RBS is integrated and finally the site-specific parameters are loaded with OSS-RC.

Initial Tuning : TEMS Investigation, or other similar tools, may be used to perform drive tests of the area. The results of these measurements are used to tune the network to best meet the coverage and capacity requirements.

6.1 WCDMA Covarage Zone

WCDMA is meant to provide universal coverage in a number of diverse environments by using terrestrial and satellite components. The goal is to allow users to roam from a private cordless or fixed network, through PLMN micro and macro cells to a rural area, covered by a satellite network, with minimal communication breaks. UTRA is specified for all zones, except the last, which will be served by the satellite components.

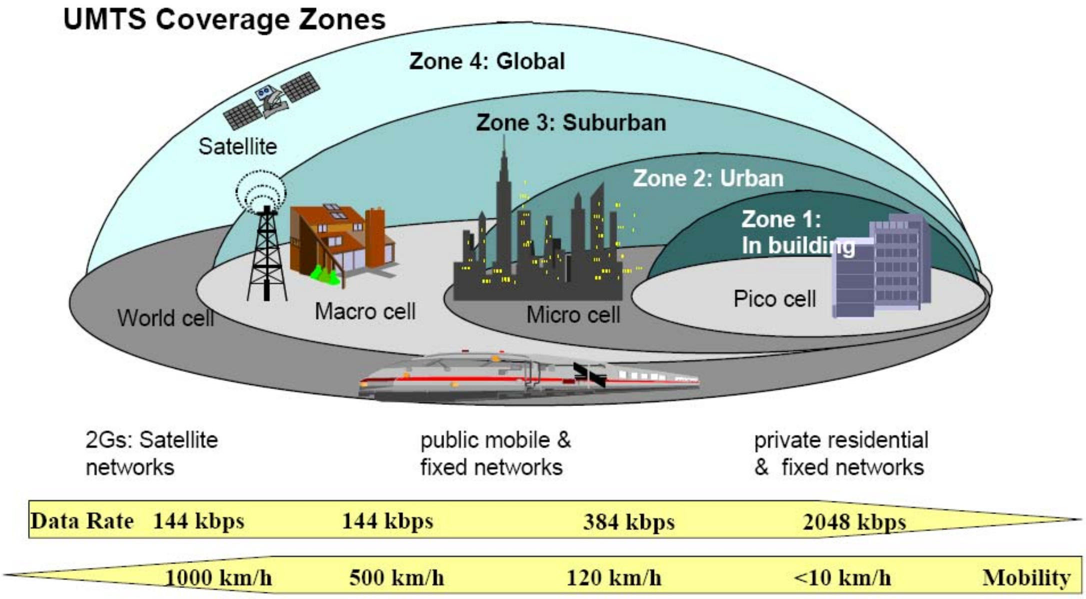


Figure 6.2 WCDMA coverage zones by area

The data rates available in each zone depend on the level of (speed) of the user and the population density:

- 2Mbps in indoor/office, high-density environments (Pico cells) with pedestrian speeds.
- 384 kbps – 2 Mbps within a city's radius and speeds no greater than 120 km/h.
- 144 kbps - 384 kbps for medium density, suburban areas and speeds in the range of 120-500 km/h.
- Up to 144 kbps in remote areas (mountains, oceans) with speeds of up to 1000 km/h (airplanes)

6.2 Definition of Enviroments

Dense Urban:

Areas within the Urban perimeter. This includes densely developed areas where built up features do not appear distinct from each other. The typical street pattern is not parallel. The average building height is below 40 m. The average building density is > 35%.

Urban:

Built up areas with building blocks, where features do appear more distinct from each other in comparison to Dense Urban. The street pattern could be parallel or not. The average building height is below 40 m. The average building density is from 8 % to 35%.

Suburban:

Suburban density typically involves laid out street patterns in which streets are visible. Building blocks may be as small as 30 by 30 m, but are typically larger and include vegetation cover. Individual houses are frequently visible. The average building height is below 20 m. The average building density is from 3 % to 8%.

Rural:

Small and scattered built up areas in the outskirts of larger built-up environments. The average building height is below 20 m. The average building density is < 3 %.

CHAPTER SEVEN
WCDMA CAPACITY

7.1 Energy Per Bit To Noise Ratio (Eb/No)

Figure 7.1 below illustrates how noise introduced by the air interface produces bit errors in the received data stream.

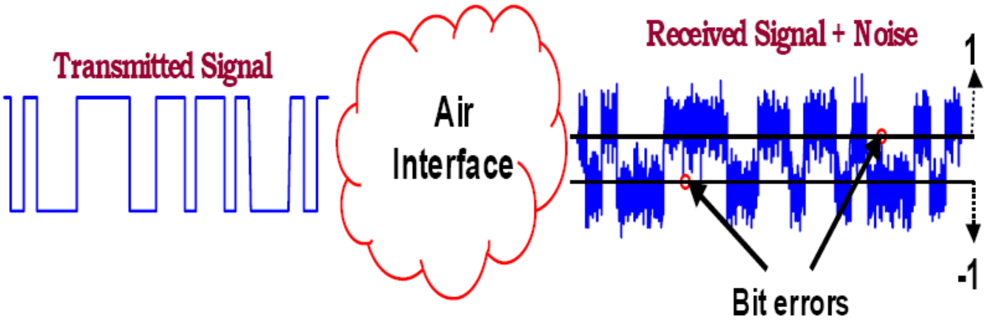


Figure 7.1 Air interface noise producing bit errors

The bit error rate is proportional to ratio of energy per bit (Eb) to noise power density (No). This ratio is realistically and conceptually illustrated in Figure 7.2 below.

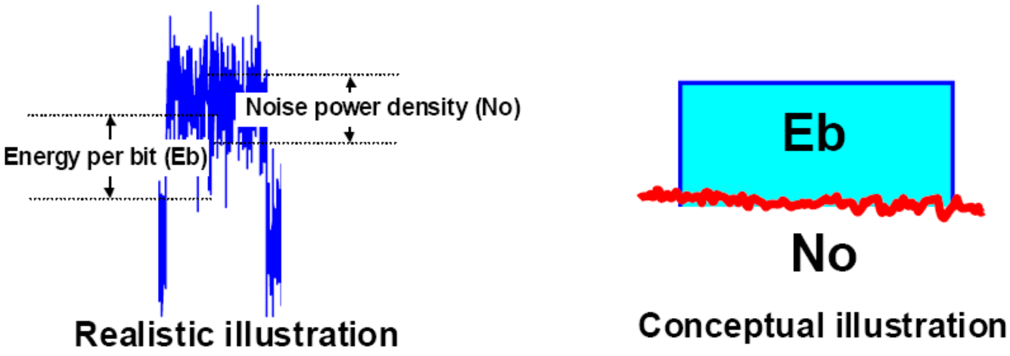


Figure 7.2 Realistic and conceptual illustration of Eb/No

The conceptual illustration makes it easier to understand that this ratio must always be positive. In other words Eb must always be above No. The exact amount depends on a number of factors that will be explained in this chapter.

This ratio is normally expressed in dB, that is 10 log (Eb/No) dB.

The illustration in Figure 7.3 below is intended to show that in an ideal environment the BER (or Block Error Rate –BLER) for channel A, that has an Eb/No of 1 dB, would be higher than that experienced on channel B that has an Eb/No of 6 dB. Since Eb is not as much above No it is more likely that the receiver will misinterpret some symbols.

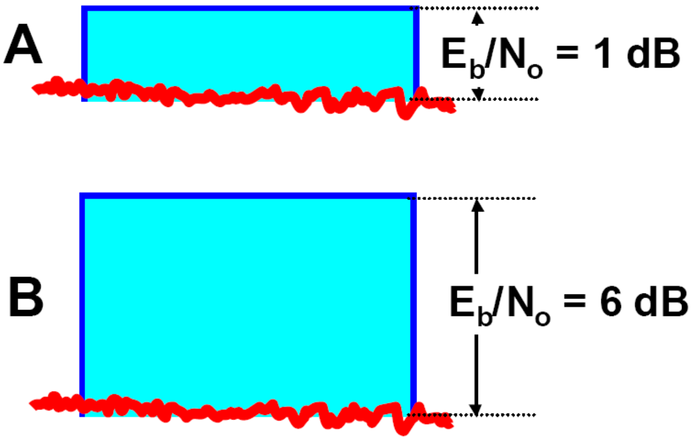


Figure 7.3 Eb/No and BER or BLER

7.2 Fast (Rayleigh) Fading

In certain environments one user's radio signal may be reflected of many surfaces producing multipath reflections, as illustrated in Figure 7.4 below.

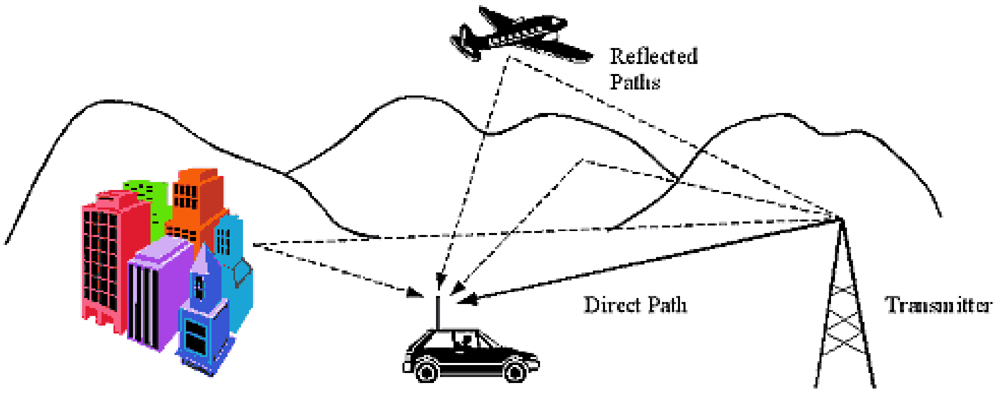


Figure 7.4 Fast (rayleigh) fading

The received signal contains many time-delayed replicas. Figure 7.5 below illustrates what would happen if two of these multipath reflections (#1 and #2) arrived at the receiver with equal amplitude and phase shifted by half a wavelength.

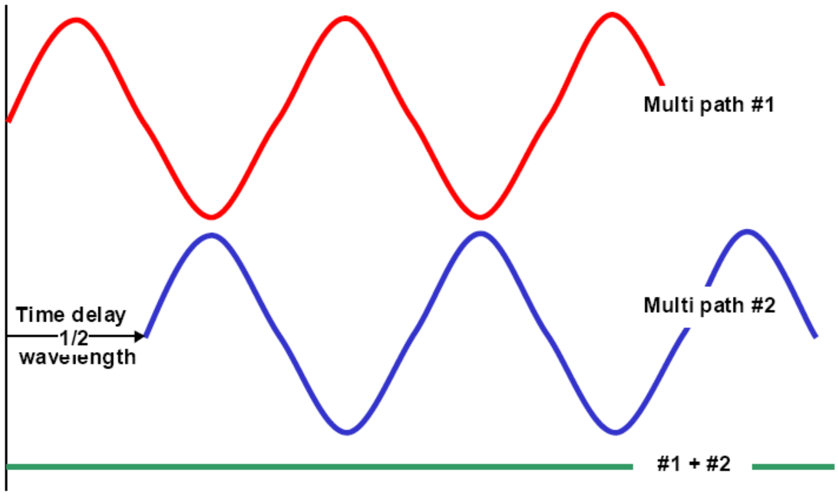


Figure 7.5 Destructive summation of two multipath components

The result is that they cancel each other out. This may be referred to as ‘destructive summation’ and will be occurring all the time in mulitpath environments. The overall result of this is that the signal will experience fading. This type of fading is known as fast, or Rayleigh fading and takes place even as the receiver moves across short distances.

Fast (Rayleigh) fading is related to the carrier frequency, the geometry of multipath vectors and the vehicle speed. As a rule of thumb there are up to four fades per second for each kilometer per hour of travel. For example a mobile traveling at 10 km/h experiences approximately 40 fades/s. This is illustrated in Figure 7.6 below.

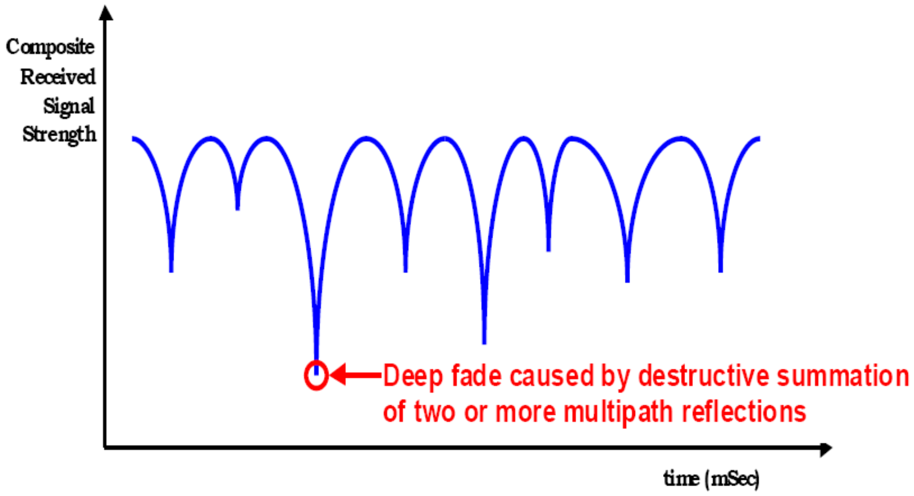


Figure 7.6 Fast (Rayleigh) Fading

7.3 Eb/No And Fast (Rayleigh) Fading

In the example in Figure 7.7 below the effect of fast fading on Eb/No and BER or BLER can be seen, where the original 1dB Eb/No is no longer adequate to maintain the BER or BLER due to fast fading.

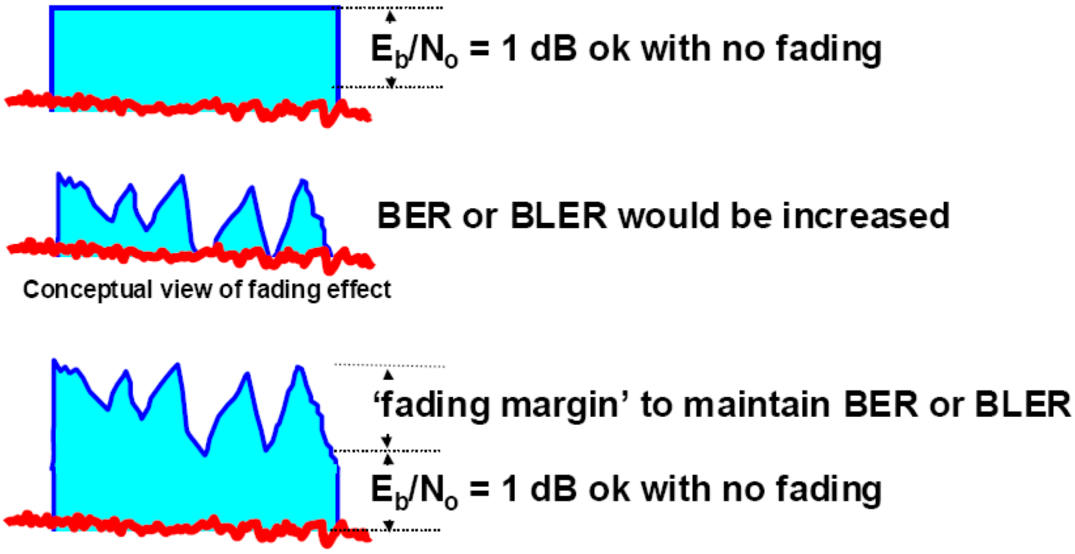


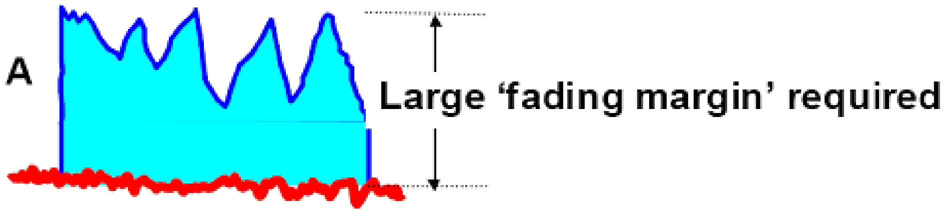
Figure 7.7 Eb/No and fast (rayleigh) fading

To maintain the same BER or BLER a ‘fast fading margin’ should be added to the original Eb/No. The size of this margin will depend on degree of fast fading (speed and environment of UE).

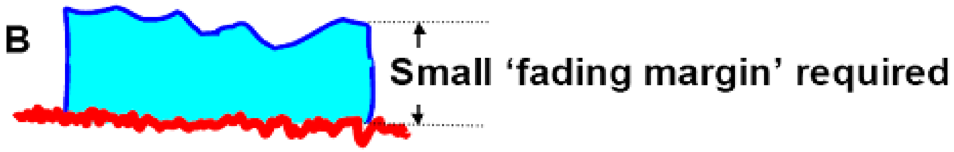
7.4 Eb/No And Fast Power Control

WCDMA employs inner loop power control at 1500 updates per second. This is capable of reducing the effect of fast fading for low UE speeds. The accuracy of this power control will affect the ‘fast fading margin’ required. This is dependent on how well the channel is being estimated from the embedded pilot bits and how accurately the power control commands are being decoded.

To maintain the same BER on channel A and B in Figure 7.8 below, channel A requires a large fading margin due to the inaccuracy of power control (channel estimation) but channel B only requires a small fading margin because the power control (channel estimation) is more accurate.



Inaccurate inner loop power control (poor channel estimation)



Accurate inner loop power control (good channel estimation)

Figure 7.8 Eb/No and Fast power Control

Due to the difference in channel estimation in this example it can be said that: A BER = B BER but A Eb/No>B Eb/No

7.5 Uplink Capacity

The uplink capacity of a WCDMA cell will depend on which channel models it is has to serve.

7.5.1 Eb/No And C/I

A formula to relate Eb/No and carrier to interference ratio before despreading (γ), is derived in the following way:

The definition for signal to noise ratio of a digital stream is:

Signal-to-noise ratio per bit: The ratio given by Eb/No, where Eb is the signal energy per bit and No is the noise energy per hertz of noise bandwidth.

From this it can be said that:

$Eb = S/R_{info}$ where S = signal energy and Rinfo is the bit rate
$No = N/B$ where N = noise energy and B is the bandwidth

Therefore:

$Eb/No=(S/R_{info}) . (B/N) = (S/N) . (B/R_{info})$

Since B is proportional to the chip rate:

$(B/R_{info})=(\text{Chip Rate} / R_{info})=\text{Processing Gain (PG)}$

In the uplink N will be predominately interference (I) from other

UEs and S will be the received carrier power (C)

$Eb/No = C/I\ PG = \gamma.PG$

Since Eb/No and γ are normally given in dB:

Eb/No = γ+ 10log(PG)

Solving for γ gives Equation as illustrated in Figure 7.9 below.

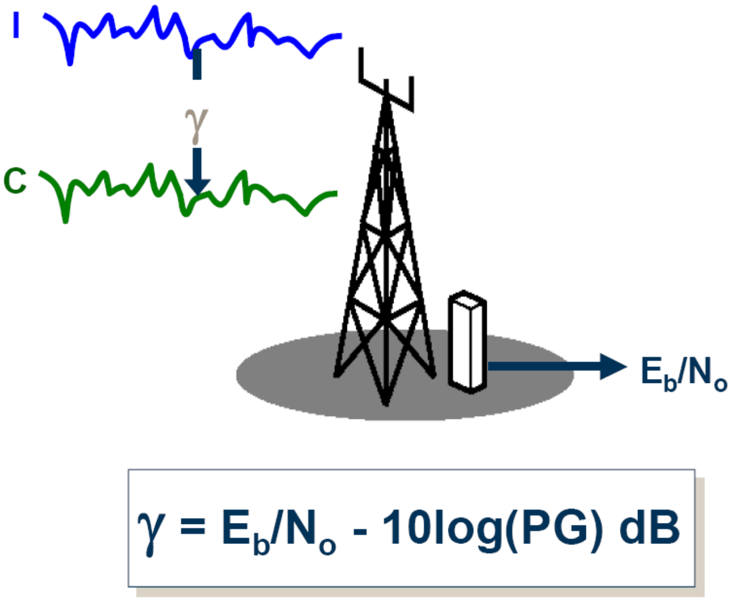


Figure 7.9 Eb/No and C/I (γ)

7.5.2 Uplink Maximum Number Of Channels (M_{pole})

The uplink pole capacity, M_{pole}, is the theoretical limit for the number of UEs that a cell can support. It is service (RAB) dependent. At this limit the interference level in the system is infinite and thus the coverage reduced to zero. The formula for uplink Mpole is given by Equation below.

$$M_{pole} = \left(\frac{1}{1+F}\right) \cdot \left(1+\frac{1}{\gamma}\right) \cdot (1+G_{DTX}) \qquad (7.1)$$

Where:

F = Uplink Interference factor

GDTX = Uplink gain from Discontinuous Transmission

Note: γ must be in linear units $10^{(\gamma/10)}$

7.5.3 Uplink Intercell Interference Factor (F)

F is the ratio between the interference from other cells (I_{other}) and the interference generated in the own cell (I_{own}) $F = I_{other}/ I_{own}$

This will depend on the characteristics of the cell plan, fading and antenna beam width.

The F values used throughout this document have been obtained through simulations.

The uplink F value is illustrated in Figure 7.10 below.

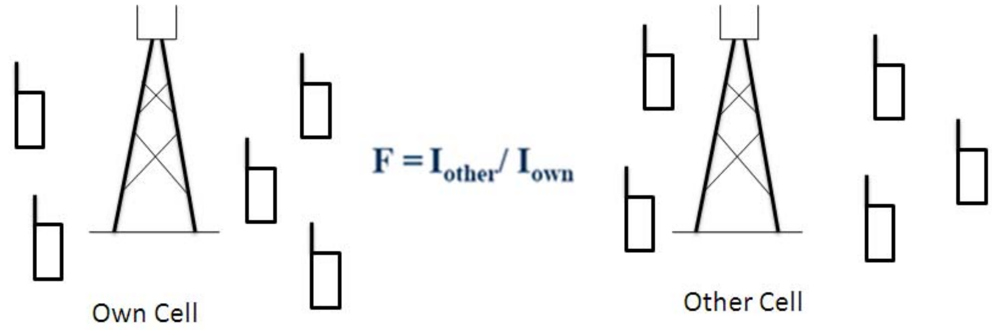


Figure 7.10 Uplink F value

Where
Iown = Interference generated by UEs in the cell
Iother = Interference generated by UEs in other cells Other Cell
For a 3-sector Urban Site a value of 0.79 should be used

7.5.4 DTX Gain (GDTX)

Discontinuous Transmission (DTX) gain is calculated from the reduction in bits between the various transport formats of the physical channel. These values will depend on the RAB. The uplink and downlink values for the AMR Speech and Interactive 64/64 RABs dimensioning are illustrated in Figure 7.11 below.

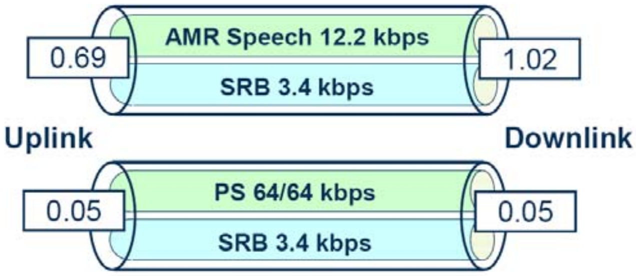


Figure 7.11 GDTX for speech and interactive RABs

7.5.5 Urban/ Dense Urban Uplink M_{pole} Values

For planning purposes it is assumed that all users in Urban and Dense Urban environments conform to the TU, 3km/h channel model.

Table 7.1 Urban/ Dense Urban Uplink Mpole Values

Service Type	M_{pole}
Conversational/Speech 12.2 kbps RB+ 3.4 kbps SRB	70
Conversational 64 kbps CS RB + 3.4 kbps SRB	17
Interactive 64 kbps PS RB + 3.4 kbps SRB	16
Streaming 57.6 kbps CS RB + 3.4 kbps SRB	21
Streaming 16 kbps PS RB + 8 kbps PS RB + 3.4 kbps SRB	34
Conversational/Speech 12.2 kbps RB+ 0 kbps PS RAB 3.4 kbps SRB	70
Conversational/Speech 12.2 kbps RB+ 64 kbps PS RAB 3.4 kbps SRB	13
Conversational 64 kbps CS RB+ 8 kbps PS RAB 3.4 kbps SRB	14

7.6 Downlink Capacity

The downlink equations are more complex than the uplink ones. For the downlink it is not as easy to separate the coverage and capacity in the way that is done for the uplink. The main difference from the uplink is that the UEs in the downlink share one common power source. Thus the cell range is not dependent only on how many UEs there are in the cell but also on the geographical distribution of the UEs.

Despite orthogonal codes, the downlink channels cannot be perfectly separated due to multipath propagation. This means that a fraction of the BS power will be experienced as interference. Also, the amount of downlink interference, caused by neighboring base stations transmitting channels that are non-orthogonal with the serving base station, depends on the user equipment position.

7.6.1 Downlink M_{pole}

Equation below should be used to calculate the downlink Mpole for the services to be supported.

$$M_{pole} = \frac{(1+\alpha.\gamma).(1+G_{DTX})}{\gamma.(\alpha+F).\left[1+\sum_{b=2}^{n_{AS}} \frac{K(b).\left[(1+\alpha.\gamma).(b-1)-G_{SHO}(b)\right]}{1+\alpha.\gamma+G_{SHO}(b)}\right]} \tag{7.2}$$

Where:

γ is the downlink C/I target (linear scale) for the RAB.

α is the non-orthogonality factor of the Cell.

F is the downlink intercell interference factor.

κ is the fraction of users that are in soft/softer handover.

n_{AS} is the typical size of the active set

b is the active links for the connection (b ≥2 soft handover)

G_{SHO} is the system average of soft handover gain.

G_{DTX} is the downlink DTX gain.

7.6.2 Downlink C/I Value (γ)

To account for fast fading, a compensation (ε) must be added to the calculated γvalue. The compensation values are listed in Table 7.2 below.

Table 7.2 Downlink C/I compensation values

Enviroment	ε[dB]
TU, 3km/h	0.5
TU, 50km/h	0.4
RA, 3km/h	2.0
RA, 50km/h	1.6
RA, 120km/h	0.0

For planning purposes it is assumed that all users in Urban and Dense Urban environments conform to the TU, 3km/h channel model.

7.6.3 Downlink Non-Orthogonality Factor (α)

Due to multi-path propagation the downlink channel separation is not perfect. Table 7.3 below, shows the a values to be used to account for the fraction of power lost due to interference between orthogonal codes.

Table 7.3 Downlink non-orthogonality factors

Enviroment	α
Rural Area (RA)	0.15
Typical Urban (TU)	0.64

For planning purposes it is assumed that all users in Urban and Dense Urban environments conform to the TU channel model.

7.6.4 Downlink Intercell Interference Factor (F)

As is the case in the uplink, the F value will depend on the Site configuration. Typical values for planning purposes with a two dimensional and three dimensional models where the antenna tilt is considered are given in Table 7.4 and Table 7.5 below.

Table 7.4 Downlink F values for Mpole calculations with fast fading

Site Configuration	F
Omni	0.48
Three-sector	0.72
Six-sector	0.84

Table 7.5 Downlink F values for three-sector sites with tilt

Cell Radius	500 m	1000 m	1500 m	2000 m	2500 m
Electrical tilt (degree)	7	5	4	2	1
Three-sector	0.39	0.59	0.70	0.89	1.23

7.6.5 Downlink Soft Handover Variables (K, N_{AS}, B And G_{SHO})

κ and G_{SHO} will vary depending on the site configuration and the number of active links (b). Table 7.6 below, shows the values that should be used for dimensioning purposes, assuming a 3dB handover threshold and maximum active set of 2, for the various site configurations.

Table 7.6 Downlink soft handover variables

Site Configuration	G_{SHO}	**κ(%)**
Omni	0.67	23
Three-sector	0.67	26
Six-sector	0.68	29

7.6.6 Downlink DTX Gain (GDTX)

Downlink DTX gain is calculated from the reduction in bits between the various transport formats of the physical channel.

Table 7.7 below, shows downlink G_{DTX} values that should be used for dimensioning purposes.

Table 7.7 G_{DTX} values

RB Configuration	G_{DTX}(%)
Speech 12.2 kbps RB+ 3.4 kbps SRBs	102
64 kbps CS RB + 3.4 kbps SRBs	5
64 kbps PS RB + 3.4 kbps SRBs	5
128 kbps PS RB + 3.4 kbps SRBs	2
384 kbps PS RB + 3.4 kbps SRBs	1
57.6 kbps CS RB + 3.4 kbps SRBs	6
Streaming 64 kbps PS RB+ 8 kbps PS RB = 3.4 kbps SRBs	6

7.6.7 Urban/ Dense Urban Downlink M_{pole} Values

For planning purposes it is assumed that all users in Urban and Dense Urban environments conform to the TU, 3km/h channel model.

The Table 7.8 below, shows downlink M_{pole} values for dimensioning a cell that is part of a 3-sector site in an Urban (U) or Dense Urban (DU) Environment.

Table 7.8 Downlink U/DU Mpole values

Service Type	M_{pole}
Conversational/Speech 12.2 kbps RB+ 3.4 kbps SRB	60
Conversational 64 kbps CS RB + 3.4 kbps SRB	7.8
Interactive 64 kbps PS RB + 3.4 kbps SRB	8.9
Interactive 128 kbps PS RB + 3.4 kbps SRB	5.4
Interactive 384 kbps PS RB + 3.4 kbps SRB	1.9
Streaming 64 kbps PS RB + 8 kbps PS RB + 3.4 kbps SRB	10
Streaming 128 kbps PS RB + 8 kbps PS RB + 3.4 kbps SRB	6.2
Conversational 64 kbps CS RB+ 8 kbps PS RAB 3.4 kbps SRB	6.3
Conversational/Speech 12.2 kbps RB+ 0 kbps PS RAB 3.4 kbps SRB	60
Conversational/Speech 12.2 kbps RB+ 64 kbps PS RAB 3.4 kbps SRB	7.4

7.7 Maximum Cell Loading (Q_{max})

Where a WCDMA cell offers Circuit Switched and Best Effort (BE) services, its load will be made up of the conversational load (Q_c), that is generated by the Voice and CS RABs and best effort load (Q_{BE}) that is generated by Packet Switched RABs.

The maximum load on the cell (Q_{max}) will be the sum of both of these loads, as given by equation below:

$$Qmax = number\_of\_subs(Qc + QBE) \qquad (7.3)$$

Conversational load (Qc) = traffic_per_sub_CS/max possible conversational channels.

Best Effort load (QBE) = BE_CH_Req/max possible packet channels.

Since the maximum possible conversational and packet channels is M_{pole}, CS and M_{pole}, PS respectively and 'BE_CH_Req' is given equation below:

$$\text{BE\_CH\_Req} = \frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times \text{bit\_rate}} \tag{7.4}$$

For the BH we can assume the PS bit rate is 64 kbps and hence the maximum load (Q_{max}) is given equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right) + \left(\frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times 64 \times 10^3 \times M_{pole,PS}}\right)\right] \tag{7.5}$$

A WCDMA system cannot be loaded up to 100%. To secure a well performing network the uplink and downlink load used in the dimensioning process should not exceed 70 % for the uplink and 76% for the downlink.

CHAPTER EIGHT
WCDMA COVERAGE

8.1 Radio Wave Propagation

Many factors, including absorption, refraction, reflection, diffraction, and scattering affect the wave propagation. However, in free space an electromagnetic wave travels indefinitely if unimpeded. This does not mean there are no transmission losses, as we will see in this first simple model where isotropic emission from the transmitter and line of sight between the two antennas separated by a distance, d, in free space are assumed figure 8.1.

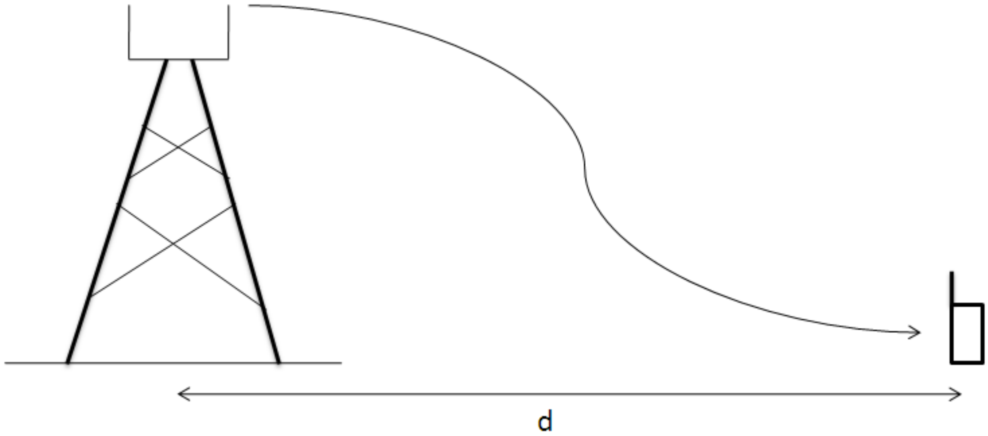


Figure 8.1 Free space path loss

Since an isotropic antenna, by definition, distributes the emitted power, Pt, equally in all directions, the power density, Sr, (power per area unit) decreases as the irradiated area, $4\pi d^2$, at distance d, increases, that is:

$$S_r = \frac{P_t}{4\pi d^2} \tag{8.1}$$

If the transmitting antenna has a gain, Gt, it means that it is concentrating the radiation towards the receiver. The power density at the receiving antenna increases with a factor proportional to Gt, that is:

$$S_r = \frac{P_t . G_t}{4\pi d^2} \tag{8.2}$$

The power received by the receiving antenna, Pr, is proportional to the effective area, Ar, of that antenna, that is:

$$P_r = S_r . A_r \tag{8.3}$$

It can be shown that the effective area of an antenna is proportional to the antenna gain, Gr, and the square of the wavelength, λ, of the radio wave involved, that is:

$$A_r = \frac{G_r . \lambda^2}{4\pi} \tag{8.4}$$

and, hence, the received power becomes

$$P_r = \frac{P_t . G_t . G_r . \lambda^2}{(4\pi d)^2} \tag{8.5}$$

The transmission loss can be calculated as the ratio between the transmitted power and received power, that is:

$$\text{loss} = \frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t . G_r . \lambda^2} \tag{8.6}$$

Radio engineers work with the logarithmic unit dB so the transmission loss, *L*, then

becomes

$$L = 10\log(\text{loss}) = 10\log\left(\frac{(4\pi d)^2}{G_t . G_r . \lambda^2}\right) = 20\log\left(\frac{4\pi d}{\lambda}\right) - 10\log(G_r) - 10\log(G_t) \tag{8.7}$$

Radio engineers treat the antenna gains, 10log(Gr) and 10log (Gt), separately, so that what is given in the literature as the path loss, Lp, is only the term 20log(4πd/λ). In clearer terms, the path loss in free space is given by equation below.

$$\text{FreeSpacePathLoss} L_p = 20\log\left(\frac{4\pi d}{\lambda}\right) \tag{8.8}$$

Note that the wavelength dependency of the path loss does not correspond to losses in free space as such. It is a consequence of the finite effective receiver area.

This transmission loss expression is fairly general. The only thing which changes when we improve our models is the expression for the path loss. The antenna gain is normally given in dBi, that is, as 10log(*G*), where gain means a reduction of the total transmission loss, *L*, between a transmitting and receiving antenna.

This model helps us to understand the most important features of radio wave propagation. That is, the received power decreases when the distance between the antennas increases and the transmission loss increases when the wavelength decreases (or alternatively when the frequency increases).

For cell planning, it is very important to be able to estimate the signal strengths in all parts of the area to be covered, that is, to predict the path loss. The model, described in this section, can be used as a first approximation. However, more complicated models exist. Improvements can be made by accounting for:

- The fact that radio waves are reflected towards the earth's surface.
- Transmission losses, due to obstructions in the line of sight.
- The finite radius of the curvature of the earth.
- The topographical variations in a real case, as well as the different attenuation properties of different terrain types, such as forests, urban areas, etc.

The best models used are semi-empirical, that is, based on measurements of path loss/attenuation in various terrain. The use of such models is motivated by the fact that radio propagation cannot be measured everywhere. However, if measurements are taken in typical environments, the parameters of the model can be finetuned so that the model is as good as possible for that particular type of terrain.

8.2 Link Budget Calculations

This section describes the margins, losses and gains that must be considered when making uplink and downlink link budget calculations.

In an ideal situation, the maximum uplink possible path loss (Lpmax) between the UE and RBS would be the difference between the maximum UE output power (PUE) and the uplink system sensitivity (SUL) as illustrated in Figure 8.2 below.

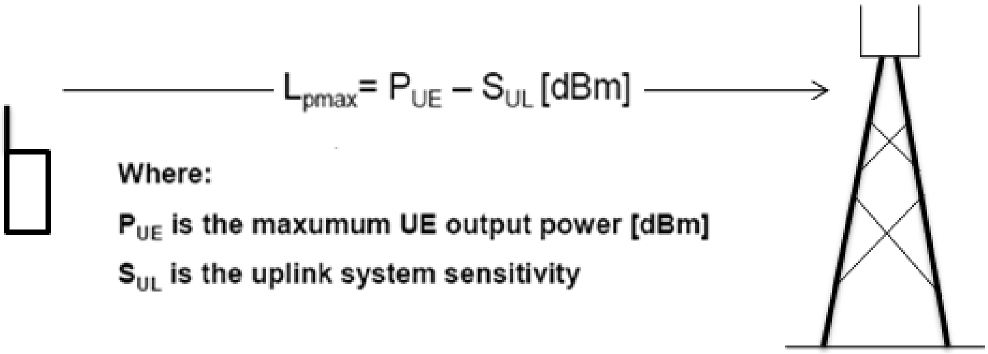


Figure 8.2 Ideal uplink maximum path loss

In the downlink the ideal situation maximum path loss (Lpmax) would be the difference between the RBS power at the system reference point (PTX,ref) and the UE sensitivity (SUE) as illustrated in Figure 8.3 below.

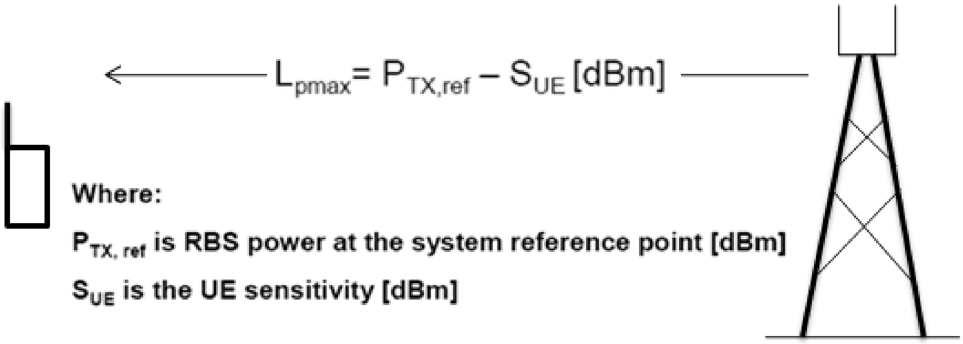


Figure 8.3 Ideal downlink maximum path loss

However in a network design, various margins must be added in order to cater for various uncertainties and additional losses that cannot be determined exactly along with any additional gains and losses between the RBS and UE.

When these margins, losses and gains are taken into account the maximum uplink path becomes:

Lpmax= PUE – SUL – Bx– Lx + Ga [dBm] (8.9)

Where:

Bx is the uplink link budget margins [dB]

Lx is the is the uplink link budget losses [dB]
Ga Sum of RBS and UE antenna gain (Ga) [dBi]

The Uplink Radio Network Design maximum path loss is illustrated in Figure 8.4 below.

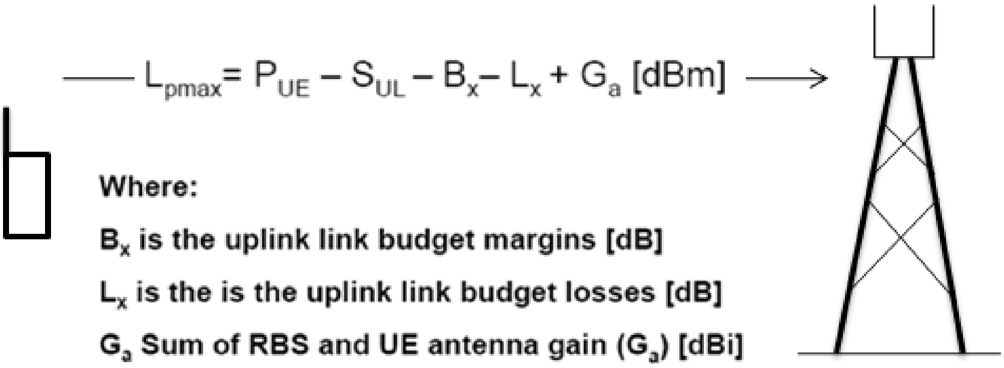


Figure 8.4 Uplink radio network design maximum path loss

In the downlink the maximum uplink path becomes:

$$L_{pmax} = P_{TX,ref} - S_{UE} - B_x - L_x + G_a \text{ [dBm]} \qquad (8.10)$$

Where:
Bx is the downlink link budget margins [dB]
Lx is the is the downlink link budget losses [dB]
Ga Sum of RBS and UE antenna gain (Ga) [dBi]

The downlink Radio Network Design maximum path loss is illustrated in Figure 8.5 below.

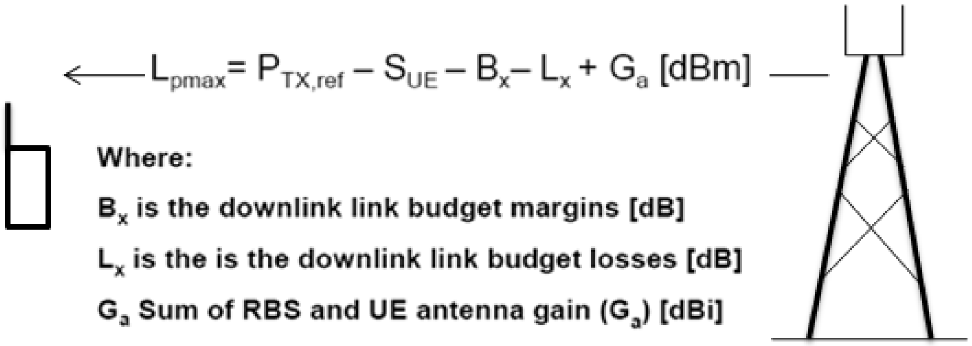


Figure 8.5 Downlink radio network design maximum path loss

8.3 Link Budget Margins

The link budget margins that should be used for radio network design are listed below:

- Uplink Interference margin (BIUL) [dB]
- Downlink Interference margin (BIDL) [dB]
- Log-Normal Fading margin (BLNF) [dB]
- Power Control margin (BPC) [dB]

8.3.1 Uplink Interference Margin (B_{IUL})

The more load in the system, the more interference will be generated. This will have the apparent effect that the receiver noise floor is raised in a loaded system as compared to an unloaded system as illustrated in Figure 8.6 below. The increase is referred to as noise rise or interference margin and is denoted by (B_{IUL}).

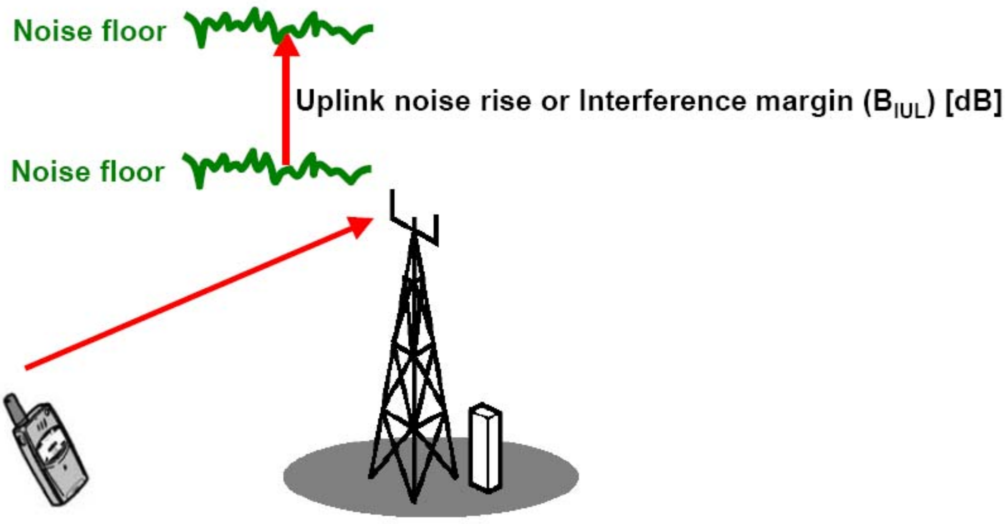


Figure 8.6 Uplink interference margin (BIUL)

B_{IUL} can be calculated from the relative uplink system load using Equation 8.11 below:

$$B_{IUL} = 10\log\left[\frac{1}{1-Q}\right](dB) \tag{8.11}$$

Where Q is the uplink system load that can vary between 0 and 1.

8.3.2 Downlink Interference Margin (B_{IDL})

The downlink noise rise (or the downlink interference margin) (B_{IDL}) is a margin that takes into account the fact that the receiver noise floor (i.e. noise floor at the UE) is higher in a loaded WCDMA system than in an unloaded one. This is true also for the uplink noise rise. But the downlink noise rise depends also on the output power of the transmitter and the location of the users as opposed to the uplink counterpart.

In the example in Figure 8.7 below it can be seen that the noise rise due to UE3 is higher at UE1 than UE2. It should be remembered that the location and requirement of UE3 would also affect the noise rise in UE1 and UE2.

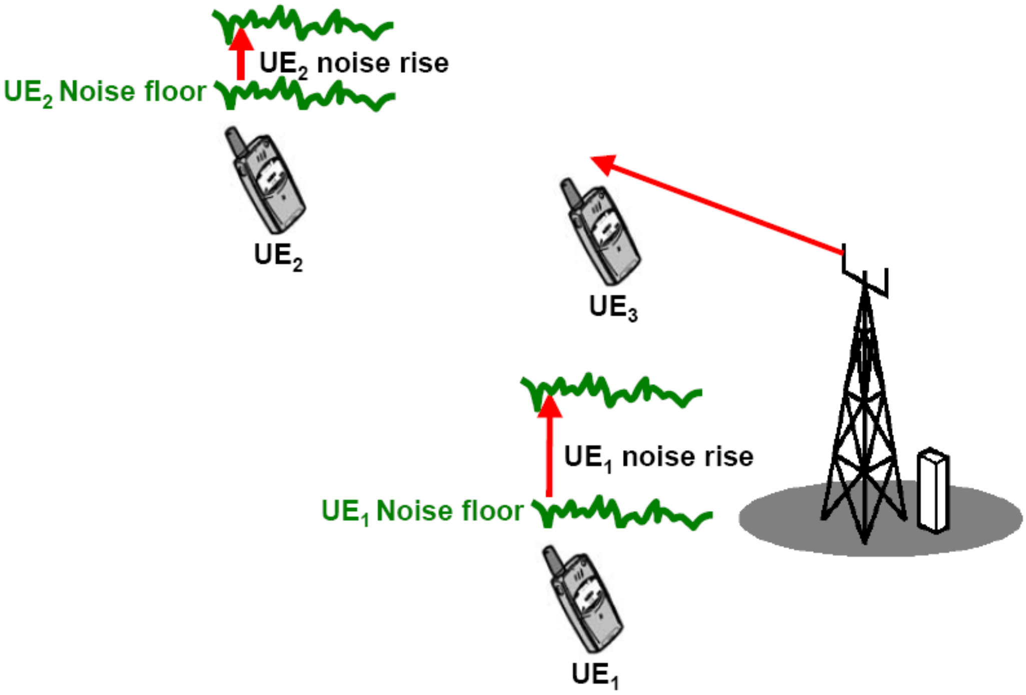


Figure 8.7 Downlink Interference margin (BIDL)

If the noise rise is evaluated for a UE located at the cell border, equation 8.12 below is used to calculate B_{IDL}.

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right).\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)(dB) \tag{8.12}$$

Where:

α = non-orthogonality factor of the Cell. For CPICH calculations this is assumed to be 1.

F = average ratio between the received inter-cell and intra-cell interference. (At the cell border F is assumed to be 2.1)

$P_{tot,ref}$ = total power at the reference point in W

N_t = thermal noise power density (-174 dBm/Hz = 3.98 X 10 $^{-21}$ W/Hz)

N_f = Noise figure of the UE (7dB= 5.01)

R_{chip} = system chip rate in 3.84 MHz = 3.84 X10^6 Hz

L_{sa} = the calculated attenuation in linear units

It is assumed that, non-orthogonality factor, $\alpha=1$ in equation 18 when calculating DL noise rise for the CPICH. The reason for assuming $\alpha=1$ is the fact that P-CPICH signal quality is measured as Ec/No (defined as RSCP/RSSI). Since RSSI is measured before the rake receiver (at UE antenna connector) it includes all interference, both orthogonal and non orthogonal. Hence the sensitivity of the pilot channel is determined without the effect of the orthogonality.

8.3.3 Log-Normal Fading Margin (B_{LNF})

However, a radio signal envelope is composed of a fast fading signal super imposed on a slow fading signal as shown in Figure 8.8 below.

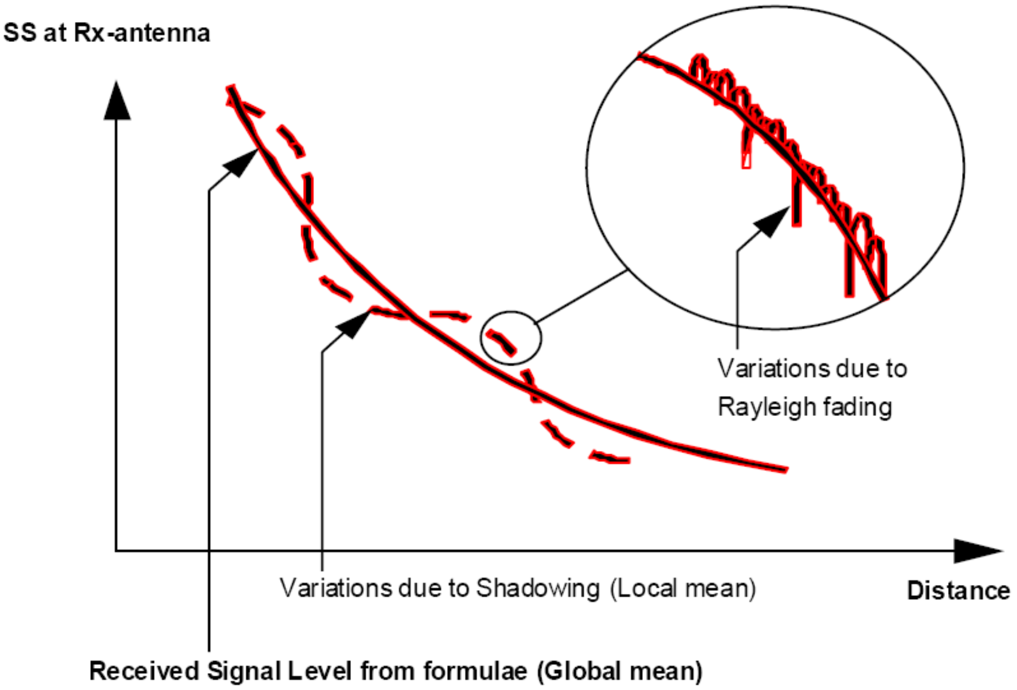


Figure 8.8 Signal Variations

These fading signals are the result of obstructions and reflections. They yield a signal, which is the sum of a possibly weak, direct, line-of-sight signal, and several indirect, or reflected signals.

The short term or fast fading (Rayleigh fading) signal (peak-topeak distance ≈ $\lambda/2$) is usually present during radio communication, due to the fact that the mobile antenna is lower than the surrounding structures, such as trees and buildings. These act as reflectors. The resulting signal consists of several waves with various amplitudes and phases. Sometimes these almost completely cancel out each other.

This can lead to a signal level below the receiver sensitivity. In open fields where a direct wave is dominating, this type of fading is less noticeable.

The first and most simple solution is to use more power at the transmitter(s), thus providing a fading margin. This fading magrin is incorporated in the Eb/No value, which is service, environment and speed dependant.

Another way to reduce the harm done by Rayleigh fading is to use space diversity, which reduces the number of deep fading dips. Diversity means that two signals are received which have slightly different "histories" and, therefore, the "best" can be used, or even better: the two can be combined. Receiver diversity is also incorporated in the uplink Eb/No values.

Assuming that fast fading has been removed (averaged out), the local mean value of the signal strength fluctuates in a way not modeled in the prediction algorithm. This deviation of the local (measured) mean has nearly a normal distribution in dB with a standard deviation σLNF(o), typically 6 - 12 dB depending on the environment.

In the result from a prediction in for example a WCDMA planning tool, 50% of the locations (for example at the cell borders) can be considered to have a signal strength that exceeds the prediction value. In order to plan for more than 50% probability of signal strength above the prediction value, a lognormal fading margin, (B_{LNF}) is added to the link budget during the design process.

The lognormal fading margins reflect the case where the UE has the possibility to make soft handover to other cells when experiencing poor coverage. Allowing handover means that the lognormal fading margins can be reduced as compared to the single cell case. The reduction is referred to as handover gain. By calculating the lognormal fading margins required in a single cell the handover gain can be computed. The lognormal fading margins for a single cell can be calculated by means of Jakes' formulas as it the case in GSM.

It is customary to divide the handover gain into hard handover gain and soft handover gain. Hard handover gain is a handover gain of the same type as in conventional TDMA systems. There the UE has the possibility to perform handover but can only be connected to one cell at a time. Soft handover gain is the additional gain that is obtained when a UE is allowed to connect to several cells at the same time. The handover gain depends on coverage probability and site configuration.

If outdoor base stations are used to provide indoor coverage Building Penetration Loss (L_{BPL}) must be take into consideration.

L_{BPL} is defined as the difference between the average signal strength immediately outside the building and the average signal strength over the ground floor of the building. L_{BPL} for different buildings is also log-normally distributed with a standard deviation of σ_{BPL}. Variations of the loss over the ground floor could be described by a stochastic variable, which is log-normally distributed with a zero mean value and a standard deviation of σfloor.

Here σ_{BPL} and σfloor are lumped together by adding the two as if they were Standard deviations in two independent log-normally distributed processes. The resulting Standard deviation, σindoor or $\sigma_{LNF(i)},$ could be calculated as the square root of the sum of the squares and is typically 8 – 9 dB.

The total log-normal fading is composed of both the outdoor lognormal fading, $\sigma_{LNF(o)},$ and the indoor log-normal fading $\sigma_{LNF(i)}.$ The total standard deviation of the lognormal fading is given by the square sum:

$$\sigma_{LNF(o+i)} = \sqrt{\sigma_{LNF(o)}^{2} + \sigma_{LNF(i)}^{2}} \tag{8.13}$$

These various standard deviations are illustrated in Figure 8.9 below.

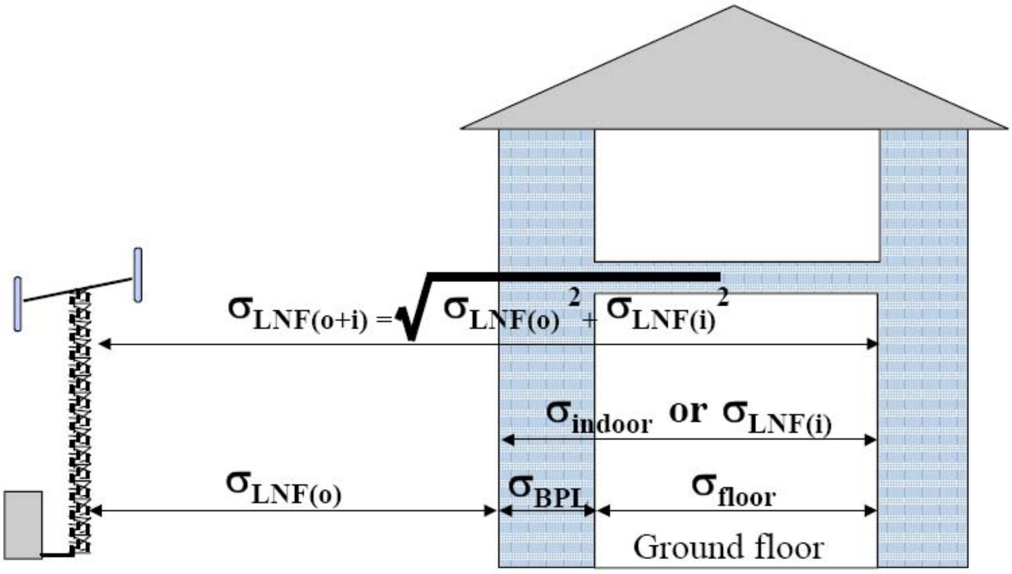


Figure 8.9 Link budget standard deviations

To dimension for indoor coverage using outdoor base stations the $\sigma_{LNF(o+I)}$ standard deviation should be used.

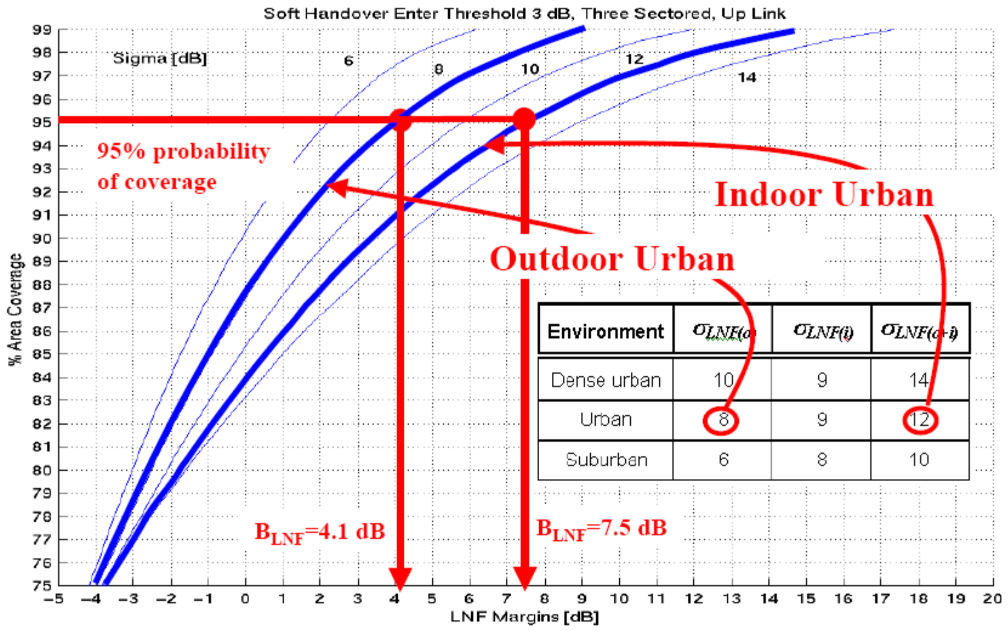
The complete list of standard deviation values for calculating link budgets in dense urban, urban and suburban environments is given in Table 8.1 below.

Table 8.1 Standard deviation values

Enviroment	$\sigma_{LNF(o)}$	$\sigma_{LNF(i)}$	$\sigma_{LNF(o+i)}$
Dense Urban	10	9	14
Urban	8	9	12
Suburban	6	8	10

Once the standard deviation (σ_{LNF}) has been established the required lognormal fading margin (B_{LNF}) to achieve the desired probability of coverage may be obtained from appropriate lognormal fading margin graph.

An uplink example for a 3-sector urban site, including soft handover gain, is illustrated in Figure 8.10 below.



Environment	$\sigma_{LNF(o)}$	$\sigma_{LNF(i)}$	$\sigma_{LNF(o-i)}$
Dense urban	10	9	14
Urban	8	9	12
Suburban	6	8	10

Figure 8.10 LNF margins for urban environment

From Figure 8.10 it can bee seen that a 4.1 dB lognormal fading margin (B_{LNF}) for indoor and 7.5 dB for outdoor would be required to produce a 95 % probability of coverage.

Table 8.2 below, is a list of the uplink lognormal margins margin (B_{LNF}) to be used for uplink dimensioning calculations using 3-sector sites.

Table 8.2 Uplink BLNF for 3-sector site, including soft handover

Enviroment	σ_{LNF}[dB]	Area				
		75%	85%	90%	95%	98%
Rural,suburban	6	-4.1	-1.7	0.0	2.3	4.6
Urban	8	-3.9	-0.9	1.1	4.1	7.2
Dense Urban,suburban indoor	10	-3.8	-0.1	2.3	5.9	9.6
Urban indoor	12	-3.8	0.6	3.4	7.5	12.1
Dense urban indoor	14	-3.8	1.1	4.3	9.0	14.3

Table 8.3 below, is a list of the downlink lognormal margins margin (B_{LNF}) to be used for downlink dedicated channel dimensioning calculations for 3-sector sites.

Table 8.3 Downlink BLNF for 3-sector site, including soft handover

Enviroment	σ_{LNF}[dB]	Area				
		75%	85%	90%	95%	98%
Rural,suburban	6	-4.7	-2.3	-0.7	1.5	3.8
Urban	8	-4.5	-1.4	0.5	3.4	6.4
Dense Urban,suburban indoor	10	-4.4	-0.6	1.8	5.2	8.9
Urban indoor	12	-4.1	0.2	2.9	7.0	11.6
Dense urban indoor	14	-4.1	0.7	3.9	8.6	13.8

Table 8.4 below, is a list of the downlink lognormal margins margin (B_{LNF}) to be used for downlink common channel dimensioning calculations for 3-sector sites.

Table 8.4 Downlink B_{LNF} for 3-sector site, excluding soft handover

Enviroment	σ_{LNF}[dB]	Area				
		75%	85%	90%	95%	98%
Rural,suburban	6	-3.7	-1.2	0.5	2.9	5.5
Urban	8	-3.4	-0.2	1.8	4.9	8.1
Dense Urban,suburban indoor	10	-3.1	0.6	3.1	6.7	10.6
Urban indoor	12	-3.1	1.3	4.2	8.4	13.1
Dense urban indoor	14	-3.1	1.8	5.1	9.9	15.3

8.3.4 Power Control Margin (PC_{MARG})

When the UE approaches the cell border the path loss increases. The power control loop responds by increasing the UE power until the loop saturates and it is transmitting with full power. Hence power control is no longer operating. This will result in reduced uplink system sensitivity. To take this effect into consideration, a margin called Power Control margin (B_{PC}) is included in the uplink link budget.

This margin has been calculated by simulation for different channel models and UE speeds. The margin will be smaller for multi-cell environments than for single cell environments, due to increased diversity for the radio channel.

The power control margins are shown Table 8.5 below.

Table 8.5 Power control margin (B_{PC})

Enviroment	TU 3km/h	TU 50km/h	RA 3km/h	RA 50km/h	RA 120km/h
B_{PC}[dB]	0.7	0.0	4.5	1.0	0.0

8.4 Link Budget Losses

The link budget losses that should be used for radio network design are listed below:

- Body Loss (L_{BL}) [dB]
- Car Penetration Loss (L_{CPL}) [dB]
- Building Penetration Loss (L_{BPL}) [dB]
- Antenna System Controller Loss (L_{ASC}) [dB]
- Jumper and Connector Loss (L_{j+C})
- Jumper Loss (L_J) [dB]
- Feeder Loss (L_F) [dB]

8.4.1 Body Loss (L_{BL})

The human body has several negative effects on the UE performance. For example, the head absorbs energy, and the antenna efficiency of some UEs can be reduced. To cater for these effects a suitable value for Body Loss (L_{BL}) has to be included in the link budget. The body loss margin recommended by ETSI is 3 dB for 1900 MHz.

Generally, body loss is not applied to data services since the users will most likely not have the terminal at their ear.

Values for L_{BL} are given in Table 8.6.

Table 8.6 Body Loss

Loss Type	Description	Notation	Value [dB]
Body loss	Handheld speech	L_{BL}	3
	Handheld (lap-palmtop),data	$L_{BL,data}$	0

8.4.2 Car Penetration Loss (L_{CPL})

When a UE is placed in a car without an external antenna, a suitable Car penetration Loss (L_{CPL}) has to be added in order to cope with the penetration loss to reach inside the car.

Values for LBL are given in Table 8.7.

Table 8.7 Car penetration loss

Loss Type	Description	Notation	Value[dB]
Car Penetration Loss	Covered car, without external antenna	LCPL	6

8.4.3 Building Penetration Loss (L_{BPL})

Building Penetration Loss (L_{BPL}) is defined as the difference between the average signal strength immediately outside the building and the average signal strength over the ground floor of the building.

Values for LBPL are given in Table 8.8.

Note that the characteristics of different urban, suburban etc. environments can differ significantly throughout the world. Thus the values in Table 8.8 must be treated with care. They should be considered as a reasonable approximation when no other information is obtainable. Rural areas are not considered in Table 8.8 since indoor coverage is not usually calculated for them.

Table 8.8 Building penetration loss

Loss Type	Description	Notation	Value[dB]
Building Penetration Loss	Urban and Dense Urban	L_{BPL}	18
	Suburban		12

8.4.4 Antenna System Controller Insertion Loss (L_{ASC})

If an ASC is part of the RBS configuration, the ASC insertion loss (L_{ASC}) must be accounted for in the link budget calculations.

Value for LASC is given in Table 8.9.

Table 8.9 Antenna System Controller Loss

Loss Type	Description	Notation	Value[dB]
ASC Loss	Loss attributed to the ASC in the downlink	LASC	0.2

8.4.5 Jumper And Connector Loss (L_{J+C})

The insertion loss of the jumper and connectors between the RBS and the antenna must be accounted for in the link budget calculations. If an ASC is used this is not applicable for uplink calculations.

Value for LJ+C is given in Table 8.10.

Table 8.10 Jumper And Connector Loss

Loss Type	Description	Notation	Value[dB]
Jumper & Connector Loss	Jumper and connectors between ASC and RBS	LJ+C	1

8.4.6 Jumper Loss (L_J)

When the ASC is used the insertion loss of the jumper cable between it and the antenna must be accounted for in link budget calculations since the reference point is the input to the ASC.

Value for LJ is given in Table 8.11.

Table 8.11 Jumper Loss

Loss Type	Description	Notation	Value[dB]
Antenna Jumper Loss	Jumper between ASC and antenna	LJ	0.2

8.4.7 Feeder Loss (L_F)

The Feeder Loss (L_F) will depend on the length and type of feeder used. It should be remembered that if an ASC is used L_F can be eliminated for uplink calculations.

If an ASC is used this is not applicable for uplink calculations.

Values for L_F are given in Table 8.12.

Table 8.12 Feeder Loss

Loss Type	Description	Notation	Value[dB]
Feeder Loss	LCF 1/2 loss per 100m	L_F	11
	LCF 7/8 loss per 100 m		6.3
	LCF 1-1/4 loss per 100m		4.6
	LCF 1-5/18 loss per 100m		3.8

8.5 Link Budget Antenna Gain (G_A)

The antenna gain of the RBS and UE must also be incorporated into the link budget. This is achieved by including the term Ga which is the sum of the UE antenna gain and the RBS antenna gain.

The RBS antenna gain will vary depending on the type, however for the UE 0 dBi is assumed, unless otherwise specified.

Antenna Gain (Ga) is illustrated in Figure 8.11 below.

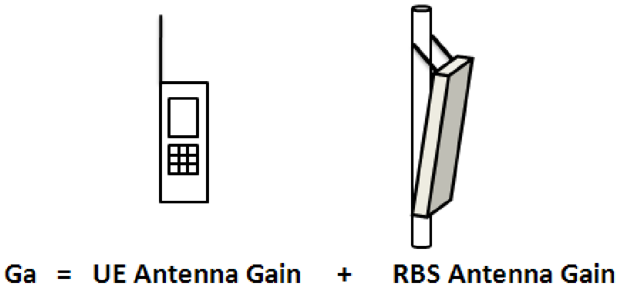


Figure 8.11 Link budget antenna gain (Ga)

8.6 Uplink Link Budget Calculations

The margins that are relevant in the uplink are listed below:

- Uplink Interference margin (BIUL) [dB]
- Log-Normal Fading margin (BLNF) [dB]
- Power Control margin (BPC) [dB]

If an ASC is used the relevant losses are listed below:

- Body Loss (LBL) [dB]
- Car Penetration Loss (LCPL) [dB]
- Building Penetration Loss (LBPL) [dB]
- Jumper Loss (LJ) [dB]

And the relevant gain is:

- Antenna gain (Ga) [dBi]

These link budget losses are illustrated in Figure 8.12 below:

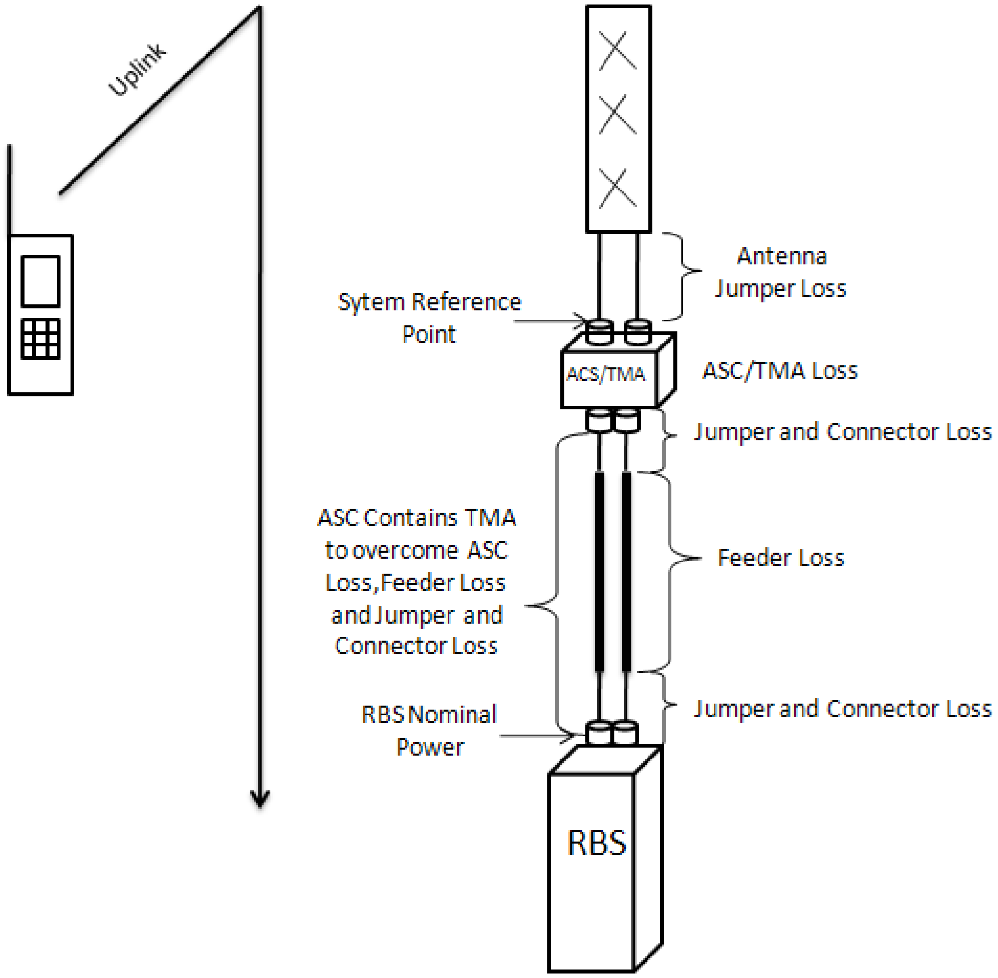


Figure 8.12 Uplink link budget losses

The Maximum uplink Path Loss (L_{pmax}) is given below:

$$L_{p\max} = P_{UE} - S_{UL} - B_{IUL} - B_{LNF} - B_{PC} - L_{BL} - L_{CPL} - L_{BPL} - L_{J} + G_{ant}(dB) \quad (8.14)$$

S_{UL} = Uplink system sensitivity

B_{IUL}= Uplink Interference margin

B_{LNF} = Log-Normal Fading magrin

B_{PC} = Power Control magrin

L_{BL} = Body Loss

L_{CPL} = Car Penetration Loss

L_{BPL} = Building Penetration Loss

L_{J} = Jumper Loss

G_{ant} = Antenna gain

8.7 Uplink System Sensitivity (S_{UL})

The uplink system sensitivity (S_{UL}) for is given below:

$$S_{UL} = N_t + N_f + 10\log R_{info} + E_b / N_o + L_F (dBm) \quad (8.15)$$

Where:

N_t is thermal noise power density (-174 dBm/Hz)

N_f is the noise figure (2.3 dB with or 3.3 dB without an ASC)

R_{info} is the information bit rate [bps]

Eb/No is energy per bit/ noise power density for the service [dB]

L_F is the feeder loss (0 dB with ASC)

Since each service will have different uplink sensitivity and (different margins) we will end up with various maximum path losses. For planning purposed it is assumed that 100 % of users in an Urban or Dense Urban environment conform to the TU 3km/h 3GPP channel model. The various service maximum path losses (Lpmax) are illustrated in Figure 8.13 below.

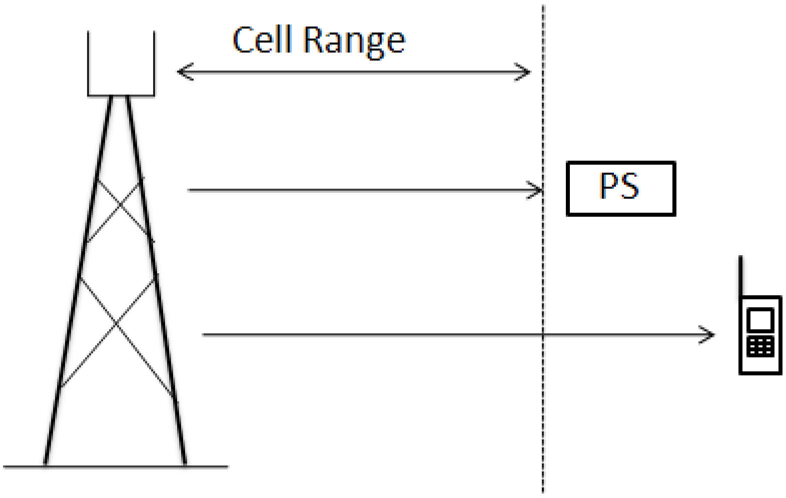


Figure 8.13 Maximum uplink path losses

Which ever Lpmax is the smallest will be the service that determines the uplink cell range (R). In the illustration in Figure 8.13 it is the PS service.

8.8 Okumura-Hata Propagation Formula

$$L_{path} = A - 13.82 \log H_b + (44.9 - 6.55 \log H_b) \log R - a(H_m)[dB] \qquad (8.16)$$

Where

A = 155.1 for urban

A = 147.9 for suburban and semi-open areas

A = 135.8 for rural

A = 125.4 for open areas.

H_b = base station antenna height [m]

H_m = UE antenna height [m]

R = distance from transmitter [km]

$a(Hm) = 3.2(Log(11.75*Hm))^2 - 4.97$ or for 1.5m antenna a(1.5) = 0

When H_b = 30m and H_m =1.5m the OH formula can be written as:

$$L_{path} = (A - 20.41) + 35.22 \log R \qquad (8.17)$$

$$L_{path} = a + b.\log R[dB] \qquad (8.18)$$

Where

a = 155.1 - 20.41 = 134.69 for urban areas

a = 147.9 - 20.41 = 127.49 for suburban and semi-open areas

a = 135.8 - 20.41 = 115.39 for rural areas

a = 125.4 - 20.41 = 104.99 open areas

b = 35.22

R = range [km]

When roughly estimating the size of macro cells, without taking into account specific terrain features in the area, the Okumura-Hata propagation formula can be solved for R to give below.

$$R_{p\max} = 10^{\alpha}, \text{where}\alpha = (L_{p\max} - a)/b\left[\text{dB}\right] \qquad (8.19)$$

It must be emphasized that the Okumura-Hata formula only can be used for rough estimates. For more precise numbers, networkplanning tools should be used.

8.9 Site Coverage Area

This range may now be used to calculate the coverage area of the site using for omni, three-sector and six sector sites respectively as illustrated in figure 8.14 below.

A=coverage area

d=site to site distance

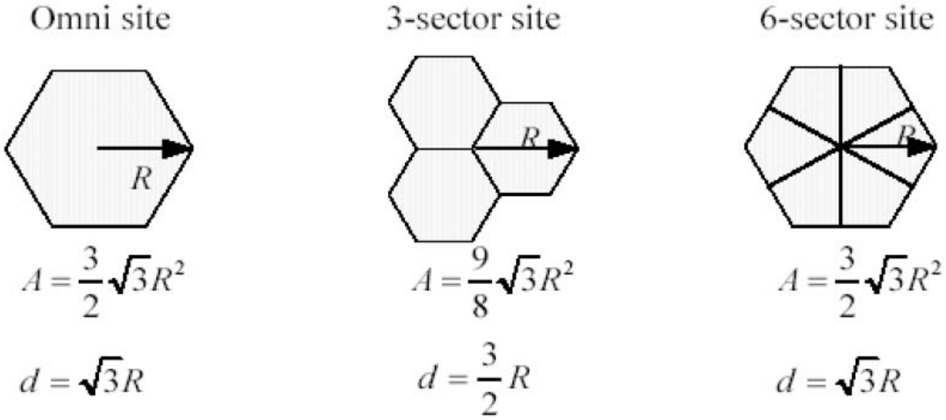


Figure 8.14 Relationships between coverage area and cell range

8.10 Downlink Dimensioning

The Antenna System Controller (ASC) contains a Tower Mounted Amplifier (TMA) that is designed to overcome feeder losses for the Uplink but will introduce extra losses in the downlink. These losses are illustrated in Figure 8.15 below.

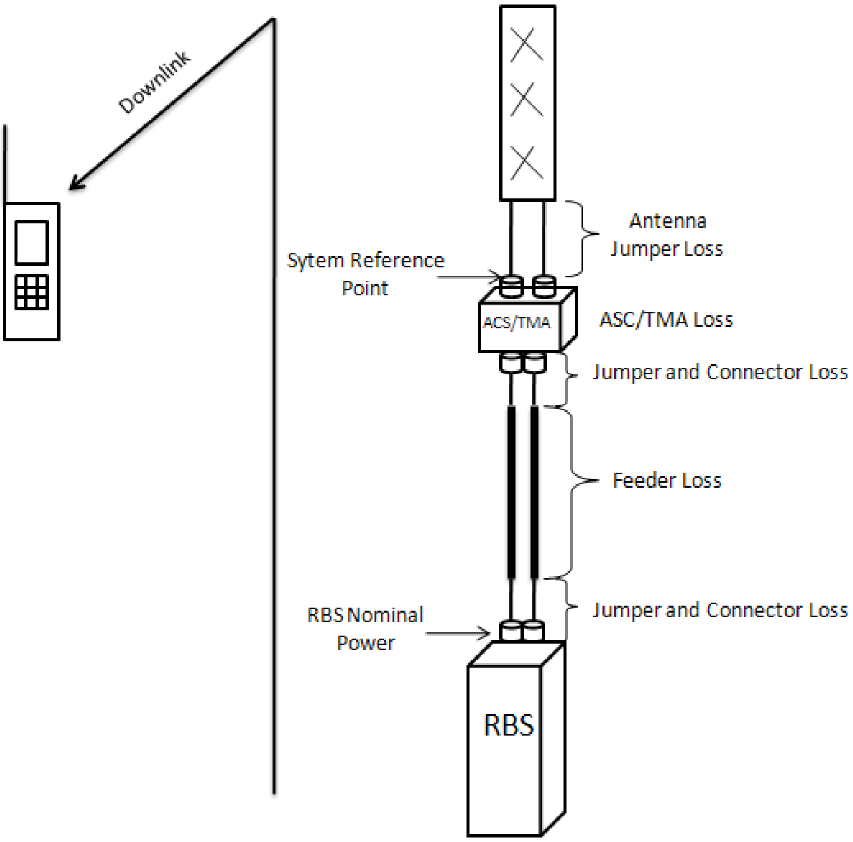


Figure 8.15 Downlink link budget losses

8.10.1 RBS Nominal Power ($P_{NOM,RBS}$)

The RBS nominal power ($P_{nom,RBS}$) is the power present at the top of the cabinet.

This is given by equation below:

$$P_{nom,RBS}=\text{MCPA power} - \text{cabinet losses [W]} \qquad (8.20)$$

For a RBS with 20W MCPA$_S$,$P_{nom,RBS}$=17.4 W

8.10.2 Reference Point Nominal Power (P_{NOMREF})

The nominal power at the reference point ($P_{nom,ref}$) in a system with an ASC is the power present at the top of the ASC. This is given by equation below:

$$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC} \text{ [dBm]} \quad (8.21)$$

Where:

$P_{nom,RBS}$ RBS nominal power (17.4 W for 20W MCPA)

L_{J+C} jumper and connector loss e.g. 1 dB

L_F is the feeder loss e.g. 30m of LCF 7/8" = 1.9 dB

L_{ASC} ASC insertion loss e.g. 0.2 dB

With the example values above the Reference Point Nominal Power is worked out as below:

$P_{nom,RBS}$ = 17.4 W = 10log(17400) dBm = 32.4 dBm

$P_{nom,ref}$ = 32.4 – 1 – 1.9 – 0.2 = 29.3 dBm = 8.5 W

Once the uplink cell range has been established the following checks are made to ensure the relevant powers do not exceed the recommended values as below:

1. CPICH Power ($P_{CPICH,\, ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Where:

$P_{nom,ref}$ is the nominal RBS power at the system reference point.

$P_{CPICH,\, ref}$ is the CPICH power at the system reference point.

$P_{tot,ref}$ is the average total output power at the system reference point.

$P_{DCH,ref}$ is the maximum power allocated to one single user.

Check 1: CPICH Power (PCPICH, ref $\leq$ 0.1 Pnom,ref)

The CPICH power check is performed with the following steps:

Step : 1

Calculate UE CPICH Sensitivity using 8.22 equation below :

$$S_{UE,CPICH}=N_t + N_f + 10\ \log R_{chip} + E_c/N_o\ [\text{dBm}] \qquad (8.22)$$

Where:

Nt is thermal noise power density (-174 dBm/Hz)

Nf is the UE noise figure (7 dB is assumed for planning)

Rchip is the chip rate (3.84 X 10^6 bps)

Ec/No is CPICH energy per chip/ noise power density (-16 dB)

Step : 2

Calculate the path loss at the uplink cell range using Okumura-Hata :

$$L_{path} = a + b\ \log R\ [\text{dB}] \qquad (8.23)$$

Where

a = 155.1 - 20.41 = 134.69 for urban areas

a = 147.9 - 20.41 = 127.49 for suburban and semi-open areas

a = 135.8 - 20.41 = 115.39 for rural areas

a = 125.4 - 20.41 = 104.99 open areas

b = 35.22

Step : 3

Calculate the signal attenuation (Lsa) at this range using 8.24 equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB] (8.24)

Where:

L_{path} is the pathloss calculated in step 2 [dB]

B_{LNF} is the log-normal fading margin excluding soft handover [dB]

B_{PC} is the power control margin (0dB as CPICH does not use iner Loop PC)

L_{BL} is the body loss [dB]

L_{CPL} is the Car Penetration Loss – N/A for indoor coverage

L_{BPL} is the building Penetration Loss – for indoor coverage only [dB]

L_J is the jumper loss [dB]

G_a is the sum of UE and RBS antenna gain in [dBi]

Step : 4

Calculate the downlink Interference margin (B_{IDL}) at maximum load using 8.25 equation below.

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha + F}{N_t . N_f . R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[\mathrm{dB}] \qquad (8.25)$$

Where:

$\alpha = 1$ (for CPICH)

F = 2.1 (CPICH measured at Cell border)

Ptot,ref = 0.75 X Pnom,ref [W]

Nt = thermal noise power density

(-174 dBm/Hz = 3.98×10^{-21} W/Hz)

Nf = Noise figure of the UE (7dB= 5.01)

Rchip = system chip rate in 3.84 MHz = 3.84×10^{6} Hz

L_{sa} = the calculated attenuation from Step 3 in linear units

Step : 5

Calculate $P_{CPICH,ref}$ using 8.26 equation below.

$P_{CPICH,ref} = L_{sa} + S_{UE,CHICH} + B_{IDL}$ [dBm] (8.26)

Where:

L_{sa} is the value calculated in step 3 [dB]

$S_{UE,CHICH}$ is the value calculated in step 1 [dBm]

B_{IDL} is the value calculated in step 4 [dB]

Step : 6

Check that $P_{CPICH,ref} \leq 0.1$ Pnom,ref

Check 2: Total Power ($P_{total, Ref} \leq 0.75\ P_{nom,Ref}$)

The total power check is performed with the following steps:

Step : 1

Calculate the Common Channel Power at the reference point ($P_{CCH,ref}$) using 8.27 equation below.

$$P_{CCH,ref}=2.5\ P_{CPICH,ref} \quad [W] \tag{8.27}$$

Where:

$P_{CPICH,ref}$ is the value calculated in Check 1 [W]

Step : 2

Calculate the DCH signal attenuation (L_{sa}) using 8.28 equation below.

$$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_{J} - G_{a} \quad [dB] \tag{8.28}$$

Where:

L_{path} is the pathloss calculated in check 1 [dB]

B_{LNF} is the log-normal fading margin including soft handover [dB]

B_{PC} is the power control margin [dB]

L_{BL} is the body loss [dB]

L_{CPL} is the Car Penetration Loss – N/A for indoor coverage

L_{BPL} is the building Penetration Loss – for indoor coverage only [dB]
L_J is the jumper loss [dB]
G_a is the sum of UE and RBS antenna gain in [dBi]

Step : 3

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1 - Q} \qquad (8.29)$$

Where:
$P_{CCH,ref}$ is the value calculated in step 1. [W]
H is a factor related to the path loss distribution of the UEs within the cell, calculated according to equation 32. Speech H values for an Urban 3-sector site are given in Table 8.13.
L_{sa} is the attenuation value calculated in check 1 [linear units]
Q is the downlink system load.

Step : 4

Check that $P_{tot,ref} \leq 0.75\ P_{non,ref}$
Calculation of H value;
The H value used in step2 is calculated with equation 8.30 below:

$$H = \rho.\gamma.N.\sum_{b=1}^{n_{AS}} \left(\frac{b}{1 + \alpha.\gamma + G_{SHO}(b)} \right).\phi \qquad (8.30)$$

Where:
ρ is the user density per cell which depends on cell type and load.
γ is the downlink C/I target (linear scale) for the RAB.
N is the receiver noise
α is the non-orthogonality factor of the Cell.
b is the active links for the connection (b ≥2 soft handover)
GSHO is the system average of soft handover gain.

Φ is an integral and can be calculated through numerical integration for different types of site configurations. For urban 3- sector sites a value of 1.103 may be used to calculate H.

Speech and PS 64 H values for a 3-sector urban site are given in Table 8.13 below.

Table 8.13 Speech and PS 64 H values for Urban 3-sector site

Cell Load	Speech H Value	PS64 H Value
40%	7.42421×10^{-15}	7.43294×10^{-15}
45%	8.35224×10^{-15}	8.36206×10^{-15}
50%	9.28026×10^{-15}	9.29118×10^{-15}
55%	1.02083×10^{-14}	1.02203×10^{-14}
60%	1.11363×10^{-14}	1.11494×10^{-14}
65%	1.20643×10^{-14}	1.20785×10^{-14}
70%	1.29924×10^{-14}	1.30077×10^{-14}
75%	1.39204×10^{-14}	1.39368×10^{-14}

Check 3: DCH Power ($P_{DCH,Ref} \leq 0.3\ P_{nom,Ref}$)

The DCH power check is performed with the following steps:

Step : 1

Calculate UE DCH Sensitivity using equation 8.31 below.

$$S_{UE}=N_t+N_f+10\log R_{info}+E_b/N_o \text{ [dBm]} \tag{8.31}$$

Where:

Nt is thermal noise power density (-174 dBm/Hz)

Nf is the UE noise figure (7 dB is assumed for planning)

Rinfo is the information bit rate [bps]

Eb/No is energy per bit/ noise power density for the service [dB]

Step : 2

Calculate the DCH signal attenuation (L_{sa}) using 8.32 equation below.

$$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a \ \text{[dB]} \tag{8.32}$$

Where:

L_{path} is the pathloss calculated in check 1 [dB]

B_{LNF} is the log-normal fading margin including soft handove [dB]

B_{PC} is the power control margin [dB]

L_{BL} is the body loss [dB]

L_{CPL} is the Car Penetration Loss – N/A for indoor coverage

L_{BPL} is the building Penetration Loss – for indoor coverage only [dB]

L_J is the jumper loss [dB]

G_a is the sum of UE and RBS antenna gain in [dBi]

Step : 3

Calculate the downlink Interference margin (B_{IDL}) at the specified load.

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha + F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[\text{dB}] \tag{8.33}$$

Where:

$\alpha = 0.64$ from TU

$F = 0.72$ (for 3-sector Urban Site)

$P_{tot,ref}$= the value calculated in check 2 [W]

N_t = thermal noise power density (-174 dBm/Hz = 3.98×10^{-21} W/Hz)

N_f = Noise figure of the UE (7dB= 5.01)

R_{chip} = system chip rate in 3.84 MHz = 3.84×10^6 Hz

L_{sa} = the calculated attenuation from step 2 [linear units]

Step : 4

Calculate DCH power at the reference point ($P_{DCH,ref}$) using equation 8.43 below.

$$P_{DCH,ref}=L_{sa}+S_{UE}+B_{IDL}\ \ [\text{dBm}] \tag{8.34}$$

Where:

L_{sa} = the attenuation calculated in step 2 [dB]

S_{UE} is the value calculated in step 1 [dBm]

B_{IDL} is the value calculated in step 3 [dB]

Step : 5

Check that $P_{DCH,ref} \leq 0.3\ P_{nom,ref}$

CHAPTER NINE

CITY PLAN FOR 3G WCDMA

The objective of the design project is to illustrate how to dimension a WCDMA system with respect to both coverage and capacity. An Erlang B table is below.

Table 9.1 Erlang B Table

(N)	0,2%	0,5%	1%	1,5%	2%	3%	5%	7%	10%	15%
1	0,002	0,005	0,010	0,02	0,020	0,031	0,053	0,075	0,111	0,176
2	0,065	0,105	0,153	0,19	0,223	0,282	0,381	0,470	0,595	0,796
3	0,249	0,349	0,455	0,53	0,602	0,715	0,899	1,06	1,27	1,60
4	0,535	0,701	0,869	0,99	1,09	1,26	1,52	1,75	2,05	2,50
5	0,900	1,13	1,36	1,52	1,66	1,88	2,22	2,50	2,88	3,45
6	1,33	1,62	1,91	2,11	2,28	2,54	2,96	3,30	3,76	4,44
7	1,80	2,16	2,50	2,73	2,94	3,25	3,74	4,14	4,67	5,46
8	2,31	2,73	3,13	3,40	3,63	3,99	4,54	5,00	5,60	6,50
9	2,85	3,33	3,78	4,08	4,34	4,75	5,37	5,88	6,55	7,55
10	3,43	3,96	4,46	4,80	5,08	5,53	6,22	6,78	7,51	8,62
11	4,02	4,61	5,16	5,53	5,84	6,33	7,08	7,69	8,49	9,69
12	4,64	5,28	5,88	6,27	6,61	7,14	7,95	8,61	9,47	10,8
13	5,27	5,96	6,61	7,03	7,40	7,97	8,83	9,54	10,5	11,9
14	5,92	6,66	7,35	7,81	8,20	8,80	9,73	10,5	11,5	13,0
15	6,58	7,38	8,11	8,59	9,01	9,65	10,6	11,4	12,5	14,1
16	7,26	8,10	8,88	9,39	9,83	10,5	11,5	12,4	13,5	15,2
17	7,95	8,83	9,65	10,19	10,7	11,4	12,5	13,4	14,5	16,3
18	8,64	9,58	10,4	11,00	11,5	12,2	13,4	14,3	15,5	17,4
19	9,35	10,3	11,2	11,82	12,3	13,1	14,3	15,3	16,6	18,5
20	10,1	11,1	12,0	12,65	13,2	14,0	15,2	16,3	17,6	19,6
21	10,8	11,9	12,8	13,48	14,0	14,9	16,2	17,3	18,7	20,8
22	11,5	12,6	13,7	14,32	14,9	15,8	17,1	18,2	19,7	21,9
23	12,3	13,4	14,5	15,16	15,8	16,7	18,1	19,2	20,7	23,0

24	13,0	14,2	15,3	16,01	16,6	17,6	19,0	20,2	21,8	24,2
25	13,8	15,0	16,1	16,87	17,5	18,5	20,0	21,2	22,8	25,3
26	14,5	15,8	17,0	17,72	18,4	19,4	20,9	22,2	23,9	26,4
27	15,3	16,6	17,8	18,59	19,3	20,3	21,9	23,2	24,9	27,6
28	16,1	17,4	18,6	19,45	20,2	21,2	22,9	24,2	26,0	28,7
29	16,8	18,2	19,5	20,32	21,0	22,1	23,8	25,2	27,1	29,9
30	17,6	19,0	20,3	21,19	21,9	23,1	24,8	26,2	28,1	31,0
31	18,4	19,9	21,2	22,07	22,8	24,0	25,8	27,2	29,2	32,1
32	19,2	20,7	22,0	22,95	23,7	24,9	26,7	28,2	30,2	33,3
33	20,0	21,5	22,9	23,83	24,6	25,8	27,7	29,3	31,3	34,4
34	20,8	22,3	23,8	24,72	25,5	26,8	28,7	30,3	32,4	35,6
35	21,6	23,2	24,6	25,60	26,4	27,7	29,7	31,3	33,4	36,7
36	22,4	24,0	25,5	26,49	27,3	28,6	30,7	32,3	34,5	37,9
37	23,2	24,8	26,4	27,39	28,3	29,6	31,6	33,3	35,6	39,0
38	24,0	25,7	27,3	28,28	29,2	30,5	32,6	34,4	36,6	40,2
39	24,8	26,5	28,1	29,18	30,1	31,5	33,6	35,4	37,7	41,3
40	25,6	27,4	29,0	30,08	31,0	32,4	34,6	36,4	38,8	42,5
41	26,4	28,2	29,9	30,98	31,9	33,4	35,6	37,4	39,9	43,6
42	27,2	29,1	30,8	31,88	32,8	34,3	36,6	38,4	40,9	44,8
43	28,1	29,9	31,7	32,79	33,8	35,3	37,6	39,5	42,0	45,9
44	28,9	30,8	32,5	33,69	34,7	36,2	38,6	40,5	43,1	47,1
45	29,7	31,7	33,4	34,60	35,6	37,2	39,6	41,5	44,2	48,2
46	30,5	32,5	34,3	35,51	36,5	38,1	40,5	42,6	45,2	49,4
47	31,4	33,4	35,2	36,42	37,5	39,1	41,5	43,6	46,3	50,6
48	32,2	34,2	36,1	37,34	38,4	40,0	42,5	44,6	47,4	51,7
49	33,0	35,1	37,0	38,25	39,3	41,0	43,5	45,7	48,5	52,9
50	33,9	36,0	37,9	39,17	40,3	41,9	44,5	46,7	49,6	54,0
51	34,7	36,9	38,8	40,08	41,2	42,9	45,5	47,7	50,6	55,2
52	35,6	37,7	39,7	41,00	42,1	43,9	46,5	48,8	51,7	56,3
53	36,4	38,6	40,6	41,92	43,1	44,8	47,5	49,8	52,8	57,5
54	37,2	39,5	41,5	42,84	44,0	45,8	48,5	50,8	53,9	58,7
55	38,1	40,4	42,4	43,77	44,9	46,7	49,5	51,9	55,0	59,8
56	38,9	41,2	43,3	44,69	45,9	47,7	50,5	52,9	56,1	61,0

57	39,8	42,1	44,2	45,62	46,8	48,7	51,5	53,9	57,1	62,1
58	40,6	43,0	45,1	46,54	47,8	49,6	52,6	55,0	58,2	63,3
59	41,5	43,9	46,0	47,47	48,7	50,6	53,6	56,0	59,3	64,5
60	42,4	44,8	46,9	48,40	49,6	51,6	54,6	57,1	60,4	65,6
61	43,2	45,6	47,9	49,33	50,6	52,5	55,6	58,1	61,5	66,8
62	44,1	46,5	48,8	50,26	51,5	53,5	56,6	59,1	62,6	68,0
63	44,9	47,4	49,7	51,19	52,5	54,5	57,6	60,2	63,7	69,1
64	45,8	48,3	50,6	52,12	53,4	55,4	58,6	61,2	64,8	70,3
65	46,6	49,2	51,5	53,05	54,4	56,4	59,6	62,3	65,8	71,4
66	47,5	50,1	52,4	53,99	55,3	57,4	60,6	63,3	66,9	72,6
67	48,4	51,0	53,4	54,92	56,3	58,4	61,6	64,4	68,0	73,8
68	49,2	51,9	54,3	55,86	57,2	59,3	62,6	65,4	69,1	74,9
69	50,1	52,8	55,2	56,79	58,2	60,3	63,7	66,4	70,2	76,1
70	51,0	53,7	56,1	57,73	59,1	61,3	64,7	67,5	71,3	77,3
71	51,8	54,6	57,0	58,67	60,1	62,3	65,7	68,5	72,4	78,4
72	52,7	55,5	58,0	59,61	61,0	63,2	66,7	69,6	73,5	79,6
73	53,6	56,4	58,9	60,55	62,0	64,2	67,7	70,6	74,6	80,8
74	54,5	57,3	59,8	61,49	62,9	65,2	68,7	71,7	75,6	81,9
75	55,3	58,2	60,7	62,43	63,9	66,2	69,7	72,7	76,7	83,1
76	56,2	59,1	61,7	63,37	64,9	67,2	70,8	73,8	77,8	84,2
77	57,1	60,0	62,6	64,32	65,8	68,1	71,8	74,8	78,9	85,4
78	58,0	60,9	63,5	65,26	66,8	69,1	72,8	75,9	80,0	86,6
79	58,8	61,8	64,4	66,20	67,7	70,1	73,8	76,9	81,1	87,7
80	59,7	62,7	65,4	67,15	68,7	71,1	74,8	78,0	82,2	88,9
81	60,6	63,6	66,3	68,09	69,6	72,1	75,8	79,0	83,3	90,1
82	61,5	64,5	67,2	69,04	70,6	73,0	76,9	80,1	84,4	91,2
83	62,4	65,4	68,2	69,99	71,6	74,0	77,9	81,1	85,5	92,4
84	63,2	66,3	69,1	70,93	72,5	75,0	78,9	82,2	86,6	93,6
85	64,1	67,2	70,0	71,88	73,5	76,0	79,9	83,2	87,7	94,7
86	65,0	68,1	70,9	72,83	74,5	77,0	80,9	84,3	88,8	95,9
87	65,9	69,0	71,9	73,78	75,4	78,0	82,0	85,3	89,9	97,1
88	66,8	69,9	72,8	74,73	76,4	78,9	83,0	86,4	91,0	98,2
89	67,7	70,8	73,7	75,68	77,3	79,9	84,0	87,4	92,1	99,4

90	68,6	71,8	74,7	76,63	78,3	80,9	85,0	88,5	93,1	100,6
91	69,4	72,7	75,6	77,58	79,3	81,9	86,0	89,5	94,2	101,7
92	70,3	73,6	76,6	78,53	80,2	82,9	87,1	90,6	95,3	102,9
93	71,2	74,5	77,5	79,48	81,2	83,9	88,1	91,6	96,4	104,1
94	72,1	75,4	78,4	80,43	82,2	84,9	89,1	92,7	97,5	105,3
95	73,0	76,3	79,4	81,39	83,1	85,8	90,1	93,7	98,6	106,4
96	73,9	77,2	80,3	82,34	84,1	86,8	91,1	94,8	99,7	107,6
97	74,8	78,2	81,2	83,29	85,1	87,8	92,2	95,8	100,8	108,8
98	75,7	79,1	82,2	84,25	86,0	88,8	93,2	96,9	101,9	109,9
99	76,6	80,0	83,1	85,20	87,0	89,8	94,2	97,9	103,0	111,1
100	77,5	80,9	84,1	86,16	88,0	90,8	95,2	99,0	104,1	112,3

9.1 Dimensioning Flow

In Figure 9.1 a sample RAN dimensioning process is shown. This method is by no means the only way to dimension a network, but it is a common method to do so.

Naturally, the process is dependent on the particular scenario being dimensioned. The process illustrated in figure 9.1 below, merely, attempts to cover the most important aspects.

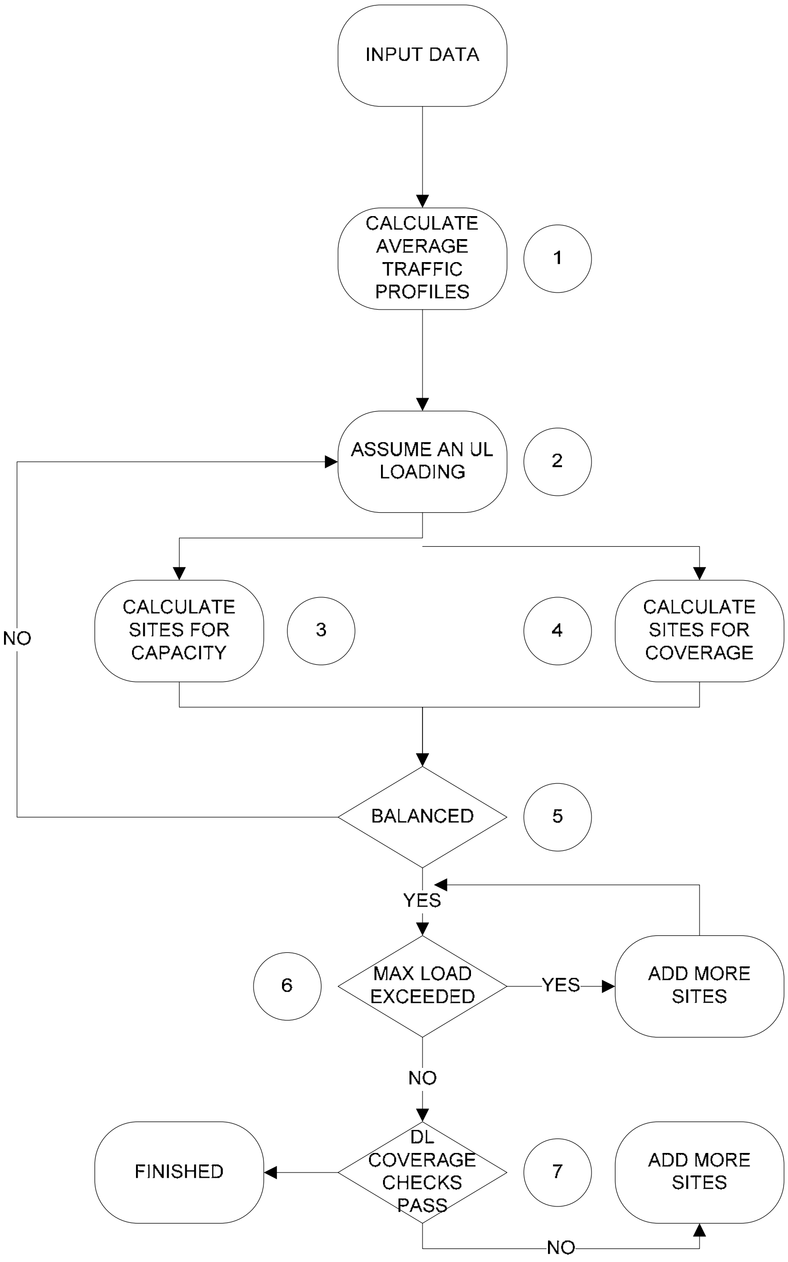


Figure 9.1 Sample RAN dimensioning process

The uplink iteration process is designed to find the number of sites and loading that produces a balance between the number of sites needed for coverage and capacity. As the uplink load increases the number of sites required for capacity reduces since more channels are available. However since the uplink interference margin (B_{IUL}) increases with load the number of sites for capacity increases. This convergence of site numbers is depicted in Figure 9.2 below.

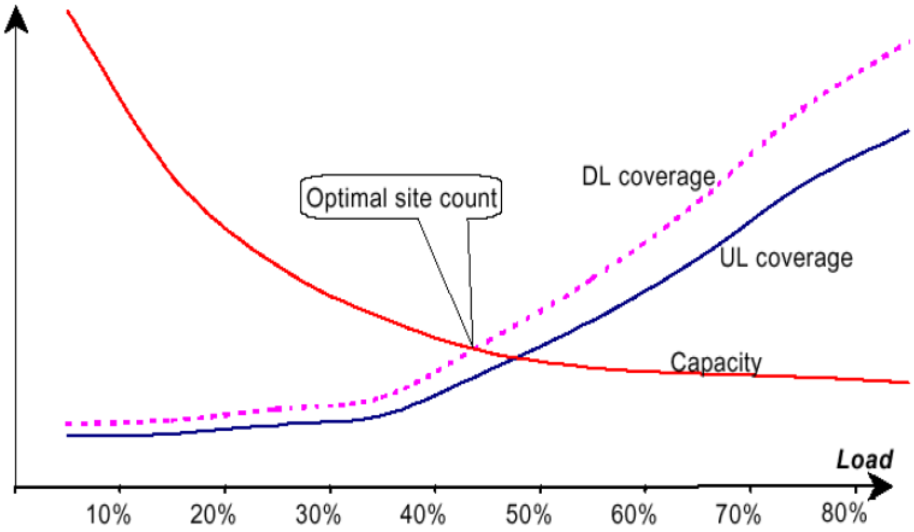


Figure 9.2 Site convergence

9.2 City Plan Exercise

Calculate how many 3-sector sites with the configuration below would be required to provide 95% indoor coverage in urban and %98 indoor coverage in dense urban in City A.

Figure 9.3 Planned City

- Coverage area in urban area = 10km^2
- Coverage area in denseurban area = 5km^2
- Antenna height in urban area = 20 m
- Antenna height in denseurban area = 25 m
- Feeder type in urban and dense urban areas = LCF 7/8”
- Jumper and connector loss in urban and dense urban areas = 1dB
- Antenna gain in urban and dense urban area = 18.5 dBi
- ASC used in urban and dense urban area =Yes
- Antenna Jumper loss in urban and dense urban area = 0.2 dB
- Maximum Uplink load in urban and dense urban area <70%
- Maximum Downlink Load in urban and dense urban area <76%
- 20W MCPA = $P_{nom,RBS}$ = 17.4 W
- UE Maximum output power = 24 dBm
- Number of UMTS subscribers in urban area = 50.000
- Number of UMTS voice subscribers in urban area =50.000
- Number of UMTS packet data subscribers in urban area =10.000
- Number of UMTS subscribers in denseurban area = 30.000
- Number of UMTS voice subscribers in denseurban area =30.000
- Number of UMTS packet data subscribers in denseurban area =15.000
- Average data rate per user in urban area = 64 kbps
- Average data rate per user in denseurban area = 128 kbps
- Blocking rate in urban area=%2
- Blocking rate in denseurban area=%1
- BHCA speech in urban area= 0.5
- BHCA speech in denseurban area=0.6
- BHCA video telephony in urban area=0.2
- BHCA video telephony in denseurban area=0.4
- Average speech call duration in urban area = 1 min
- Average speech call duration in denseurban area = 2 min
- Average CS call duration in urban area = 0.5 min
- Average CS call duration in denseurban area = 1 min
- BH uplink+downlink data volume per subscribers in urban area = 1000 kbit

- BH uplink+downlink data volume per subscribers in denseurban = 1500 kbit
- Ratio uplink/downlink traffic in urban area =10%
- Ratio uplink/downlink traffic in denseurban =20%

Solution:

Step 1. Calculate Average Traffic Profile

In urban area:

Using equation below we can calculate the traffic in Erlangs for the speech service:

Traffic (A) = BHCA X MHT
BHCA = 0.5
MHT = 1 min = (1/60) = 0.016 hours
Traffic (A) =0.5 x 0.016 =$8x10^{-3}$ E =8 mE

Using equation below we can account for the weighting of the service:

BH Traffic per sub (mE) = A X Weighting factor
BH Traffic per sub (mE) = 8 x (50000/50000) = 8 mE

For the PS we must first convert the BH requirement from kbit to KB below:

BH UL+DL data volume per subs (kbit) = 1000 kbit
Ratio uplink/downlink traffic = %10
KB in BH – Total = 125
KB in BH – UL = 12.5 KB
KB in BH – DL = 112.5 KB

The BH average KB per sub is given in Equation below:

Average PS Kbyte in BH = Weighting factor X Kbyte in BH
Average UL PS KB in BH =(10000/50000) X 12.5 = 2.5 KB
Average DL PS KB in BH =(10000/50000) X 112.5 = 22.5 KB

In denseurban area:

Using equation below we can calculate the traffic in Erlangs for the speech service:

Traffic (A) = BHCA X MHT
BHCA = 0.7
MHT = 2 min = (2/60) = 0.033 hours
Traffic (A) =0.7 x 0.033 =23.1 x10^{-3} E =23.1 mE

Using equation below we can account for the weighting of the service:

BH Traffic per sub (mE) = A X Weighting factor
BH Traffic per sub (mE) = 23.1 x (30000/30000) = 23.1 mE

For the PS we must first convert the BH requirement from kbit to KB below:

BH UL+DL data volume per subs (kbit) = 1500 kbit
Ratio uplink/downlink traffic = %15
KB in BH – Total = 187.5
KB in BH – UL = 28.12 KB
KB in BH – DL = 159.38 KB

The BH average KB per sub is given in Equation below:

Average PS Kbyte in BH = Weighting factor X Kbyte in BH
Average UL PS KB in BH =(10000/30000) X 28.12 = 9.373 KB
Average DL PS KB in BH =(10000/30000) X 159.38 = 53.126 KB

Step 2. Assume An Uplink Load

We do not dimension for loads less than 20% and the maximum allowed load in this network is 70% for UL and 76 &DL. An initial loading figure of 50% (a noise rise of 2.2 dB) is probably a good starting value.

Step 3. Sites Required For Uplink Capacity (50% Load)

In urban area:

We know that the conversational load (Qc) is equal to the number of speech channels (M) divided by Mpole, therefore the number of channels can be derived from the formula below:

$M = Q_c \text{ x } M_{pole}$
Uplink Mpole for Speech for a 3-sector urban site is 70
M = 0.5 x 70 = 35 channels

Assuming a GoS of 2% the offered traffic for 35 channels can be extrapolated to be 26.44 Erlangs, from the Erlang table.

Offered Traffic = number of subs X traffic per sub
number of subs = Offered Traffic/traffic per sub
The ‘traffic per sub’ from the input data is 8 mE
number of subs = $26.44 /(8 \text{ X } 10^{-3}) = 3305$

Each sector can support 3305 subscribers, therefore one 3-sector site can support (3305X3) = 9915 subscribers.

The number of sectors required is given by:

(Total number of subs)/(subs supported by a site)

50000/9915= 5.04

6 sites meets the UL Capacity requirement at 50% load.

In denseurban area:

$M = Q_c$ x M_{pole}
Uplink Mpole for Speech for a 3-sector urban site is 70
M = 0.5 x 70 = 35 channels

Assuming a GoS of 1% the offered traffic for 35 channels can be extrapolated to be 24.64 Erlangs, from the Erlang table.

Offered Traffic = number of subs X traffic per sub
number of subs = Offered Traffic/traffic per sub
The ‘traffic per sub’ from the input data is 11.25 mE
number of subs = 24.64 /(23.1 X 10^{-3}) = 1066.6=1067

Each sector can support 1067 subscribers, therefore one 3-sector site can support (1067X3) = 3201 subscribers.

The number of sectors required is given by:

(Total number of subs)/(subs supported by a site)
30000/3201= 9.37

10 sites meets the UL Capacity requirement at 50% load.

Step 4. Sites Required For Uplink Coverage (50% Load)

In urban area:

The table below shows the link budgets for 50% load:

For 50% load $B_{IUL} = 10\log\left[\frac{1}{1-Q}\right][dB] = 10\log\left[\frac{1}{1-0.5}\right] = 3.01$

Table 9.2 Link budget values for urban area

Link Budget Terms	Speech, TU3	PS, TU3
P_{UE}	24	24
S_{UL}	-124.5	-120.1
B_{IUL}	3.01	3.01
Urban Indoor B_{LNF}	7.5	7.5
B_{PC}	0.7	0.7
L_{BL}	3	0
L_{BPL}	18	18
L_J	0.2	0.2
G_a	18.5	18.5

$\mathbf{L}_{pmax}= P_{UE} - S_{UL} - B_{IUL} - B_{LN} - B_{PC} - L_{BL} - L_{BPL} - L_J + G_a$

$\mathbf{L}_{pmaxSpeech}= 24 - (-124.5) – 3.01 – 7.5 – 0.7 – 3 – 18 – 0.2 + 18.5 = 134.59$

$\mathbf{L}_{pmaxPS}= 24 - (-120.1) – 3.01 – 7.5 – 0.7 – 0 – 18 – 0.2 + 18.5 = 133.19$

Lowest P_{max}=133.19

$$R_{p\max} = 10^{\alpha}, \text{where} \alpha = (L_{p\max} - a)/b[dB]$$

$\alpha = (133.19 – 134.69) / 35.22 = -0.042$

$R_{pmax}=10^{-0.042}=0.907$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.R^2$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.0.907^2 = 1.60km^2$

Sites Required for 12 km^2 = 12/1.60 = 7.5 = 8 site required

In denseurban area:

The table below shows the link budgets for 50% load:

For 50% load $B_{IUL} = 10\log\left[\frac{1}{1-Q}\right][\mathrm{dB}] = 10\log\left[\frac{1}{1-0.5}\right] = 3.01$

Table 9.3 Link budget values for denseurban area

Link Budget Terms	Speech, TU3	PS, TU3
P_{UE}	24	24
S_{UL}	-124.5	-120.1
B_{IUL}	3.01	3.01
Dense Urban Indoor B_{LNF}	14.3	14.3
B_{PC}	0.7	0.7
L_{BL}	3	0
L_{BPL}	18	18
L_J	0.2	0.2
G_a	18.5	18.5

$\mathbf{L}_{pmax}= P_{UE} - S_{UL} - B_{IUL} - B_{LN} - B_{PC} - L_{BL} - L_{BPL} - L_J + G_a$

$\mathbf{L}_{pmaxSpeech}= 24 - (-124.5) – 3.01 – 14.3 – 0.7 – 3 – 18 – 0.2 + 18.5 = 127.79$

$\mathbf{L}_{pmaxPS}= 24 - (-120.1) – 3.01 – 14.3 – 0.7 – 0 – 18 – 0.2 + 18.5 = 126.39$

Lowest P_{max}=126.39

$R_{p\max} = 10^{\alpha}, \text{where} \alpha = (L_{p\max} - a)/b[\mathrm{dB}]$

$\alpha = (126.39 – 134.69) / 35.22 = -0.2356$

$R_{pmax}=10^{-0.2356}=0.5812$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.R^2$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.0.5812^2 = 0.658km^2$

Sites Required for 5 km^2 = 5/0.658 = 7.59= 8 site required

Step 5. Check For Coverage / Capacity Balance

In urban area 6 sites are needed for UL Capacity and 8 sites for coverage so the network is not balanced at 50% load.In denseurban area 10 sites are needed for UL Capacity and 8 sites for coverage so the network is not balanced at 50% load.For urban area step 3 and step 4 will need to be %40 load and for dense urban area Step 3 and 4 will need to be repeated for 60% load.

Step 3. Sites Required For Uplink Capacity (40% Load)

In urban area:

We know that the conversational load (Qc) is equal to the number of speech channels (M) divided by Mpole, therefore the number of channels can be derived from the formula below:

$M = Q_c \times M_{pole}$
Uplink Mpole for Speech for a 3-sector urban site is 70
$M = 0.4 \times 70 = 28$ channels

Assuming a GoS of 2% the offered traffic for 35 channels can be extrapolated to be 20.15 Erlangs, from the Erlang table.

Offered Traffic = number of subs X traffic per sub
number of subs = Offered Traffic/traffic per sub
The ‘traffic per sub’ from the input data is 8 mE
number of subs = $20.15 /(8 \times 10^{-3}) = 2518.7=2519$

Each sector can support 2519 subscribers, therefore one 3-sector site can support (2519X3) = 7557 subscribers.

The number of sectors required is given by:

(Total number of subs)/(subs supported by a site)
50000/7557= 6.61

7 sites meets the UL Capacity requirement at 40% load.

Step 4. Sites Required For Uplink Coverage (40% Load)

In urban area:

The table below shows the link budgets for 50% load:

For 50% load $B_{IUL} = 10\log\left[\frac{1}{1-Q}\right][dB] = 10\log\left[\frac{1}{1-0.4}\right] = 2.2$

Table 9.4 Link budget values for urban area

Link Budget Terms	Speech, TU3	PS, TU3
P_{UE}	24	24
S_{UL}	-124.5	-120.1
B_{IUL}	2.2	2.2
Urban Indoor B_{LNF}	7.5	7.5
B_{PC}	0.7	0.7
L_{BL}	3	0
L_{BPL}	18	18
L_J	0.2	0.2
G_a	18.5	18.5

$\mathbf{L}_{pmax}= P_{UE} - S_{UL} - B_{IUL} - B_{LN} - B_{PC} - L_{BL} - L_{BPL} - L_J + G_a$

$\mathbf{L}_{pmaxSpeech}= 24 - (-124.5) – 1.66 – 7.5 – 0.7 – 3 – 18 – 0.2 + 18.5 = 135.4$

$\mathbf{L}_{pmaxPS}= 24 - (-120.1) – 1.66 – 7.5 – 0.7 – 0 – 18 – 0.2 + 18.5 = 134$

Lowest P_{max}=134

$R_{p\max} = 10^{\alpha}, \text{where} \alpha = (L_{p\max} - a)/b[dB]$

$\alpha = (134 - 134.69) / 35.22 = -0.019$

$R_{pmax}=10^{-0.019}=0.957$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.R^2$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.0.957^2 = 1.78km^2$

Sites Required for 12 km^2 = 12/1.78 = 6.74 = 7 site required

Step 3. Sites Required For Uplink Capacity (60% Load)

In denseurban area:

$M = Q_c \times M_{pole}$

Uplink Mpole for Speech for a 3-sector urban site is 70

M = 0.6 x 70 = 42 channels

Assuming a GoS of 1% the offered traffic for 42 channels can be extrapolated to be 30.77 Erlangs, from the Erlang table.

Offered Traffic = number of subs X traffic per sub

number of subs = Offered Traffic/traffic per sub

The ‘traffic per sub’ from the input data is 23.1 mE

number of subs = 30.77 /(23.1 X 10^{-3}) = 1332

Each sector can support 5288 subscribers, therefore one 3-sector site can support (1332X3) = 3996 subscribers.

The number of sectors required is given by:

(Total number of subs)/(subs supported by a site)

300000/3996= 7,5

8 sites meets the UL Capacity requirement at 60% load.

Step 4. Sites Required For Uplink Coverage (60% Load)

In denseurban area:

The table below shows the link budgets for 60% load:

For 60% load $B_{IUL} = 10\log\left[\frac{1}{1-Q}\right][dB] = 10\log\left[\frac{1}{1-0.6}\right] = 3.97$

Table 9.5 Link budget values for denseurban area

Link Budget Terms	Speech, TU3	PS, TU3
P_{UE}	24	24
S_{UL}	-124.5	-120.1
B_{IUL}	3.97	3.97
Dense Urban Indoor B_{LNF}	14.3	14.3
B_{PC}	0.7	0.7
L_{BL}	3	0
L_{BPL}	18	18
L_J	0.2	0.2
G_a	18.5	18.5

$L_{pmax} = P_{UE} - S_{UL} - B_{IUL} - B_{LN} - B_{PC} - L_{BL} - L_{BPL} - L_J + G_a$

$L_{pmaxSpeech} = 24 - (-124.5) – 3.97 – 14.3 – 0.7 – 3 – 18 – 0.2 + 18.5 = 126.83$

$L_{pmaxPS} = 24 - (-120.1) – 3.97 – 14.3 – 0.7 – 0 – 18 – 0.2 + 18.5 = 125.43$

Lowest P_{max}=125.43

$$R_{p\max} = 10^{\alpha}, \text{where} \alpha = (L_{p\max} - a)/b[dB]$$

$\alpha = (125.43 – 134.69) / 35.22 = -0.2629$

$R_{pmax} = 10^{-0.2629} = 0.5458$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.R^2$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.0.5458^2 = 0.5804 km^2$

Sites Required for 5 km^2 = 5/0.5804 = 8.61 = 9 site required

Step 5. Check For Coverage / Capacity Balance

In urban area 7 sites are needed for UL Capacity and 7 sites for coverage so the network is balanced at 40% load.In denseurban area 8 sites are needed for UL Capacity and 9 sites for coverage so the network is not balanced at 60% load. for dense urban area Step 3 and 4 will need to be repeated for 55% load.

Step 3. Sites Required For Uplink Capacity (55% Load)

In denseurban area:

$M = Q_c \times M_{pole}$

Uplink Mpole for Speech for a 3-sector urban site is 70

M = 0.55 x 70 = 38.5=39 channels

Assuming a GoS of 1% the offered traffic for 39 channels can be extrapolated to be 28.13 Erlangs, from the Erlang table.

Offered Traffic = number of subs X traffic per sub
number of subs = Offered Traffic/traffic per sub
The ‘traffic per sub’ from the input data is 23.1 mE
number of subs = 28.13 /(23.1 X 10^{-3}) = 1217.7=1218

Each sector can support 5288 subscribers, therefore one 3-sector site can support (1218X3) = 3654 subscribers.

The number of sectors required is given by:

(Total number of subs)/(subs supported by a site)
300000/3654= 8.2

9 sites meets the UL Capacity requirement at 55% load.

Step 4. Sites Required For Uplink Coverage (55% Load)

In denseurban area:

The table below shows the link budgets for 60% load:

For 60% load $B_{IUL} = 10\log\left[\frac{1}{1-Q}\right][dB] = 10\log\left[\frac{1}{1-0.55}\right] = 3.46$

Table 9.6 Link budget values for denseurban area

Link Budget Terms	Speech, TU3	PS, TU3
P_{UE}	24	24
S_{UL}	-124.5	-120.1
B_{IUL}	3.46	3.46
Dense Urban Indoor B_{LNF}	14.3	14.3
B_{PC}	0.7	0.7
L_{BL}	3	0
L_{BPL}	18	18
L_J	0.2	0.2
G_a	18.5	18.5

$\mathbf{L}_{pmax}= P_{UE} - S_{UL} - B_{IUL} - B_{LN} - B_{PC} - L_{BL} - L_{BPL} - L_J + G_a$

$\mathbf{L}_{pmaxSpeech}= 24 - (-124.5) – 3.46 – 14.3 – 0.7 – 3 – 18 – 0.2 + 18.5 = 127.34$

$\mathbf{L}_{pmaxPS}= 24 - (-120.1) – 3.46 – 14.3 – 0.7 – 0 – 18 – 0.2 + 18.5 = 125.94$

Lowest P_{max}=125.94

$$R_{p\max} = 10^{\alpha}, \text{where} \alpha = (L_{p\max} - a)/b[\text{dB}]$$

$\alpha = (125.94 - 134.69) / 35.22 = -0.2484$

$R_{pmax}=10^{-0.2484}=0.5644$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.R^2$

Site coverage for 3 sectors = $\frac{9}{8}.\sqrt{3}.0.5644^2 = 0.62\text{km}^2$

Sites Required for 5 km^2 = 5/0.62 = 8.06 = 9 site required

Step 5. Check For Coverage / Capacity Balance

In urban area 7 sites are needed for UL Capacity and 7 sites for coverage so the network is balanced at 40% load. In denseurban area 9 sites are needed for UL Capacity and 9 sites for coverage so the network is not balanced at 55% load.

Step 6. Check That Maximum Loading Is Not Exceeded

The maximum loading is given by equation below:

$$Q_{\max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{\text{pole,CS}}}\right) + \left(\frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times 64 \times 10^3 \times M_{\text{pole,PS}}}\right)\right]$$

From step 5 we calculated that in urban area 7 sites at a load of 40% gives a balance for uplink coverage and capacity and in denseurban area 9 sites at a load of 55% gives a balance for uplink coverage and capacity

In urban area:

For uplink;

7 sites is (7x3) = 21 sectors.

21 sectors => 50000/21 = 2380.9=2381 subs/sector

For the uplink the maximum load is given by:

Peak factor for %40 load =1/0.4=2.5

$$Q_{\max} = 2381\left[\left(\frac{8.10^{-3}}{70}\right)+\left(\frac{2.5\times 1024\times 8\times 2.5}{3600\times 64\times 10^{3}\times 16}\right)\right] = 0.30$$

The maximum uplink load is 30% which should not exceed the balanced load of 40 % so 7 sites is ok for the uplink.

In denseurban area:

For uplink;

9 sites is (9x3) = 27 sectors.
27 sectors => 30000/27 = 1111.1=1112 subs/sector

For the uplink the maximum load is given by:

Peak factor for %55 load =1/0.55=1.81

$$Q_{\max} = 1112\left[\left(\frac{23.1\times 10^{-3}}{70}\right)+\left(\frac{9.373\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 16}\right)\right] = 0.40$$

The maximum uplink load is 40% which should not exceed the balanced load of 55 % so 9 sites is ok for the uplink.

In urban area:

For downlink;

7 sites is (7x3) = 21 sectors.

21 sectors => 50000/21 = 2380.9=2381 subs/sector

For the uplink the maximum load is given by:

Peak factor for %40 load =1/0.4=2.5

$$Q_{\max} = 2381\left[\left(\frac{8.10^{-3}}{60}\right)+\left(\frac{22.5\times 1024\times 8\times 2.5}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.85$$

The maximum downlink load is 85% so the limit of 75% is exceeded.

More sites will need to be added so that this load is not exceeded.

Firstly 1 sites will be added:

For uplink;

8 sites is (8x3) = 24 sectors.

24 sectors => 50000/24 = 2083.3=2084 subs/sector

For the uplink the maximum load is given by:

Peak factor for %40 load =1/0.4=2.5

$$Q_{\max} = 2084\left[\left(\frac{8.10^{-3}}{70}\right)+\left(\frac{2.5\times 1024\times 8\times 2.5}{3600\times 64\times 10^{3}\times 16}\right)\right] = 0.26$$

The maximum uplink load is 26% which should not exceed the balanced load of 40 % so 8 sites is ok for the uplink.

For downlink;

$$Q_{\max} = 2084\left[\left(\frac{8.10^{-3}}{60}\right)+\left(\frac{22.5\times 1024\times 8\times 2.5}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.74$$

The maximum downlink load is 74% so the limit of 75% is not exceeded.

The maximum uplink load is 74% which should not exceed the balanced load of 40 % so 8 sites is ok for the downlink.

In denseurban area:

For downlink;

9 sites is (9x3) = 27 sectors.
27 sectors => 30000/27 = 1111.1=1112 subs/sector

For the uplink the maximum load is given by:

Peak factor for %55 load =1/0.55=1.81

$$Q_{\max} = 1112\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.85$$

The maximum downlink load is 85% so the limit of 75% is exceeded.

More sites will need to be added so that this load is not exceeded.

Firstly 1 sites will be added:

For uplink;

10 sites is (10x3) = 30 sectors.

30 sectors => 30000/30 = 1000 subs/sector

For the uplink the maximum load is given by:

Peak factor for %55 load =1/0.55=1.81

$$Q_{\max} = 1000\left[\left(\frac{23.1.10^{-3}}{70}\right)+\left(\frac{9.373\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 16}\right)\right]=0.36$$

The maximum uplink load is 36% which should not exceed the balanced load of 55 % so 10 sites is ok for the uplink.

For downlink;

$$Q_{\max} = 1000\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 8.9}\right)\right]=0.76$$

The maximum downlink load is 76% so the limit of 75% is exceeded.

Another 1 sites will be added:

For uplink;

11 sites is (11x3) = 33 sectors.

33 sectors => 30000/33 = 909.09=910 subs/sector

Peak factor for %55 load =1/0.55=1.81

$$Q_{\max} = 910\left[\left(\frac{23.1.10^{-3}}{70}\right)+\left(\frac{9.373\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 16}\right)\right]=0.32$$

The maximum uplink load is 32% which should not exceed the balanced load of 55 % so 11 sites is ok for the uplink.

For downlink;

$$Q_{\max} = 910\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.69$$

The maximum downlink load is 69% so the limit of 75% is not exceeded.

The maximum downlink load is 69% which should not exceed the balanced load of 55% so 11 sites is ok for the downlink.

Step 7. Perform Downlink Coverage Checks

In Urban Area: (8 sites)

The following downlink coverage limits must not be exceeded for 8 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]

$P_{nom,ref} = 17.4$ W $= 42.4$ dB

$L_{J+C} = 1$ dB

$L_F = 20$m 7/8 feeder $= 1.26$ dB

$L_{ASC} = 0.2$ dB

$P_{nom,ref} = 42.4 - 1 - 1.26 - 0.2 = 39.94$ dBm = 9.86 W

8 sites covering 12 km^2 implies that the coverage area of each site is 12/8 = 1.5km^2.

We know that the area of a 3-sector site is

$A = 9/8\,(\sqrt{3})(R^2) = 1.95R^2$

$1.5 = 1.95R^2$

$R = 0.877$ km

The cell range with 8 sites is 0.877 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right) + \left(\frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times 64 \times 10^3 \times M_{pole,PS}}\right)\right]$$

$$Q_{max} = 2084\left[\left(\frac{8.10^{-3}}{60}\right) + \left(\frac{22.5 \times 1024 \times 8 \times 2.5}{3600 \times 64 \times 10^3 \times 8.9}\right)\right] = 0.74$$

Check 1: CPICH power ($P_{CPICH,\,ref} \leq 0.1\, P_{nom,ref}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH} = N_t + N_f + 10\log R_{chip} + E_c/N_o$ [dBm]

$S_{UE,CPICH} = -174 + 7 + 10\log(3.84\text{x}10^6) - 16 = -117.15$

Step 2:

Calculate the path loss at 0.877 km cell range using the simplified Okumura-Hata equation below:

$L_{path} = a + b.\log R$ [dB]

Where

a = 134.69 for urban areas

b = 35.22

R = 0.877 km

$L_{pmax} = 134.69 + 35.22\text{Log}0.877 = 132.68$ dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_{J} - G_{a}$ [dB]

Lsa= 132.68 + 7.5 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 143.58 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{143.58/10} = 2.28 \times 10^{14}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1 + \left(\left(\frac{\alpha + F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

α = 1 (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = $3.98 \text{ X } 10^{-21}$ W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref} = (0.75)x(9.86) = 7.395$ W

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{7.395}{2.28\times10^{14}}\right)\right)\right)[\text{dB}] = 3.64\text{dB}$$

$L_{sa} = 2.28 \times 10^{14}$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]

$P_{CPICH,ref} = 143.58–117.2 + 3.64 = 30.02$ dBm = 1 W

Step 6 :

We must check that this is below the limit ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH,\ ref}/\ P_{nom,ref} = 1/9.86 = 0.101$

$P_{CPICH,\ ref} = 0.101\ P_{nom,ref}$

Therefore the limit is exceeded and more sites needs to be added. One sites should be added.Go to step7.

In Urban Area: (9 sites)

The following downlink coverage limits must not be exceeded for 9 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)

3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]

$P_{nom,ref} = 17.4$ W = 42.4 dB

$L_{J+C} = 1$ dB

$L_F = 20$m 7/8 feeder = 1.26 dB

$L_{ASC} = 0.2$ dB

$P_{nom,ref} = 42.4 - 1 - 1.26 - 0.2 = 39.94$ dBm = 9.86 W

9 sites covering 12 km^2 implies that the coverage area of each site is 12/9 = 1.33km^2.

We know that the area of a 3-sector site is

$A = 9/8\ (\sqrt{3})(R^2) = 1.95R^2$

$1.33 = 1.95R^2$

$R = 0.825$ km

The cell range with 9 sites is 0.877 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right) + \left(\frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times 64 \times 10^3 \times M_{pole,PS}}\right)\right]$$

9 sites is (9x3) = 27 sectors.

27 sectors => 50000/27 = 1851.8=1852 subs/sector

For the uplink the maximum load is given by:

Peak factor for %40 load =1/0.4=2.5

$$Q_{\max} = 1852\left[\left(\frac{8.10^{-3}}{60}\right)+\left(\frac{22.5\times 1024\times 8\times 2.5}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.65$$

Check 1: CPICH Power ($P_{CPICH,\ REF} \leq 0.1\ P_{NOM,REF}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH}=N_t + N_f + 10\ \log R_{chip}+E_c/N_o$ [dBm]

$S_{UE,CPICH}=-174 + 7 + 10\log(3.84x10^6) - 16 = -117.15$

Step 2:

Calculate the path loss at 0.877 km cell range using the simplified Okumura-Hata equation below:

$L_{path} = a + b.\log R$ [dB]

Where

a = 134.69 for urban areas

b = 35.22

R = 0.825 km

$L_{pmax} = 134.69 + 35.22\text{Log}0.825 = 131.74$ dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]

Lsa= 131.74 + 7.5 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 142.64 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{142.64/10} = 1.83 \text{ x } 10^{14}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 1$ (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = $3.98 \text{ x } 10^{-18}$ mW/Hz = $3.98 \text{ X } 10^{-21}$ W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref} = (0.75)x(9.86) = 7.395$ W

$L_{sa} = 1.83 \text{ x } 10^{14}$

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{7.395}{1.83\times10^{14}}\right)\right)\right)[dB] = 4.20dB$$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]

$P_{CPICH,ref} = 142.64–117.2 + 4.20 = 29.64$ dBm = 0.92 W

Step 6 :

We must check that this is below the limit ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH,\ ref}/\ P_{nom,ref} = 0.92/9.86 = 0.09$

$P_{CPICH,\ ref} = 0.09\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 2: Total Power ($P_{TOT,\ REF} \leq 0.75\ P_{NOM,REF}$)

Step1 :

First we must calculate $P_{CCH,ref}$ using equation below:

$P_{CCH,ref}$=2.5 $P_{CPICH,ref}$ [W]
$P_{CCH,ref}$=2.5 x 0.92 = 2.3 [W]

Step2 :

We must calculate the greatest signal attenuation using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]
$L_{sa(speech)}$= 131.74 + 7.5 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 142.64 dB
$L_{sa(PS64)}$= 131.74 + 7.5 + 0.7 + 0 + 0 + 18 + 0.2 – 18.5 = 139.64 Db

The greatest DCH attenuation is that for speech 142.64 dB
We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{142.64/10} = 1.83 \times 10^{14}$

Step 3:

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1 - Q}$$

$$P_{tot,ref} = \frac{2.3 + (1.29924 \times 10^{-14} \times 1.83 \times 10^{14})}{1 - 0.4} = 8.91W$$

Step 4 :

Check that $P_{tot,ref} \leq 0.75\ P_{nom,ref}$

$P_{tot,ref}/\ P_{nom,ref} = 8.91/9.86 = 0.90$
$P_{tot,ref} = 0.90\ P_{nom,ref}$

Therefore the limit is exceeded and more sites needs to be added. One sites should be added. Go to step7.

In Urban Area: (10 sites)

The following downlink coverage limits must not be exceeded for 10 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]
$P_{nom,ref} = 17.4$ W = 42.4 dB
$L_{J+C} = 1$ dB
$L_F = 20$m 7/8 feeder = 1.26 dB
$L_{ASC} = 0.2$ dB
$P_{nom,ref} = 42.4 - 1 - 1.26 - 0.2 = 39.94$ dBm = 9.86 W

10 sites covering 12 km^2 implies that the coverage area of each site is 12/10 = $1.2km^2$.

We know that the area of a 3-sector site is

$A= 9/8 (\sqrt{3})(R^2) = 1.95R^2$
$1.2=1.95R^2$
$R=0.784$ km

The cell range with 10 sites is 0.784 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right) + \left(\frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times 64 \times 10^3 \times M_{pole,PS}}\right)\right]$$

10 sites is (10x3) = 30 sectors.
30 sectors => 50000/30 = 1666.6=1667 subs/sector

For the uplink the maximum load is given by:

Peak factor for %40 load =1/0.4=2.5

$$Q_{max} = 1852\left[\left(\frac{8.10^{-3}}{60}\right) + \left(\frac{22.5 \times 1024 \times 8 \times 2.5}{3600 \times 64 \times 10^3 \times 8.9}\right)\right] = 0.58$$

Check 1: CPICH Power ($P_{CPICH, REF} \leq 0.1\ P_{NOM,REF}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH}=N_t + N_f + 10 \log R_{chip} + E_c/N_o$ [dBm]

$S_{UE,CPICH}$=-174 + 7 + 10log(3.84x10^6) – 16 = -117.15

Step 2:

Calculate the path loss at 0.784 km cell range using the simplified Okumura-Hata equation below:

$L_{path} = a + b.\log R$ [dB]

Where
a = 134.69 for urban areas
b = 35.22
R = 0.825 km
L_{pmax} = 134.69 + 35.22Log0.784 = 130.96 dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]
Lsa= 130.96 + 7.5 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 141.86 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{141.86/10} = 1.53 \times 10^{14}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha + F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 1$ (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = 3.98×10^{-21} W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref} = (0.75)x(9.86) = 7.395$ W

$L_{sa} = 1.53 \times 10^{14}$

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{7.395}{1.53\times10^{14}}\right)\right)\right)[dB] = 4.70dB$$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]

$P_{CPICH,ref} = 141.86–117.2 + 4.70 = 29.36$ dBm = 0.86 W

Step 6 :

We must check that this is below the limit ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH,\ ref}/\ P_{nom,ref} = 0.86/9.86 = 0.087$

$P_{CPICH,\ ref} = 0.087\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 2: Total Power ($P_{TOT,\ REF} \leq 0.75\ P_{NOM,REF}$)

Step1 :

First we must calculate $P_{CCH,ref}$ using equation below:

$P_{CCH,ref}=2.5\ P_{CPICH,ref}$ [W]

$P_{CCH,ref}=2.5 \times 0.86 = 2.15$ [W]

Step2 :

We must calculate the greatest signal attenuation using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_{J} - G_{a}$ [dB]

$L_{sa(speech)} = 130.96 + 7.5 + 0.7 + 3 + 0 + 18 + 0.2 - 18.5 = 141.86$ dB

$L_{sa(PS64)} = 130.96 + 7.5 + 0.7 + 0 + 0 + 18 + 0.2 - 18.5 = 138.86$ dB

The greatest DCH attenuation is that for speech 141.86 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{141.86/10} = 1.53 \times 10^{14}$

Step 3 :

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1-Q}$$

$$P_{tot,ref} = \frac{2.15 + (1.29924 \times 10^{-14} \times 1.53 \times 10^{14})}{1-0.4} = 6.89\mathrm{W}$$

Step 4:

Check that $P_{tot,ref} \leq 0.75\ P_{nom,ref}$

$P_{tot,ref}/\ P_{nom,ref} = 6.89/9.86 = 0.69$

$P_{tot,ref} = 0.69\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 3: DCH Power ($P_{DCH, REF} \leq 0.3\ P_{NOM,REF}$) – Speech

Firstly the check is made for speech:

Step 1:

Calculate UE DCH Sensitivity using equation below:

$S_{UE}=N_t+N_f+10\log R_{info}+E_b/N_o$ [dBm]

For speech TU 3:

N_t = -174 dBm/Hz

N_f = 7

R_{info} = 15600 bps

Eb/No = 7.2 dB

S_{UE} = -174 + 7 + 10 log (15600) + 7.2 = -117.9 dBm

Step 2:

Calculate the downlink Interference margin (BIDL) at the specified load using equation below.

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

α = 0.64

F = 0.72 (for 3-sector Urban Site)

N_t = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = 3.98×10^{-21} W/Hz

N_f = 7dB = 5.01

R_{chip} = 3.84 Mcps 3.84 x 10^6 cps

$P_{tot,ref}$ = 6.89 W (from check 2)

L_{sa} = 141.86 dB = $10^{141.86/10}$ = 1.53 x 10^{14} (from check 2)

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{0.64+0.72}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{6.89}{1.53\times10^{14}}\right)\right)\right)[\mathrm{dB}] = 2.25\mathrm{dB}$$

Step 3:

Calculate DCH power at the reference point ($P_{DCH,ref}$) using equation below.

$P_{DCH,ref}=L_{sa}+S_{UE}+B_{IDL}$ [dBm]

$P_{DCH,ref}$ = 141.86 –117.9 + 2.25 = 26.21 dBm = 0.417 W

Step 4:

Check that $P_{DCH,ref} \leq 0.3\ P_{nom,ref}$

$P_{DCH,ref}/\ P_{nom,ref}$ = 0.417/9.86 = 0.042

$P_{DCH,ref}$ = 0.042 $P_{nom,ref}$

Therefore the limit is not exceeded.

Check 3: DCH Power ($P_{DCH,\ REF} \leq 0.3\ P_{NOM,REF}$) – PS64

Secondly the check is made for speech:

Step 1:

Calculate UE DCH Sensitivity using equation below:

$S_{UE}=N_t+N_f+10\log R_{info}+E_b/N_o$ [dBm]

For speech TU 3:

N_t = -174 dBm/Hz

N_f = 7

R_{info} = 76400 bps

Eb/No = 6.4 dB

S_{UE} = -174 + 7 + 10 log (67400) + 6.4 = -112.3 dBm

Step 2:

Calculate the downlink Interference margin (BIDL) at the specified load using equation below.

$$B_{IDL} = 10\log\left(1 + \left(\left(\frac{\alpha + F}{N_t . N_f . R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 0.64$

F = 0.72 (for 3-sector Urban Site)

N_t = -174 dBm/Hz = 3.98 x 10^{-18} mW/Hz = 3.98 X 10 $^{-21}$ W/Hz

N_f = 7dB = 5.01

R_{chip} = 3.84 Mcps 3.84 x 10^6 cps

$P_{tot,ref}$ = 6.89 W (from check 2)

L_{sa} = 138.86 dB = $10^{138.86/10}$ = 7.69 x 10^{13} (from check 2)

$$B_{IDL} = 10\log\left(1 + \left(\left(\frac{0.64 + 0.72}{3.98 \times 10^{-21} \times 5.01 \times 3.84 \times 10^6}\right) . \left(\frac{6.89}{7.69 \times 10^{13}}\right)\right)\right)[dB] = 4.13dB$$

Step 3:

Calculate DCH power at the reference point ($P_{DCH,ref}$) using equation below.

$P_{DCH,ref} = L_{sa} + S_{UE} + B_{IDL}$ [dBm]

$P_{DCH,ref}$ = 138.86 –112.3 + 4.13 = 30.69 dBm = 1.17 W

Step 4:

Check that $P_{DCH,ref} \leq 0.3\ P_{nom,ref}$

$P_{DCH,ref}/\ P_{nom,ref} = 1.17/9.86 = 0.11$
$P_{DCH,ref} = 0.011\ P_{nom,ref}$

Therefore the limit is not exceeded.

It would appear that 10 Sites meets the requirements for this Network in urban area.

Step 7. Perform Downlink Coverage Checks

In Dense Urban Area: (11 sites)

The following downlink coverage limits must not be exceeded for 11 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]
$P_{nom,ref} = 17.4\ W = 42.4\ dB$
$L_{J+C} = 1\ dB$
$L_F = 25m\ 7/8$ feeder $= 1.57\ dB$

$L_{ASC} = 0.2$ dB

$P_{nom,ref} = 42.4 - 1 - 1.57 - 0.2 = 39.43$ dBm = 8.77 W

11 sites covering 5 km^2 implies that the coverage area of each site is 5/11 = 0.45 km^2.

We know that the area of a 3-sector site is

$A = 9/8\,(\sqrt{3})(R^2) = 1.95R^2$

$0.45 = 1.95R^2$

$R = 0.48$ km

The cell range with 11 sites is 0.48 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right)+\left(\frac{\text{PS\_data\_per\_sub}\times 1024\times 8\times \text{Peak\_Factor}}{3600\times 64\times 10^3\times M_{pole,PS}}\right)\right]$$

11 sites is (11x3) = 33 sectors.

33 sectors => 30000/33 = 909.09=910 subs/sector

Peak factor for %55 load =1/0.55=1.81

$$Q_{max} = 910\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^3\times 8.9}\right)\right] = 0.69$$

Check 1: CPICH Power ($P_{CPICH,\,REF} \leq 0.1\ P_{NOM,REF}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH} = N_t + N_f + 10\log R_{chip} + E_c/N_o$ [dBm]

$S_{UE,CPICH}$=-174 + 7 + 10log(3.84x10^{6}) – 16 = -117.15

Step 2:

Calculate the path loss at 0.48 km cell range using the simplified Okumura-Hata equation below:

L_{path} = a + b.logR [dB]
Where
a = 134.69 for urban areas
b = 35.22
R = 0.48 km
L_{pmax} = 134.69 + 35.22Log0.48 = 123.46 dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]
Lsa= 123.46 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 141.16 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{141.16/10} = 1.3 \text{ x } 10^{14}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha + F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 1$ (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = $3.98 \text{ X } 10^{-21}$ W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref} = (0.75)x(8.77) = 6.57W$

$L_{sa} = 1.3 \times 10^{14}$

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{6.57}{1.3\times10^{14}}\right)\right)\right)[dB] = 4.83dB$$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]

$P_{CPICH,ref} = 141.16–117.2 + 4.83 = 28.79$ dBm = 0.75 W

Step 6 :

We must check that this is below the limit ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH,\ ref}/\ P_{nom,ref} = 0.75/8.77 = 0.085$

$P_{CPICH,\ ref} = 0.085\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 2: Total Power ($P_{TOT,\ REF} \leq 0.75\ P_{NOM,REF}$)

Step1 :

First we must calculate $P_{CCH,ref}$ using equation below:

$P_{CCH,ref}$=2.5 $P_{CPICH,ref}$ [W]

$P_{CCH,ref}$=2.5 x 0.85 = 2.12 [W]

Step2 :

We must calculate the greatest signal attenuation using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]

$L_{sa(speech)} = 123.46 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 141.16$ dB

$L_{sa(PS64)} = 122.16 + 14.3 + 0.7 + 0 + 0 + 18 + 0.2 – 18.5 = 138.16$ dB

The greatest DCH attenuation is that for speech 141.16 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{141.16/10} = 1.3 \text{ x } 10^{14}$

Step 3 :

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1 - Q}$$

$$P_{tot,ref} = \frac{2.12 + (1.29924 \times 10^{-14} \times 1.3 \times 10^{14})}{1 - 0.55} = 8.46\text{W}$$

Step 4 :

Check that $P_{tot,ref} \leq 0.75\ P_{nom,ref}$

$P_{tot,ref}/\ P_{nom,ref} = 8.46/8.77 = 0.96$

$P_{tot,ref} = 0.96\ P_{nom,ref}$

Therefore the limit is exceeded and more sites needs to be added. One sites should be added. Go to step7.

Step 7. Perform Downlink Coverage Checks

In Dense Urban Area: (12 sites)

The following downlink coverage limits must not be exceeded for 12 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]
$P_{nom,ref} = 17.4$ W = 42.4 dB
$L_{J+C} = 1$ dB
$L_F = 25$m 7/8 feeder = 1.57 dB
$L_{ASC} = 0.2$ dB
$P_{nom,ref} = 42.4 - 1 - 1.57 - 0.2 = 39.43$ dBm = 8.77 W

12 sites covering 5 km^2 implies that the coverage area of each site is 5/12 = 0.41 km^2.

We know that the area of a 3-sector site is
$A = 9/8\ (\sqrt{3})(R^2) = 1.95R^2$
$0.41 = 1.95R^2$

R=0.458 km

The cell range with 12 sites is 0.458 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right)+\left(\frac{\text{PS\_data\_per\_sub}\times 1024\times 8\times \text{Peak\_Factor}}{3600\times 64\times 10^{3}\times M_{pole,PS}}\right)\right]$$

12 sites is (12x3) = 36 sectors.

36 sectors => 30000/36 = 833.3=834subs/sector

Peak factor for %55 load =1/0.55=1.81

$$Q_{max} = 834\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.61$$

Check 1: CPICH Power ($P_{CPICH,\ REF} \leq 0.1\ P_{NOM,REF}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH}=N_t + N_f + 10\ \log R_{chip} + E_c/N_o$ [dBm]

$S_{UE,CPICH}=-174 + 7 + 10\log(3.84\text{x}10^6) - 16 = -117.15$

Step 2:

Calculate the path loss at 0.458 km cell range using the simplified Okumura-Hata equation below:

$L_{path} = a + b.\log R$ [dB]

Where

a = 134.69 for urban areas

b = 35.22

R = 0.458 km

L_{pmax} = 134.69 + 35.22Log0.458 = 122.75 dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]

Lsa= 122.75 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 140.45 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{140.45/10} = 1.1 \times 10^{14}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

α = 1 (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = $3.98 \text{ X } 10^{-21}$ W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref}$ = (0.75)x(8.77) = 6.57 W

$L_{sa} = 2.28 \times 10^{14}$

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{6.57}{1.1\times10^{14}}\right)\right)\right)[dB] = 5.33dB$$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]
$P_{CPICH,ref} = 140.45–117.2 + 5.33 = 28.58$ dBm = 0.72 W

Step 6 :

We must check that this is below the limit ($P_{CPICH, ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH, ref}/\ P_{nom,ref} = 0.72/8.77 = 0.082$
$P_{CPICH, ref} = 0.082\ P_{nom,ref}$
Therefore the limit is not exceeded.

Check2: Total Power ($P_{TOT, REF} \leq 0.75\ P_{NOM,REF}$)

Step1 :

First we must calculate $P_{CCH,ref}$ using equation below:

$P_{CCH,ref}$=2.5 $P_{CPICH,ref}$ [W]
$P_{CCH,ref}$=2.5 x 0.72 = 1.8 [W]

Step2 :

We must calculate the greatest signal attenuation using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]

$L_{sa(speech)}$= 122.75 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 140.45 dB

$L_{sa(PS64)}$= 122.75 + 14.3 + 0.7 + 0 + 0 + 18 + 0.2 – 18.5 = 137.45 dB

The greatest DCH attenuation is that for speech 140.45 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{140.45/10} = 1.1 \text{ x } 10^{14}$

Step 3:

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1-Q}$$

$$P_{tot,ref} = \frac{1.8 + (1.29924 \times 10^{-14} \times 1.1 \times 10^{14})}{1-0.55} = 7.17W$$

Step 4:

Check that $P_{tot,ref} \leq 0.75\ P_{nom,ref}$

$P_{tot,ref}/\ P_{nom,ref} = 7.17/8.77 = 0.81$

$P_{tot,ref} = 0.81\ P_{nom,ref}$

Therefore the limit is exceeded and more sites needs to be added. One sites should be added.Go to step7.

Step 7. Perform Downlink Coverage Checks

In Dense Urban Area: (13 sites)

The following downlink coverage limits must not be exceeded for 12 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]
$P_{nom,ref} = 17.4$ W = 42.4 dB
$L_{J+C} = 1$ dB
L_F = 25m 7/8 feeder = 1.57 dB
$L_{ASC} = 0.2$ dB
$P_{nom,ref} = 42.4 - 1 - 1.57 - 0.2 = 39.43$ dBm = 8.77 W

13 sites covering 5 km^2 implies that the coverage area of each site is 5/13 = 0.38 km^2.

We know that the area of a 3-sector site is

$A = 9/8\ (\sqrt{3})(R^2) = 1.95R^2$
$0.38 = 1.95R^2$
$R = 0.441$ km

The cell range with 13 sites is 0.441 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = Number\_of\_Subs\left[\left(\frac{traffic\_per\_sub\_CS}{M_{pole,CS}}\right)+\left(\frac{PS\_data\_per\_sub\times 1024\times 8\times Peak\_Factor}{3600\times 64\times 10^{3}\times M_{pole,PS}}\right)\right]$$

13 sites is (13x3) = 39 sectors.

39 sectors => 30000/39 = 769.2=770subs/sector

Peak factor for %55 load =1/0.55=1.81

$$Q_{max} = 770\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.56$$

Check 1: CPICH Power ($P_{CPICH,\,REF} \leq 0.1\ P_{NOM,REF}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH}=N_t + N_f + 10\ \log R_{chip}+E_c/N_o$ [dBm]

$S_{UE,CPICH}=-174 + 7 + 10\log(3.84x10^{6}) - 16 = -117.15$

Step 2:

Calculate the path loss at 0.458 km cell range using the simplified Okumura-Hata equation below:

$L_{path} = a + b.\log R$ [dB]

Where

a = 134.69 for urban areas

b = 35.22

R = 0.441 km

$L_{pmax} = 134.69 + 35.22\text{Log}0.441 = 122.16$ dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]

Lsa= 122.16 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 139.86 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{139.86/10} = 9.68 \text{ x } 10^{13}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

α = 1 (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = $3.98 \text{ x } 10^{-18}$ mW/Hz = $3.98 \text{ X } 10^{-21}$ W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref} = (0.75)\text{x}(8.77) = 6.57$ W

$L_{sa} = 9.68 \text{ x } 10^{13}$

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{6.57}{9.68\times10^{13}}\right)\right)\right)[\text{dB}] = 5.73\text{dB}$$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]
$P_{CPICH,ref} = 139.86–117.2 + 5.73 = 28.39$ dBm = 0.69 W

Step 6 :

We must check that this is below the limit ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH,\ ref}/\ P_{nom,ref} = 0.69/8.77 = 0.078$
$P_{CPICH,\ ref} = 0.078\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 2: Total Power ($P_{TOT,\ REF} \leq 0.75\ P_{NOM,REF}$)

Step1 :

First we must calculate $P_{CCH,ref}$ using equation below:

$P_{CCH,ref}$=2.5 $P_{CPICH,ref}$ [W]
$P_{CCH,ref}$=2.5 x 0.69 = 1.72 [W]

Step2 :

We must calculate the greatest signal attenuation using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]
$L_{sa(speech)}$= 122.16 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 139.86 dB
$L_{sa(PS64)}$= 122.16 + 14.3 + 0.7 + 0 + 0 + 18 + 0.2 – 18.5 = 136.86 dB

The greatest DCH attenuation is that for speech 139.86 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{139.86/10} = 9.68 \times 10^{13}$

Step 3:

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1-Q}$$

$$P_{tot,ref} = \frac{1.72 + (1.29924 \times 10^{-14} \times 9.68 \times 10^{13})}{1-0.55} = 6.61\mathrm{W}$$

Step 4:

Check that $P_{tot,ref} \leq 0.75\ P_{nom,ref}$

$P_{tot,ref} / P_{nom,ref} = 6.61/8.77 = 0.753$
$P_{tot,ref} = 0.753\ P_{nom,ref}$

Therefore the limit is exceeded and more sites needs to be added. One sites should be added.Go to step7.

Step 7. Perform Downlınk Coverage Checks

In Dense Urban Area: (14 sites)

The following downlink coverage limits must not be exceeded for 14 sites.

1. CPICH Power ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)
2. Total Power ($P_{tot,ref} \leq 0.75\ P_{nom,ref}$)
3. DCH Power ($P_{DCH,ref} \leq 0.3\ P_{nom,ref}$)

Before these checks can be made the nominal power at the reference point, cell range and load must be calculated.

The nominal power at the reference point ($P_{nom,ref}$) is calculated using equation below:

$P_{nom,ref} = P_{nom,RBS} - L_{J+C} - L_F - L_{ASC}$ [dBm]
$P_{nom,ref} = 17.4$ W = 42.4 dB
$L_{J+C} = 1$ dB
$L_F = 25$m 7/8 feeder = 1.57 dB
$L_{ASC} = 0.2$ dB
$P_{nom,ref} = 42.4 - 1 - 1.57 - 0.2 = 39.43$ dBm = 8.77 W

14 sites covering 5 km^2 implies that the coverage area of each site is 5/14 = 0.35 km^2.

We know that the area of a 3-sector site is

$A = 9/8\ (\sqrt{3})(R^2) = 1.95R^2$
$0.35 = 1.95R^2$
$R = 0.423$ km

The cell range with 14 sites is 0.423 km.

The maximum downlink load must be calculated using equation below:

$$Q_{max} = \text{Number\_of\_Subs}\left[\left(\frac{\text{traffic\_per\_sub\_CS}}{M_{pole,CS}}\right) + \left(\frac{\text{PS\_data\_per\_sub} \times 1024 \times 8 \times \text{Peak\_Factor}}{3600 \times 64 \times 10^3 \times M_{pole,PS}}\right)\right]$$

14 sites is (14x3) = 42 sectors.
42 sectors => 30000/42 = 714.2=715subs/sector
Peak factor for %55 load =1/0.55=1.81

$$Q_{\max} = 715\left[\left(\frac{23.1\times 10^{-3}}{60}\right)+\left(\frac{53.126\times 1024\times 8\times 1.81}{3600\times 64\times 10^{3}\times 8.9}\right)\right] = 0.52$$

Check 1: CPICH Power ($P_{CPICH,\ REF} \leq 0.1\ P_{NOM,REF}$)

Step 1:

Calculate UE CPICH Sensitivity using equation below:

$S_{UE,CPICH}=N_t + N_f + 10\ \log R_{chip}+E_c/N_o$ [dBm]

$S_{UE,CPICH}=-174 + 7 + 10\log(3.84\text{x}10^6) - 16 = -117.15$

Step 2:

Calculate the path loss at 0.458 km cell range using the simplified Okumura-Hata equation below:

$L_{path} = a + b.\log R$ [dB]

Where

a = 134.69 for urban areas

b = 35.22

R = 0.423 km

$L_{pmax} = 134.69 + 35.22\text{Log}0.423 = 121.52$ dB

Step 3:

Calculate the CPICH signal attenuation (Lsa) at this range using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a$ [dB]

$Lsa= 121.52 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 - 18.5 = 139.22$ dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{139.22/10} = 8.35 \times 10^{13}$

Step 4:

Calculate the downlink Interference margin (B_{IDL}) at maximum load using equation below:

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha + F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 1$ (for CPICH calculations)

F = 2.1 (at Cell border)

Nt = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = 3.98×10^{-21} W/Hz

Nf = 7dB = 5.01

Rchip = 3.84 Mcps 3.84 x 106 cps

$P_{tot,ref}$= at max load $P_{tot,ref} = 0.75\ P_{nom,ref} = (0.75)x(8.77) = 6.57$ W

$L_{sa} = 9.68 \times 10^{13}$

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{1+2.1}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{6.57}{8.35\times10^{13}}\right)\right)\right)[dB] = 6.21dB$$

Step 5 :

$P_{CPICH,ref}$ can now be calculated using equation below:

$P_{CPICH,ref} = L_{sa} + S_{UE,CPICH} + B_{IDL}$ [dBm]

$P_{CPICH,ref} = 139.22–117.2 + 6.21 = 28.23$ dBm = 0.66 W

Step 6 :

We must check that this is below the limit ($P_{CPICH,\ ref} \leq 0.1\ P_{nom,ref}$)

$P_{CPICH,\ ref}/\ P_{nom,ref} = 0.66/8.77 = 0.078$

$P_{CPICH,\ ref} = 0.075\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 2: Total Power ($P_{TOT,\ REF} \leq 0.75\ P_{NOM,REF}$)

Step1 :

First we must calculate $P_{CCH,ref}$ using equation below:

$P_{CCH,ref}=2.5\ P_{CPICH,ref}\quad [W]$

$P_{CCH,ref}=2.5 \times 0.66 = 1.65\quad [W]$

Step2 :

We must calculate the greatest signal attenuation using equation below.

$L_{sa} = L_{path} + B_{LNF} + B_{PC} + L_{BL} + L_{CPL} + L_{BPL} + L_J - G_a\quad [dB]$

$L_{sa(speech)}= 121.52 + 14.3 + 0.7 + 3 + 0 + 18 + 0.2 – 18.5 = 139.22$ dB

$L_{sa(PS64)}= 121.52 + 14.3 + 0.7 + 0 + 0 + 18 + 0.2 – 18.5 = 136.22$ dB

The greatest DCH attenuation is that for speech 139.22 dB

We must convert this to a linear value as below:

$L_{sa\ (linear)} = 10^{139.22/10} = 8.35 \times 10^{13}$

Step 3:

Calculate the total power at the reference point ($P_{tot,ref}$) using equation below.

$$P_{tot,ref} = \frac{P_{CCH,ref} + (H.L_{sa})}{1 - Q}$$

$$P_{tot,ref} = \frac{1.65 + (1.29924 \times 10^{-14} \times 8.35 \times 10^{13})}{1 - 0.55} = 6.07\,W$$

Step 4:

Check that $P_{tot,ref} \leq 0.75\ P_{nom,ref}$

$P_{tot,ref}/\ P_{nom,ref} = 6.07/8.77 = 0.69$

$P_{tot,ref} = 0.69\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 3: DCH Power ($P_{DCH,\ REF} \leq 0.3\ P_{NOM,REF}$) – Speech

Firstly the check is made for speech:

Step 1:

Calculate UE DCH Sensitivity using equation below:

$S_{UE}=N_t+N_f+10\log R_{info}+E_b/N_o$ [dBm]

For speech TU 3:

$N_t = -174$ dBm/Hz

$N_f = 7$

$R_{info} = 15600$ bps

$Eb/No = 7.2$ dB

$S_{UE} = -174 + 7 + 10 \log (15600) + 7.2 = -117.9$ dBm

Step 2:

Calculate the downlink Interference margin (BIDL) at the specified load using equation below.

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 0.64$

F = 0.72 (for 3-sector Urban Site)

N_t = -174 dBm/Hz = 3.98 x 10^{-18} mW/Hz = 3.98 X 10 $^{-21}$ W/Hz

N_f = 7dB = 5.01

R_{chip} = 3.84 Mcps 3.84 x 10^6 cps

$P_{tot,ref}$ = 6.07 W (from check 2)

L_{sa} = 139.22 dB = $10^{139.22/10}$ = 8.35 x 10^{13} (from check 2)

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{0.64+0.72}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right).\left(\frac{6.07}{8.35\times10^{13}}\right)\right)\right)[dB] = 3.6dB$$

Step 3:

Calculate DCH power at the reference point ($P_{DCH,ref}$) using equation below.

$P_{DCH,ref}=L_{sa}+S_{UE}+B_{IDL}$ [dBm]

$P_{DCH,ref}$ = 139.22 –117.9 + 3.6 = 24.92 dBm = 0.31 W

Step 4:

Check that $P_{DCH,ref} \leq 0.3\ P_{nom,ref}$

$P_{DCH,ref}/\ P_{nom,ref}$ = 0.31/8.77 = 0.035

$P_{DCH,ref} = 0.035\ P_{nom,ref}$

Therefore the limit is not exceeded.

Check 3: DCH Power ($P_{DCH,\ REF} \leq 0.3\ P_{NOM,REF}$) – PS64

Secondly the check is made for speech:

Step 1:

Calculate UE DCH Sensitivity using equation below:

$S_{UE}=N_t+N_f+10\log R_{info}+E_b/N_o$ [dBm]

For speech TU 3:

N_t = -174 dBm/Hz

N_f = 7

R_{info} = 76400 bps

Eb/No = 6.4 dB

S_{UE} = -174 + 7 + 10 log (67400) + 6.4 = -112.3 dBm

Step 2:

Calculate the downlink Interference margin (BIDL) at the specified load using equation below.

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{\alpha+F}{N_t.N_f.R_{chip}}\right)\left(\frac{P_{tot,ref}}{L_{sa}}\right)\right)\right)[dB]$$

Where:

$\alpha = 0.64$

F = 0.72 (for 3-sector Urban Site)

N_t = -174 dBm/Hz = 3.98×10^{-18} mW/Hz = 3.98×10^{-21} W/Hz

N_f = 7dB = 5.01

R_{chip} = 3.84 Mcps 3.84×10^6 cps

$P_{tot,ref}$ = 6.07 W (from check 2)

L_{sa} = 136.22 dB = $10^{136.22/10} = 4.18 \times 10^{13}$ (from check 2)

$$B_{IDL} = 10\log\left(1+\left(\left(\frac{0.64+0.72}{3.98\times10^{-21}\times5.01\times3.84\times10^{6}}\right)\cdot\left(\frac{6.07}{4.18\times10^{13}}\right)\right)\right)[\mathrm{dB}] = 5.53\mathrm{dB}$$

Step 3:

Calculate DCH power at the reference point ($P_{DCH,ref}$) using equation below.

$P_{DCH,ref}=L_{sa}+S_{UE}+B_{IDL}$ [dBm]
$P_{DCH,ref} = 136.22 - 112.3 + 5.53 = 29.45$ dBm = 0.88 W

Step 4:

Check that $P_{DCH,ref} \leq 0.3\ P_{nom,ref}$

$P_{DCH,ref}/\ P_{nom,ref} = 0.88/8.77 = 0.1$
$P_{DCH,ref} = 0.1\ P_{nom,ref}$

Therefore the limit is not exceeded.

It would appear that 14 Sites meets the requirements for this Network in denseurban area.

9.3 Site Selection

In WCDMA UMTS network we should be carreful to site selection. Pilot pollution effects the user data bit rate. If you need high data bit rate your cells should not overshooting. Overshooting is unexpected event in the network.

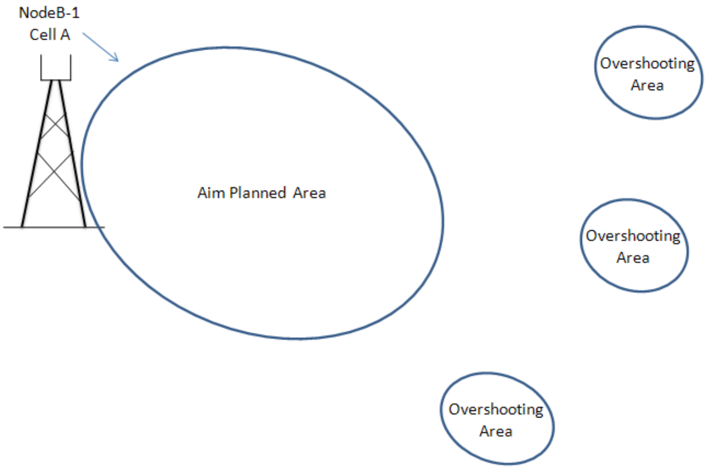


Figure 9.4 Overshooting Area

If you want to hinder the overshooting change the antenna tilt, antenna direction change, antenna type change or change the site location.

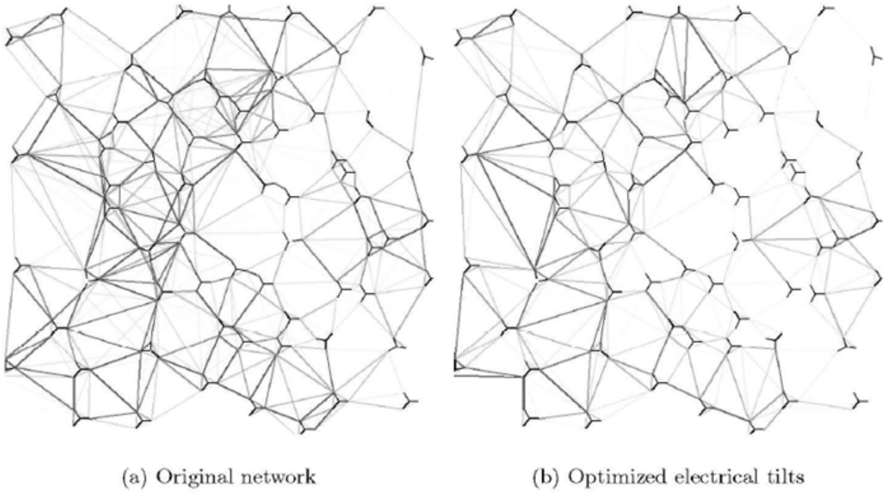
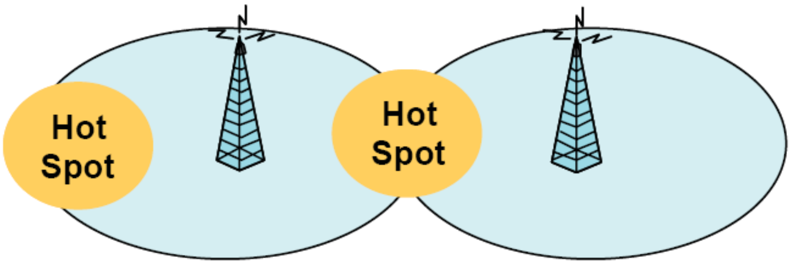

(a) Original network
(b) Optimized electrical tilts

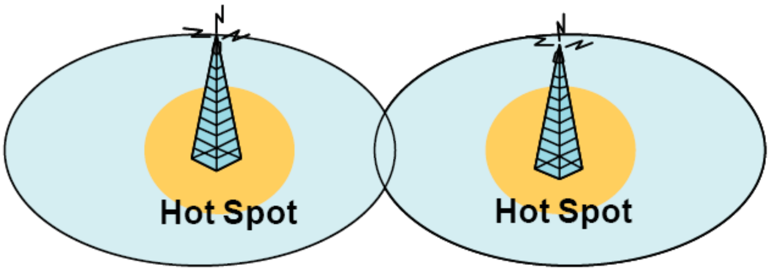
Figure 9.5 Effect of Tilt Adjusting On Mutual Interference

Coverage and capacity planning in WCDMA are interrelated. In low traffic areas, WCDMA planning is quite similar to GSM planning, because the load does not have a great impact on coverage. Of course, many details differ between the systems, but the main principles can be applied to both. In high traffic areas, unlike for GSM, there is no clear split between coverage, interference, and capacity planning of WCDMA.

Node B should be closer the hot spot area because, if node B is far from hot spot area signal strength decreases. Decreasing in the signal strength causes the pilot pollution because there is no powerful singal in that area.



a) Lower coverage and capacity (inefficient design)



b) Higher coverage and capacity (optimum design)

Figure 9.6 Site Selection in Hot Spot

In UE's active set has max 3 Cells. We prefer the first cell in active set and the other cells in the monitoring list. Actually this is a very difficult possibility because too many of cells do overshooting to lots of areas. The wanted optimum case is being two or three cells in the active set and the other cells' signal strength should be weaker than 10 or 15 db in active set cells' signal strength.

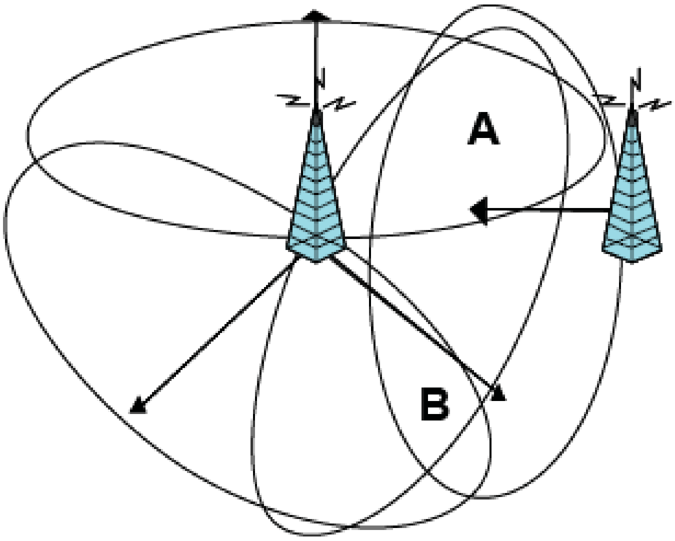


Figure 9.7 Example of inefficent desing

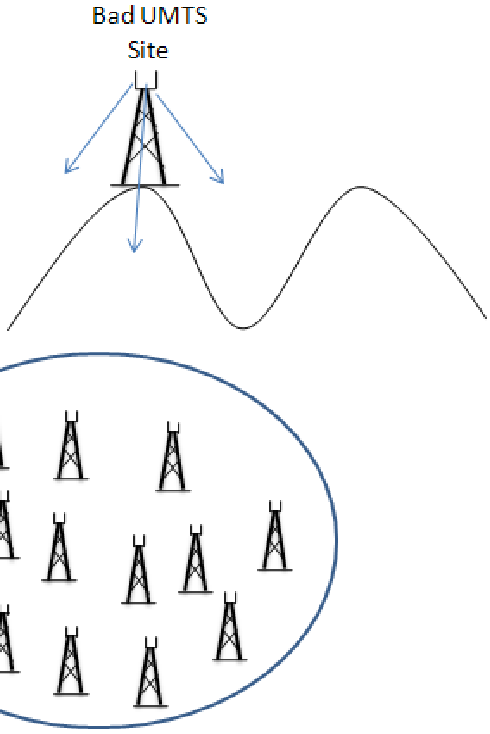


Figure 9.8 Bad UMTS site desing

CHAPTER TEN
CONCLUSION

Some informations are important while designing third generation radio network. It is necessary for the planning area, target key performance indicator, building height, voice and data rates per user to know for a good design.

Firstly, it is necessary to calculate uplink and downlink link budget values that affect capacity and coverage with the use of these datas given below.

After the calculation of the link budget values, the needed coverage base station numbers for coverage key performance indicator are calculated. After the calculation of coverage base station values, according to the voice and data values per user, it is controlled whether the base station numbers are adequate or not. Usually, base station numbers in urban areas are not sufficient for the voice and data rate per user.

Only downlink link budget values are calculated for coverage key performance indicator. However, both uplink and downlink link budget values, for capacity key performance indicator are calculated.

In order to supply necessary capacity according to data and voice rate per user , base station is added to network. Base station locations are determined after the network is enough for the coverage and capacity. Network quality should be in a high quality level while determining the locations of the base stations.

After the steps which are applied below, network will have reached the target coverage and capacity key performance indicator.

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