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Third Generation Networks Radio Dimensioning

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☐ ABSTRACT ☐

This research is an evaluation study of the new generation of mobile communication networks WCDMA in order to provide cellular coverage for the required area and the number of required node Bs as well as the associated capacity, design, and dimensioning in terms of methodology, uplink and down link budget calculations, steps, and analysis.

The planning and design of the third generation networks which provide the mobile internet and video calling are about 10 times more complicated than second generation networks.

Key Words: 3G, WCDMA, UMTS, Mobile Communications, Node B Dimensioning, Network design.

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تصميم وحساب التغطية والسعة لشبكات الجيل الثالث

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□ الملخّص □

يهدف هذا البحث الى توضيح طريقة التصميم والحساب لشيكات الجيل الثالث الخليوية من ناحية الاسس والقواعد التي يجب اتباعها من Hجل التصميم والحساب لمدى التغطية الخليوية وبالتالي إيجاد العدد الكافي للمحطات من أجل تامين الخدمة الخليوية الحديثة ومستوى السعة الضروية لهذة الشبكات. حيث يستعرض هذاالبحث بالتفصيل حساب بارامترات الوصلة الصاعدة والهابطة إضافةً إلى التحليل المناسب لعملية التخطيط والتصميم لشبكات الجيل الثالث التي تتطلب من مهندسي التخصيط والتصميم جهدا كبيراً حيث إن تخطيط شبكات الجيل الثالث وتصميمها والتي تؤمن خدمات الإنترنت الخليوية النقالة إضافةً إلى خدمات المكالمات الفيديوية هي أعقد بحوالي عشر مرات منها لشبكات الجيل الثاني.

كلمات مفتاحية: الجيل الثالث ، الاتصالات الخليوية، أداء الشبكات ، تصميم الشبكات الخليوية.

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1. Background and Purpose of the Trail

3G technology offers a fast access to a wide range of mobile internet services. A good network design enables high quality and performance network for fast end-user access where it is necessary to calculate the required number of Node Bs and the capacity which can be provided by those nodes.

This research is an evaluation study of the new generation of mobile communication networks WCDMA, design and dimensioning in terms of methodology, calculation steps, and analysis.

This research can be considered an important guide for third generation mobile networks planning design.

2. Research Methodology

Communication software companies have developed many different PC based radio network dimensioning tools. Those tools have been developed as internal tools with the objective of being able to support customer requests for system dimensioning. The general methodology and guidelines used by those tools have been outlined in the sections below, in addition to an example of uplink and down link budget calculations.

3. Radio Network Dimensioning Methodology

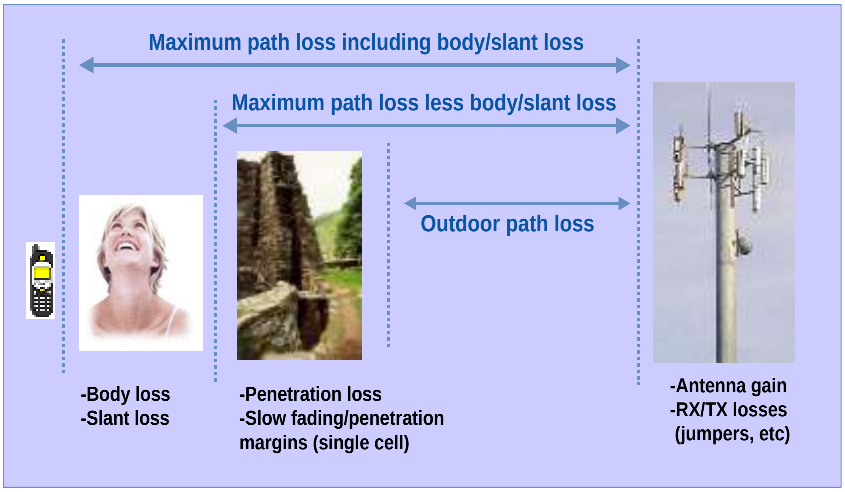

Figure 1 illustrates the overall process.

The first step is to evaluate an initial cell range assuming coverage limited scenario based upon the maximum permissible system load. This is done using a link budget that includes the noise rise due to the assumed level of system loading.

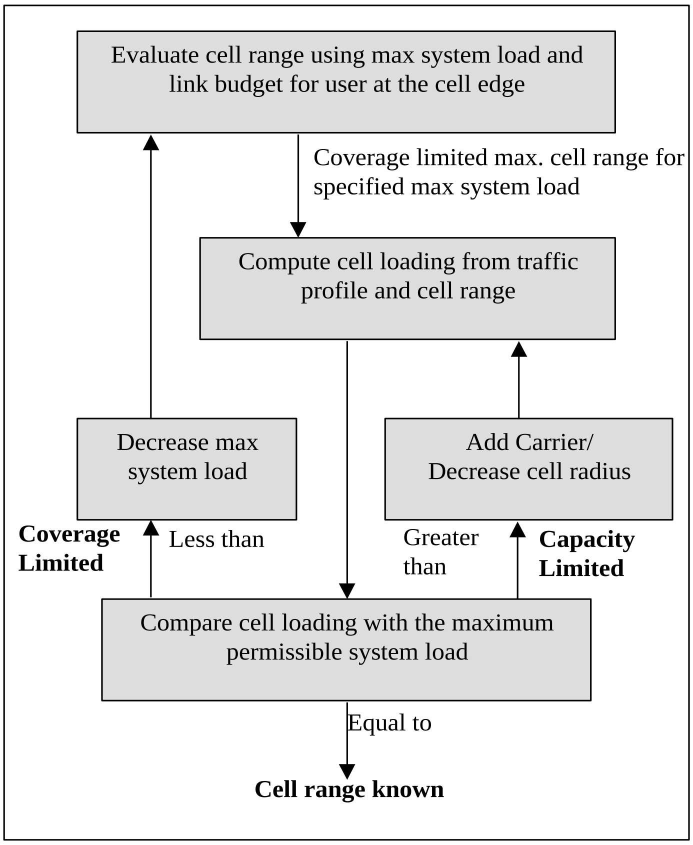

Figure 2 – The process used for system dimensioning

This defines the coverage limited cell range for the specified maximum permissible system load [1], [8],[16].

Following computation of a cell range, the number of users within each cell can be evaluated. The traffic profile specified by the user can then be used to determine whether or not the maximum permissible system loading is exceeded. The fractional load due to each service type is combined to give the overall system load. The process for computing fractional loads is illustrated in Figure 3.

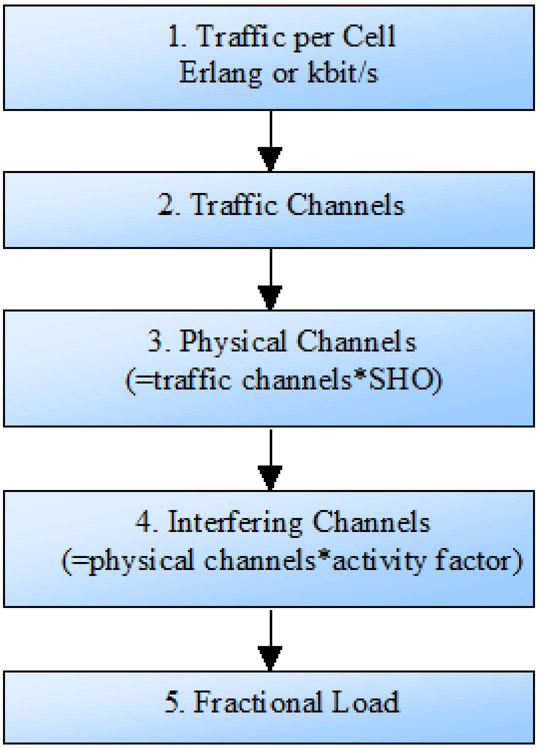

Figure 3 – The process used for system dimensioning

Step one: Definition of the traffic per cell. This is usually defined in terms of Erlangs for voice and real time (RT) data services and in terms of kbits/sec for non real time (NRT) data services.

Step two: Evaluation of the traffic channel requirement per cell for each service class. For voice and RT data services the calculations are based upon the Erlang B formula and for NRT data services upon throughput. The two equations are given below.

Voice and RT data $tchs = ErlangBchs(bloc\_prob; traffic)$

NRT data $$tchs = \frac{traffic}{throughput * R} \qquad (1)$$

R is the service bit rate. The blocking probability is typically assumed to be 1%. The throughput is typically assumed to be 0.75. This figure incudes a L2 protocol overhead of 5%, a L2 re-transmission overhead of 10% and 15% of buffer headroom to avoid overflow.

Step three: Evaluation of the physical channel requirement per carrier for each service class. This is completed separately for uplink and downlink. In the case of the uplink,

$$ph\_chs = \frac{tchs}{carriers} \qquad (2)$$

Initially a single carrier is assumed. This is later increased if there is need to do so for capacity reasons. In the case of the downlink,

$$ph\_chs = \frac{tchs \times (1 + Soft\_HO\_oh)}{carriers} \qquad (3)$$

Step four: Evaluation of interfering channels per cell for each service class. This requires a direct multiplication of the physical channel requirement with the corresponding service activity factor i.e.

$$int\_chs = ph\_chs \times activity \qquad (4)$$

Step five: Evaluation of the fractional loads for UL and DL. The uplink fractional load for a service class is given by:

$$fL\_UL = \frac{\mathrm{int}\_chs \times \left(\frac{E_b}{N_0} - MDCgain\_UL\right)}{\frac{W}{R}} \times \left(1 + a_j \times i\_UL\right) \qquad (5)$$

The total uplink load can be obtained by summing the uplink fractional loads over all service classes.

Downlink fractional load for a service class is given by:

$$fL\_DL = \frac{\mathrm{int}\_chs \times \left(\frac{E_b}{No} - MDCgain\_DL\right)}{\frac{W}{R}} \times \left(1 - Orth\_DL + i\_DL\right) \qquad (6)$$

The total downlink load can be obtained by summing the downlink fractional loads over all service classes.

Once the actual system loading is known a comparison is made between the actual and maximum allowable figure.

4. Interference Margin

The uplink interference margin defines the allowable uplink noise rise seen in at the base station. [1], [6],[9], [14] .

The instantaneous noise rise can be related to loading (fraction of pole capacity, $M_{SYSTEMUP}$) by the simple equation (7).

An interference margin of 3 dB is recommended in the long term. In the short term, a value of 1.5 dB may be used.

Uplink interference level (dB) is above noise rise as a function of the load:

$$\Delta I_{ul} = -10 * \log \left(1 - \frac{M}{M_{systemup}}\right) \qquad (7)$$

Where

M- number of users

$M_{systemup}$ - maximum number of users in the uplink

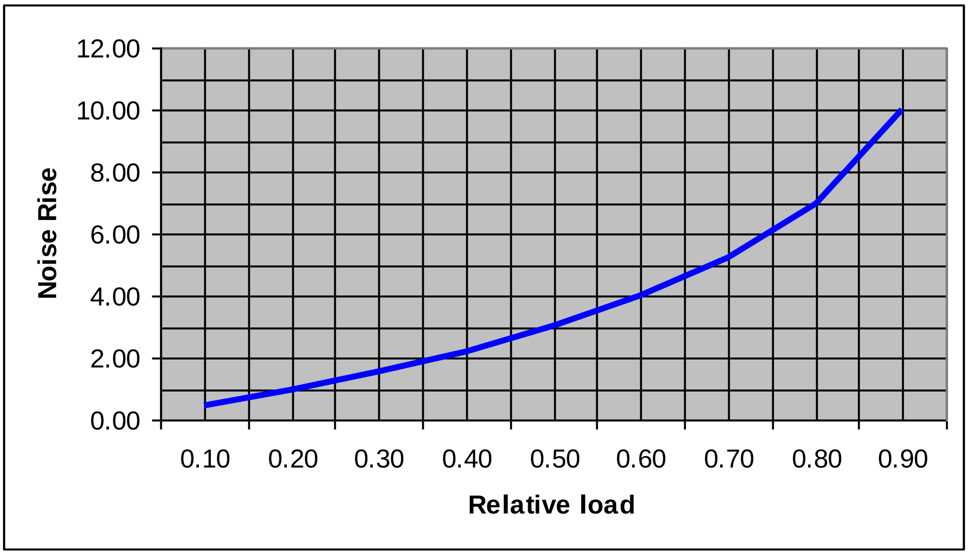

Figure 2.10.1 Classical relation between uplink loading and noise rise

A high noise rise, also known as the cell-breathing effect, is undesirable as it signifies an unstable service area. A noise rise limit of 3 dB is recommended as a long term planning assumption, which equates to 0.5% loading.

In the short term however, a lower noise rise limit maybe assumed in order reflect the low traffic levels expected in the early network. An initial planning load of 0.3%, or 1.5 dB noise rise has been proposed.

It should be noted that utilisation of such a low noise rise may limit the use of high speed uplink bearers. This is especially true for a 384 kbps bearer which is estimated to add a 3.3% load to cell, exceeding the total noise rise limits.

5. Link Budget

5.1 Uplink Budget Calculation

Table 1. shows the uplink link budget calculation for pedestrian/stationary (3 km/h) users assuming macro cell node B with MHA [1], [3], [11], [14].

Where the equation parameters for the uplink budget will be calculated as fellows:

User equipment effective radiate power:

$$UE_{EIRP} = UE_{\mathrm{Antennagain}} + UE_{\mathrm{Max\ outputpower}} \tag{8}$$

Node B receives sensitivity:

$$RX_{\mathrm{NodeB\,sensitivity}} = -174 + 10 * \log(R) + 30 + \frac{E_b}{N_o} + NF \tag{9}$$

Receive level at BS antenna:

$$\begin{aligned} RX_{Uplink} = {} & RX_{\mathrm{NodeB\,sensitivity}} + PC_{Headroom} + RX_{Losses} \\ & - RX_{\mathrm{Antennagain}} - SHO_{\mathrm{Uplinkgain}} - SHO_{\mathrm{slowfading\text{-}margin}} + IM \end{aligned} \tag{10}$$

Path loss inc. body/slant loss:

$$PL_{\min al} = UE_{EIRP} + RX_{Uplink} \tag{11}$$

Path loss not incl. body loss or slant loss:

$$PL_{No\min al} = PL_{Total} - BL - SL_{UL} \tag{12}$$

Table 1. Uplink Budget Calculations

Uplink Link Budget						
	Speech	**CS 64**	**PS 64**	**PS128**	**PS384**	unit
UE maximum output power	21.0	21.0	21.0	21.0	21.0	dBm
UE Antenna gain	0.0	0.0	0.0	0.0	0.0	dBi
UE EIRP	*21.0*	*21.0*	*21.0*	*21.0*	*21.0*	
Node B Eb/No	*6.9*	*4.1*	*3.2*	*2.6*	*2.4*	dB
Node B noise figure	2.5	2.5	2.5	2.5	2.5	dB
Information rate	12.2	64.0	64.0	128.0	384.0	bps
Node B receive sensitivity	*-123.7*	*-119.3*	*-120.2*	*-117.8*	*-113.3*	dBm
Power control headroom	2.0	2.0	0.9	0.9	0.9	dB
Base station RX losses	0.5	0.5	0.5	0.5	0.5	dB
Base station antenna gain	18.0	18.0	18.0	18.0	18.0	dB
Uplink SHO combining gain	0.5	0.5	0.5	0.5	0.5	dB
SHO slow fading margin reduction	2.0	2.0	2.0	2.0	2.0	dB
Interference margin	3.0	3.0	3.0	3.0	3.0	dB
Receive level at BS antenna	*-138.7*	*-134.3*	*-136.3*	*-133.9*	*-129.4*	dBm
Path loss inc. body/slant loss	*159.7*	*155.3*	*157.3*	*154.9*	*150.4*	dB
Body loss	5.0	2.0	2.0	2.0	2.0	dB
UL slant loss	2.0	2.0	2.0	2.0	2.0	dB
Path loss not incl. body loss or slant loss	***152.7***	***151.3***	***153.3***	***150.9***	***146.4***	

5.2 Downlink Budget Calculation

Table 2. shows the uplink link budget calculation for pedestrian/stationary users assuming macro cell node B with MHA[1], [3], [11], [14].
Where the equation parameters for the down link budget will be calculated as fellows:

Transmit code power:

$$TX_{\text{Codepower}} = Max_{\text{Carrier power}} + 10 * \log(Max_{\text{Fract. power}}) \quad (13)$$

Base station carrier EIRP:

$$BS_{\text{Carrier EIRP}} = Max_{\text{Carrier power}} - TX_{losses} + TX_{\text{Antennagain}} \quad (14)$$

Base station code EIRP:

$$BS_{\text{CodeEIRP}} = TX_{\text{Codepower}} - TX_{Losses} + TX_{\text{Antennagain}} \quad (15)$$

Downlink path loss incl. body/slant loss:

$$PL_{DL} = PL_{UL} + SL_{DL} + PL_{hf} + BL - SHO_{\mathrm{UL\,margin}} \quad (16)$$

Noise density:

$$ND = -174 + NF_{UE} \quad (17)$$

Intracell interference density:

$$ID_{\mathrm{Intracell}} = BS_{\mathrm{Carrier\ EIRP}} + 10*\log(CL*(\mathrm{N,orth})) - \mathrm{PL}_{\mathrm{DL}} + UE_{\mathrm{Antennagain}} - 10*\log(W) \quad (18)$$

Intercell interference density:

$$ID_{\mathrm{Intercell}} = BS_{\mathrm{Carrier\ EIRP}} + 10*\log(RPR\ *CL) - PL_{DL} + UE_{\mathrm{Antennagain}} - 10*\log(W) \quad (19)$$

Total noise& interference density:

$$NID_{\mathrm{Total}} = 10*\log(10\wedge(ND/10) + 10\wedge(ID_{\mathrm{Intracell}}\ /10) + 10\wedge(ID_{\mathrm{Intercell}}\ /10)) \quad (20)$$

Received code energy:

$$TX_{\mathrm{codeenergy}} = BS_{\mathrm{CodeEIRP}} - PL_{DL} + SHO_{\mathrm{DL\,gain}} \quad (21)$$

Max DL cell-edge packet bearer rate:

$$\mathrm{Max\,BR}_{\mathrm{DL}} = 10\wedge((TX_{\mathrm{Codeenergy}} - NID_{Total} - (\frac{E_b}{N_o})_{DL} - PC_{\mathrm{DL\,headroom}})/10)/1000 \quad (22)$$

Table 2. Downlink Budget Calculations.

Downlink maximum bearer rate at UL limit						
	UL Speech	**UL CS 64**	**UL PS 64**	**UL PS 128**	**UL PS 384**	Units
Node B max. carrier power	46.0	46.0	46.0	46.0	46.0	dBm
Carrier loading	0.9	0.9	0.9	0.9	0.9	%
Max. fract. power for packet user	0.5	0.5	0.5	0.5	0.5	%
TX code power	*42.5*	*42.5*	*42.5*	*42.5*	*42.5*	dBm
Base station TX losses	3.0	3.0	3.0	3.0	3.0	dB
Base station antenna gain	*18.0*	*18.0*	*18.0*	*18.0*	*18.0*	dB
BS carrier EIRP	*61.0*	*61.0*	*61.0*	*61.0*	*61.0*	dBm
BS code EIRP	*57.5*	*57.5*	*57.5*	*57.5*	*57.5*	dBm

UL Path loss less body/slant loss	*152.7*	*151.3*	*153.3*	*150.9*	*146.4*	dB
DL slant loss	2.0	2.0	2.0	2.0	2.0	dB
Higher frequency additional path loss	1.6	1.6	1.6	1.6	1.6	dB
Body loss	*5.0*	*2.0*	*2.0*	*2.0*	*2.0*	dB
UL SHO fading margin reduction	*2.0*	*2.0*	*2.0*	*2.0*	*2.0*	dB
DL path loss incl. body/slant loss	*159.3*	*154.9*	*156.9*	*154.5*	*150.0*	dB
UE noise figure	8.0	8.0	8.0	8.0	8.0	dB
Noise density	-166.0	-166.0	-166.0	-166.0	-166.0	dBm/Hz
Non-orthogonality	0.5	0.5	0.5	0.5	0.5	
Intracell interference density	*-167.6*	*-163.2*	*-165.2*	*-162.8*	*-158.3*	dBm/Hz
Other to own cell carrier power ratio	1.0	1.0	1.0	1.0	1.0	
Intercell interference density	*-164.6*	*-160.2*	*-162.2*	*-159.8*	*-155.3*	dBm/Hz
Total noise& interference density	*-161.2*	*-157.8*	*-159.4*	*-157.4*	*-153.3*	dBm/Hz
DL Eb/No	*5.3*	*5.3*	*5.3*	*5.3*	*5.3*	dB
DL power control headroom	0.9	0.9	0.9	0.9	0.9	dB
DL SHO combining gain	2.0	2.0	2.0	2.0	2.0	dB
Received code energy	-99.8	-95.4	-97.4	-95.0	-90.4	dBm
Max DL cell-edge packet bearer rate	***327.2***	***413.5***	***380.1***	***419.2***	***460.8***	kbps

6. Results and Discussion

Two cases are now possible:

- Either the system load factor resulting from the user specified traffic profile is greater than the maximum permissible level, in which case the system is capacity limited.
- Or the system load factor is less than the maximum permissible level in which case the system is coverage limited.

6.1 Coverage Limited Scenario

In this case the system loading is lower than the level used initially to compute the cell range. This means that the rise in interference floor used in the link budget calculation was pessimistic. To achieve a match between the actual system loading and that used in the link budget, the complete process is repeated with a lower value of system loading. This will lead to a lower increase in interference floor, a greater cell range, and thus more users in each cell and a greater actual system loading.

The reduction in system loading used in the link budget calculation is continued until it matches the actual system loading computed by the traffic profile. This then defines the final cell range.

6. 2 Capacity Limited Scenario

In this case the system loading is greater than the level used initially to compute the cell range. This means that either the cell capacity must be increased or the cell size decreased. The first option is to increase the cell capacity by adding additional carriers. If the system loading remains above the maximum permissible level, then the cell range must be reduced to a level similar to that where there are fewer users loading the cell. A reduction in cell range is made, and the system loading re-calculated. The reduction in cell range is done iteratively until the actual system loading matches the maximum permissible system loading. This then defines the final cell range.

7. Conclusion

The approach to third generation mobile communications WCDMA network dimensioning should allow the network planner and designer to specify the user traffic profile and loading of the network, including the data rates, asymmetry factors, user speeds, coverage and capacity requirements by implementing manufacturer Node Bs and mobile terminals data sheets and 3GPPs data too.

The path losses provided by the uplink link budget are used to estimate a supportable bearer rate on the downlink at the cell edge as defined by the uplink.

The limited power at the terminal restricts uplink bearer rates to be lower than those possible on the downlink. On the downlink, power is shared, and by allocating user a large fraction of the total carrier power it is possible to support high data rates even at the cell edge. This sharing of power makes the downlink link budget more elastic than the uplink.

As a result of link budget calculations, man can find the number of base stations which can provide sufficient coverage as stated in the requirements without exceeding specified maximum system loading. All should be done by adjusting the coverage and capacity limiting factors as well as the interference noise rise. The network dimensioning process ensures that the network is able to support the traffic presented for a range of different bearer rates without exceeding the maximum system load.

7. Acronyms and Terminology

Node B	3G base transceiver station
WCDMA	Wideband code division multiple access -3G modulation
MHA	Mast head amplifier
int_chs	Number of interfering channels
Eb/No	Target energy per bit to interference spectral density ratio
MDCgain_UL	Macro diversity gain on the uplink due to soft handover
a_j	Increase in transmit power due to power control for the jth user
i_UL	Ratio of other to own cell interference for up link
W	Chip rate
MDCgain_DL	Macro diversity gain on the downlink due to soft handover
Orth_DL	Downlink orthogonality
i_DL	Ratio of other to own cell interference for down link
M	Number of users
$M_{systemup}$	Maximum number of users in the uplink
UE_{EIRP}	User equipment effective radiate power
$UE_{\mathrm{Antennagain}}$	UE Antenna gain
$UE_{\mathrm{Max\ outputpower}}$	UE maximum output power
$RX_{\mathrm{NodeB\ sensitivity}}$	Node B receive sensitivity
R	Information rate
NF	Noise figure
RX_{Uplink}	Receive level at BS antenna
$RX_{\mathrm{NodeB\ sensitivity}}$	Node B receive sensitivity
$PC_{Headroom}$	Power control headroom
RX_{Losses}	Base station RX losses
$RX_{\mathrm{Antennagain}}$	Base station antenna gain
$SHO_{\mathrm{Uplinkgain}}$	Uplink SHO combining gain
$SHO_{\mathrm{slowfading-margin}}$	SHO slow fading margin reduction
IM	Interference margin
$PL_{\min al}$	Path loss inc. body/slant loss
$PL_{Nomin\,al}$	Path loss not incl. body loss or slant loss
PL_{Total}	Path loss inc. body/slant loss
BL	Body loss
SL_{UL}	UL slant loss
$TX_{\mathrm{Codepower}}$	Transmit code power
$Max_{\mathrm{Carrier\ power}}$	Node B max. carrier power
$Max_{\mathrm{Fract.\ power}}$	Max. fract. power for packet user
$BS_{\mathrm{Carrier\ EIRP}}$	BS carrier EIRP
TX_{losses}	Base station TX losses

$TX_{\text{Antennagain}}$	Base station antenna gain
BS_{CodeEIRP}	BS code EIRP
PL_{DL}	DL path loss incl. body/slant loss
PL_{UL}	UL Path loss less body/slant loss
SL_{DL}	DL slant loss
PL_{hf}	Higher frequency additional path loss
$SHO_{\text{UL margin}}$	UL SHO fading margin reduction
ND	Noise density
$ID_{\text{Intracell}}$	Intracell interference density
CL	Carrier loading
N,orth	Non-orthogonality
$ID_{\text{Intercell}}$	Intercell interference density
RPR	Other to own cell carrier power ratio
NID_{Total}	Total noise &interference density
$RX_{\text{codeenergy}}$	Received code energy
$SHO_{\text{DL gain}}$	DL SHO combining gain
$\text{Max BR}_{\text{DL}}$	Max DL cell-edge packet bearer rate
$PC_{\text{DL headroom}}$	DL power control headroom

REFERENCES:

1. HOLMA, HAND& TOSKALA, A. *WCDMA for UMTS* (3rdedn, 450 pp.). Chichester,UK: JohnWiley&Sons,2004,
2. 3GPP Standard in TS 25.101, 1999.
3. 'Node B system description', Nokia contract document agreed 2 October.
4. '*WCDMA Masthead Amplifier(MHA) Product Description'*, Nokia User Manual, DN0114715, issue 1-0 en.
5. 3GPP 25.104, 2000.
6. KARI, SIPILA (Nokia) '*WCDMA link performance indicators, simulator principle and examples'* NET/IMN/WNP/NSR, v 0.1.0.
7. COST-231, *Urban Transmission Loss Models for Mobile Radio in the900 and 1800 MHz bands*, TD (90) 199 Rev. 1, 1991.
8. KEN, NG '*Link budget for a personal communication network*', Mo2o,/CDOC/P2.2/KNG/REPT/3253 , Issue 1.0, 6/9/95.
9. WOLFGANG, STOERMER '*Comparison of the performance between vertically polarised and cross polar antennas*', Brian Williams, One2one/CDOC/6032, Issue 2.0, 21 September 2000.
10. EEM/TG/N-99:0042 '*WCDMA radio access network RF dimensioning guidelines'*, , 8/12/99.
11. HATA, M., "*Empirical Formula for Propagation Loss in Land Mobile Radio Services,*" IEEE Transactions on Vehicular Technology, vol.VT-29, no. 3, August, pp. 317–325,1980.
12. KARI, SIPILA '*Default power settings for common DL channels in WCDMA RAN1-1.5*', , Nokia presentation to TMO radio performance workshop, 18/06/2001
13. ETSI TS GSM 03.30. '*Nokia Ultra Site WCDMA Antenna System Product Overview*', DN00309809.
14. MIKKO, SIIRA '*Nokia WCDMA FDD BTS RF Performance'*,15/2/01.
15. LAIHO, J; WACKER; ARANAD, NOVASAD. *Radio Network Planning and Optimization for UMTS*(484pp.).Chichester, UK: John Wiley& Sons T(2002).
16. ITU-R.M.1225, "*Guidelines for evaluation of radio transmission technologies for IMT-2000."*