Coverage and Capacity Dimensioning

FDD

RECOMMENDATION

1/100 56-HSC 105 50/1-T1 Uen AE

Contents

1 Introduction

This document presents an outline and basic concepts required to dimension coverage and capacity in the Long Term Evolution (LTE) network with functions in the current release. The method presented in this document consists of concepts and mathematical calculations that are elements of a general dimensioning process.

The detailed order and flow of calculations depends on the required output and type of input for each individual dimensioning task. The method provides a specific dimensioning process example. By changing the prescribed inputs and outputs and the order of calculations, the dimensioning process can be adapted to other methods.

Input requirements for the capacity and coverage dimensioning process consists of a bitrate at the cell edge, one for downlink and one for uplink. The required output is site-to-site distance and cell capacity in the uplink and downlink.

1.1 Limitations

Limitations to the calculation methods include the following:

- The method is adapted and developed primarily for a mobile broadband service
- Quality of Service (QoS) is not handled by the method

1.2 Assumptions

Calculations for coverage and capacity are based on the following assumptions:

- All User Equipment (UE) is assumed to have two RX antennas
- All resource blocks are transmitted at the same power, including user data, control channels and control signals
- Layer 1 overhead for all control channels and control signals is included in the Signal-to-Interference-and-Noise Ratio (SINR) to bitrate relationships, see Section 10 on page 57
- The methods in this document assume that the feature ICIC - Autonomous Resource Allocation is employed. With this feature, transmission starts at random positions in the deployed frequency band so that inter-cell interference is evenly distributed over the bandwidth

1.3 Concepts and Terminology

The following terms are used in describing capacity and coverage dimensioning:

Average user bitrate

Bitrate achievable by a single user, as an average over the cell area.

When all resources in a cell are used, the average user bitrate can be the average throughput in one cell. It is a measure of average potential in a cell while all interfering cells are loaded to the dimensioned level.

Air path loss

Part of the signal attenuation that is sustained in the air.

This is the quantity that is converted to geographical distance.

Cell edge

Geographical location where the air path loss between the Radio Base Station (RBS) and the UE fulfills the quality requirement imposed on the network. Cell edge includes both the median signal attenuation at the cell border and the log-normal fading margin.

For example guaranteeing a specified bitrate at a certain probability.

Cell throughput

Throughput obtained in one cell when all cells are loaded to the dimensioning level, and the resource use is equal to the traffic load, in interfering cells as well as in interfered cells.

It is the average throughput per cell as calculated across the entire network.

Coverage (area)

Percentage of cell area that can be served in accordance with a defined quality requirement.

With a uniform subscriber density (as often assumed in a dimensioning exercise), the percentage of served area equals the percentage of served users.

Interference due to control channels

Fraction of PDSCH resources elements interfered by control channels.

Radio unit

Receiver and converter of digital data to analog signals and radio signals to digital signals

Resource block Two-dimensional unit in the time-frequency plane, consisting of a group of 12 carriers, each with 15 kHz bandwidth, and one slot of 0.5 ms

Signal attenuation

Attenuation of the radio signal between the TX reference point and the RX reference point.

SINR Quotient between the average received modulated carrier power and the average received co-channel interference power including the thermal noise power

2 LTE Overview

LTE employs the Orthogonal Frequency Division Multiple Access (OFDMA) radio access technique in the downlink, and Single Carrier Frequency Division Multiple Access (SC-FDMA) in the uplink.

LTE technology has the following characteristics:

Table 1 LTE Characteristics

Characteristic	Description
Flexible bandwidth usage	LTE is not restricted by a fixed bandwidth. The LTE standard allows bandwidth from 1.4 MHz up to 20 MHz, providing flexibility for the operator when using the spectrum.
Orthogonality in uplink and downlink	All users in a cell use transmissions that are orthogonal to each other, in both the uplink and the downlink. There is no intra-cell interference (disregarding adjacent channel interference).
Advanced coding and modulation	Depending on channel quality, LTE uses the following modulation schemes and several coding schemes within each modulation scheme: • Quadrature Phase Shift Keying (QPSK) • 16-state Quadrature Amplitude Modulation (16-QAM) • 64-state Quadrature Amplitude Modulation (64-QAM) • 256-state Quadrature Amplitude Modulation (256-QAM)
FDD and TDD	LTE supports FDD and TDD.
Advanced antenna technology	MIMO technology is used in the downlink to allow high peak rates and to improve coverage.

The orthogonality, modulation schemes, and antenna techniques contribute to enabling high peak rates close to the RBS.

2.1 Resource Block Flexible Bandwidth

A transmitted OFDMA signal can be carried by a number of parallel subcarriers. Each LTE subcarrier is 15 kHz. Twelve subcarriers (180 kHz) are grouped into a resource block. The downlink has an unused central subcarrier. Depending on the total deployed bandwidth, LTE supports a varying number of resource blocks.

The following illustration shows resource block definition:

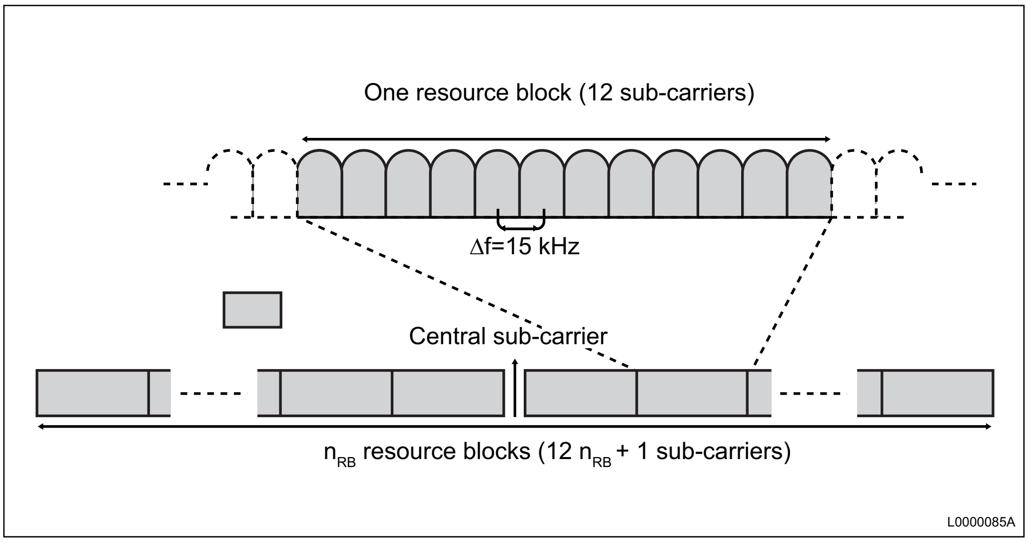

Figure 1 Resource Block Definition in Frequency Domain

A resource block is limited in both the frequency and time domains. One resource block is 12 subcarriers during one slot (0.5 ms).

In the downlink, the time-frequency plane of OFDMA structure is used to its full potential. The scheduler can allocate resource blocks anywhere, even non-contiguously.

A variant of OFDMA is used in the uplink. This variant requires the scheduled bandwidth to be contiguous, forming in effect a single carrier. The method, called SC-FDMA, can be considered a separate multiple access method.

A user is scheduled every Transmission Time Interval (TTI) of 1 ms, indicating a minimum of two consecutive resource blocks in time at every scheduling instance. The minimum scheduling in the frequency dimension is 12 subcarriers, that is the width of one resource block in the frequency dimension. The scheduler is free to schedule users both in the frequency and time domain.

The illustration in Figure 2 shows an example of two users scheduled in the time and frequency domain for the downlink and the uplink:

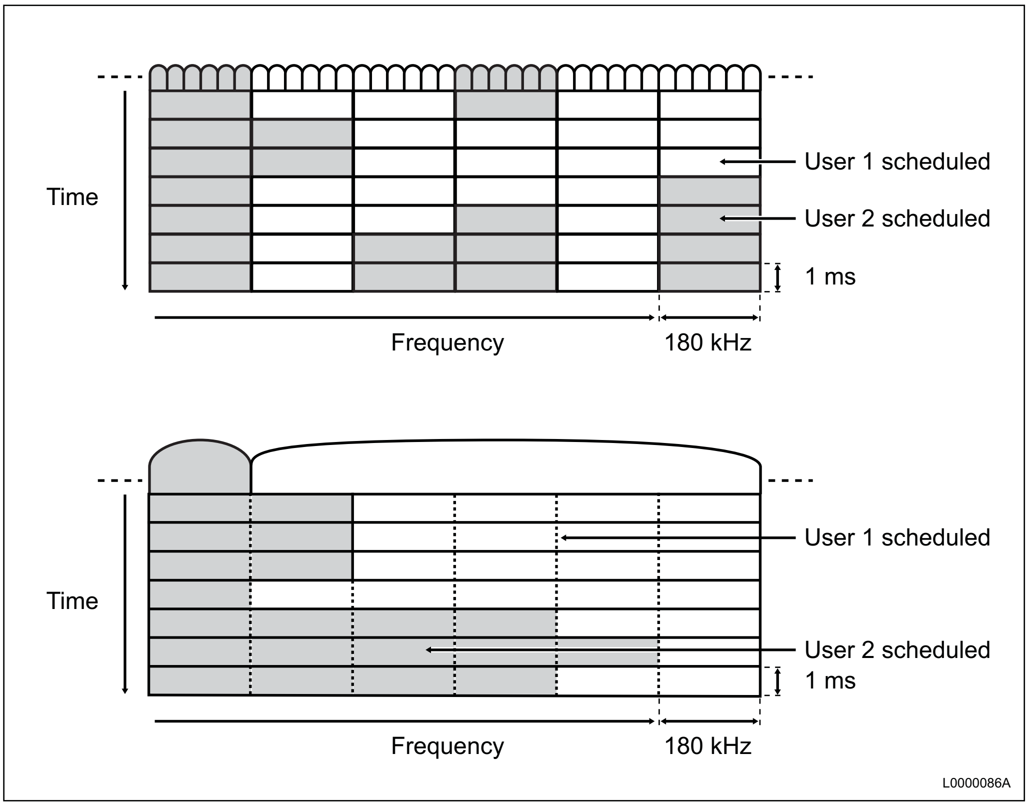

Figure 2 Downlink and Uplink User Scheduling in Time and Frequency Domain

The defined LTE bandwidths in 3GPP are the following:

Table 2 Bandwidths and Resource Blocks Specified in 3GPP

Bandwidth	**Number of Resource Blocks n_{RB}**
1.4 MHz	6
3.0 MHz	15
5.0 MHz	25
10.0 MHz	50
15.0 MHz	75
20.0 MHz	100

2.2 User Equipment

Eight UE categories have been specified by 3GPP in *3GPP TS 36.306: User Equipment (UE) radio access capabilities*. Each category is specified by a number of downlink and uplink physical layer parameter values of which a selection is listed in Table 3.

Table 3 UE Categories

UE Category	Maximum number of DL-SCH transport block bits transmitted within a TTI	Maximum number of UL-SCH transport block bits transmitted within a TTI	Maximum Number of Supported Layers for Spatial Multiplexing in DL	64 QAM Support in Uplink
1	10.296	5.160	1	No
2	51.024	25.456	2	No
3	102.048	51.024	2	No
4	150.752	51.024	2	No
5	299.552	75.376	4	Yes
6	301.504	51.024	2 or 4	No
7	301.504	51.024	2 or 4	No
8	2.998.560	1.497.760	8	Yes
9	452.256	51.024	2 or 4	No
10	452.256	51.024	2 or 4	No
11	603.008	51.024	2 or 4	No
12	603.008	51.024	2 or 4	No

3GPP has in *3GPP TS 36.101: User Equipment (UE) radio transmission and reception* specified one power class, UE power class 3, that has a maximum output power of 23 dBm.

2.3 Power Control

In the Physical Uplink Shared Channel (PUSCH), the power control algorithm enforces reception at certain power level in the RBS. This power level is henceforth referred to as the power control target. The power control target can be specified by the operator. It can be used to find a good trade-off between coverage and capacity. In addition the power control target indirectly determines the highest possible bitrate in the cell. For more information about how to select the power control target, see Section 4 on page 13.

In the Physical Downlink Shared Channel (PDSCH) a constant transmit power per resource block is used. The power per resource block depends on the power license and the system bandwidth.

Further details about power control can be found in *Power Control*.

2.4 Transmission Modes

This document supports UL dimensioning for configurations with one TX antenna in the UE and 1, 2, 4 and 8 RX antennas in the RBS. In the remainder of the document these configurations will be referred to as 1x1, 1x2, 1x4 and 1x8 respectively.

In the downlink, the document supports dimensioning of the following Transmission Modes (TM):

Table 4 Transmission Modes Supported in this Document

Transmission mode	Description	Comment
TM1	Single Input Multiple Output (SIMO)	One TX antenna in the RBS and two RX antennas in the UE.
TM3	Open Loop Spatial Multiplexing (OLSM)	Two or four TX antennas and two RX antennas in the UE.
TM4	Closed Loop Spatial Multiplexing (CLSM)	Two or four TX antennas and two RX antennas in the UE.
TM9	Multi-layer beamforming	Beam forming with 8 TX antennas and two RX antennas in the UE, including channel state information measurements.

More information can be found in the documents *Dual-Antenna Downlink Performance Package* and *Quad Antenna Uplink Performance Package*.

3 Introduction to the Dimensioning Method

The process for calculating LTE coverage and capacity can be made arbitrarily, but adapted to the dimensioning project input demands and the expected output. The process begins with defining quality requirements expressed as uplink and downlink bitrates provided with a certain probability and cell capacity (uplink and downlink).

The following figure shows the dimensioning process:

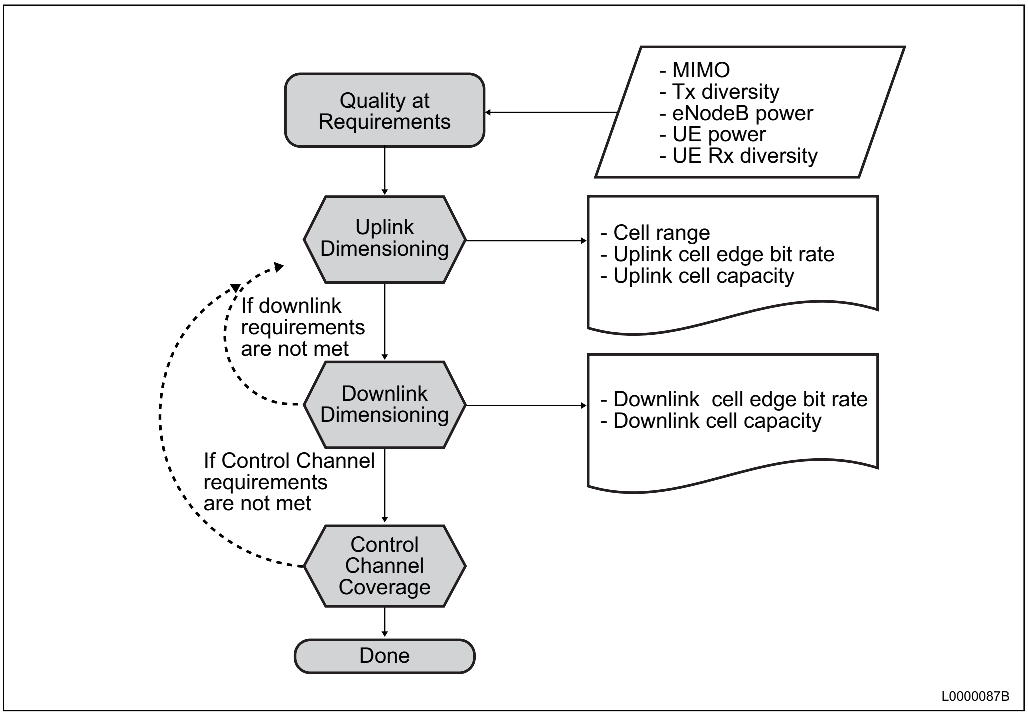

Figure 3 LTE Dimensioning Process

The process contains the following stages:

1 Quality requirement.

The coverage quality requirement is that a certain bitrate must be reached with a certain probability in the radio network, for instance 100 kbps must be reached with 98% probability.

The capacity quality requirement is that the radio network must be capable of handling a certain amount of offered traffic, for example that on average each cell in the radio network must be able to handle an offered traffic of 5 Mbps or that the radio network should be able to handle an average offered traffic of 10 Mbps per square kilometer.

2 Define prerequisites.

 The following attributes must be set:

 - Antenna configuration
 - RBS power class, for example, 20 W or 40 W
 - UE output power
 - Bandwidth
 - Frequency band

3 Uplink dimensioning.

 By gradually increasing the site-to-site distance the maximum site-to-site distance supporting the quality requirements is found.

 If the site-to-site distance is given and the quality requirements are not met, the quality requirements must be relaxed or the prerequisites modified.

4 Downlink dimensioning.

 Based on the site-to-site distance obtained in the uplink dimensioning process, the downlink coverage and cell capacity is calculated. If the downlink quality requirements are met, the site-to-site distance calculated in the uplink is the limiting. If the downlink requirements are not met, the site-to-site distance must be reduced until the downlink requirements are met.

5 Control channel coverage.

 The control channel performance at cell edge should be verified against the calculated site-to-site distance. This is to guarantee that control channel performance is not limiting cell edge performance. If control channel performance does not fulfill the quality requirement, the site-to-site distance must be reduced until the requirements are met, providing the final result.

In the coming sections the uplink dimensioning and the downlink dimensioning are described in detail.

4 Uplink Dimensioning

In many scenarios the uplink requirements are the bottleneck, so it is useful to start with the uplink dimensioning process.

4.1 Uplink Dimensioning Process

The uplink dimensioning process is described in the figure below:

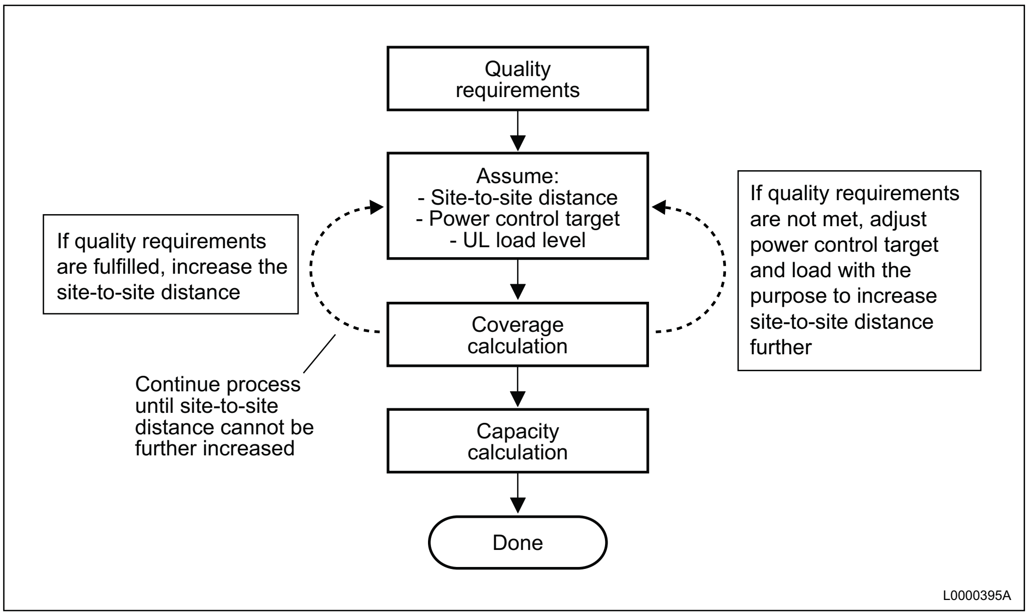

Figure 4 Uplink Dimensioning Process

The uplink dimensioning process is iterative. It takes its starting point at a short site-to-site distance (where the quality requirements are fulfilled), a certain power control setting and a certain load level. Coverage and capacity is calculated and compared to the quality requirements. In a first iteration loop, the site-to-site distance is gradually increased as long as the requirements are still fulfilled. When the coverage or capacity has been reduced to the requirement level, the power control target and load level are optimized in a second iteration loop, with the purpose of increasing the site-to-site distance further.

Instead of using an iterative approach it is possible to evaluate the coverage and capacity for all combinations of site-to-site distance, power control settings and load levels and select combination with the largest site-to-site distance fulfilling the quality requirements.

Requirements, coverage evaluation, capacity evaluation as well as the power control optimization are described in the coming sections.

4.2 Iteration Parameters

This section describes the parameters used in the iteration process.

4.2.1 Site-to-Site Distance Expressed as Signal Attenuation

To make the formulas invariant of the wave propagation characteristics, it is convenient to represent the site-to-site distance in terms of a signal attenuation value rather than a distance value. The most convenient value is the median signal attenuation experienced at the cell border, $L_{sa,cellrange}$. Conversion between $L_{sa,cellrange}$ and the maximum air path loss and site-to-site distance is described in Section 4.4.9 on page 23 and Section 11 on page 71. Starting from an initial value, $L_{sa,cellrange}$ is increased until the quality requirements are exactly fulfilled. As an initial assumption, a (low) value of $L_{sa,cellrange}$ is selected that fulfils the quality requirements. A good starting point is a value in the range of 110 to 120 dB.

4.2.2 Power Control

The power control algorithm allows the operator to adjust the power control target P_0 using `pZeroNominalPusch` operator parameter.

$$P_0 = \mathtt{pZeroNominalPusch}$$

Equation 1 Power Control Target

The path loss compensation factor α can be set to a value between 0 and 1 to allow full or partial compensation for the path loss. $\alpha = 1$ means full compensation. α uses `alpha` as operator parameter.

The setting of P_0 and α affect both coverage and capacity. A higher P_0 leads to higher cell throughput but also higher noise rise. Lower α reduces the received power of UE but also decreases the interference. Peak, average and for small cells cell-edge throughput levels can be tuned by a combined setting of the parameters P_0 and α. The default values can be used as starting values in the uplink dimensioning process. The settings can at a later stage be optimized to meet the specific quality requirements and to maximize the required site-to-site distance. This process is described in section Section 4.6 on page 25.

Further details about the power control algorithm can be found in Section 4.4.5 on page 19 and in *Power Control*.

4.2.3 PUSCH Load

The PUSCH load, Q_{PUSCH}, is defined as the fraction of the PUSCH resource blocks carrying user data. Often the load level for which dimensioning should be done is specified as a prerequisite. If not, different load levels can be tested for maximizing the site-to-site distance, as described in section Section 4.6 on page 25. If no load level is specified, a suitable starting point for the iteration is in the range of 80% to 100%.

Note: The definition of load in LTE and WCDMA differ, and the load concepts are not directly comparable. Whereas it is impossible to run a WCDMA system at 100% (WCDMA) load (corresponding to an infinite noise rise), it is perfectly possible to run an LTE system at 100% (LTE) load.

4.3 Quality Requirements

In this section the quality requirements are described for uplink dimensioning.

4.3.1 Coverage Requirements

The coverage quality requirements that a certain bitrate $R_{req,UL}$ must be reached with a certain probability in the radio network, for instance 100 kbps must be reached with 98% probability. This quality requirement will be referred to as the cell edge bitrate requirement.

An optional quality requirement relates to the bitrate supported close to the site at low signal attenuation, referred to as the high bitrate requirement or $R_{h,req,UL}$. The bitrate close to site depends to a large extent on the power control target.

4.3.2 Capacity Requirements

The capacity quality requirement is that the radio network must be capable of handling a certain amount of offered traffic, either per cell (for instance 5 Mbps per cell) or per area unit (for instance 10 Mbps per square kilometer). These capacity requirements are referred to as $T_{cell,req,UL}$ and $T_{area,req,UL}$ respectively.

4.4 Coverage Calculation

This section describes how the uplink coverage is calculated for a given combination of $L_{sa,cellrange}$, P_0, α and Q_{PUSCH}.

4.4.1 Calculation Flow

The calculation is done according to the following steps:

1 Thermal noise

2 Noise rise

3 Resource block allocation

4 Power level

5 Bitrate

6 Cell edge bitrate

7 High bitrate

8 Uplink link budget

4.4.2 Thermal Noise

The natural starting point when evaluating coverage is to calculate the thermal noise level. The thermal noise level per resource block can be calculated by the following equation.

$$N_{RB,UL} = N_t + 10\log\left(W_{RB}\right) + N_{f,RBS}$$

Equation 2 Thermal Noise

where

$\boldsymbol{N_t}$ is the thermal noise power density: -174 dBm/Hz

$\boldsymbol{W_{RB}}$ is the bandwidth per resource block: 180 kHz

$\boldsymbol{N_{f,RBS}}$ is the RBS noise figure at the RX reference point [dB]

The RBS noise figure at the RBS RX reference point depends on the Tower Mounted Amplifier (TMA) gain and the feeder loss. It can be calculated according to the following formula:

$$N_{f,RBS} = 10\log\left(N_{f,TMA} + \frac{N_{f,RU}L_f - 1}{G_{TMA}}\right)$$

Equation 3 RBS Noise Figure

where

$\boldsymbol{N_{f,TMA}}$ is the noise figure of the TMA in linear units. A typical value is 1.4 dB (1.4 linear)

$\boldsymbol{N_{f,RU}}$ is the noise figure of the RU in linear units. A typical value is 2 dB (1.6 linear)

$\boldsymbol{L_f}$ is the feeder loss between the TMA and the RU in linear units

$\boldsymbol{G_{TMA}}$ is the gain of the TMA in linear units. Ericsson TMAs have 12, 24 or 29 dB uplink gain

If no TMA is used, $N_{f,TMA} = G_{TMA} = 1$. This means that the RBS noise figure can be calculated as: $N_{f,RBS} = N_{f,RU} + L_f$ where all entities are expressed in dB. For a Remote Radio Unit (RRU) the RBS noise figure is equal to $N_{f,RU}$.

4.4.3 Noise Rise

Receiver performance is impaired by interference from other cells. This inter-cell interference is modeled using an interference margin, or "noise rise", B_{IUL}, as defined in the following equation:

$$B_{IUL} = 10\log\left(1 + \frac{Q_{PUSCH} I_{RB,UL}}{N_{RB,UL}}\right)$$

Equation 4 Noise Rise

where $I_{RB,UL}$ is the average inter-cell interference per resource block expressed in a linear scale. $I_{RB,UL}$ depends on a variety of things for example power control target, cell size, and cell isolation. To allow for pen and paper analysis, approximative values for $I_{RB,UL}$ are provided in the following graph.

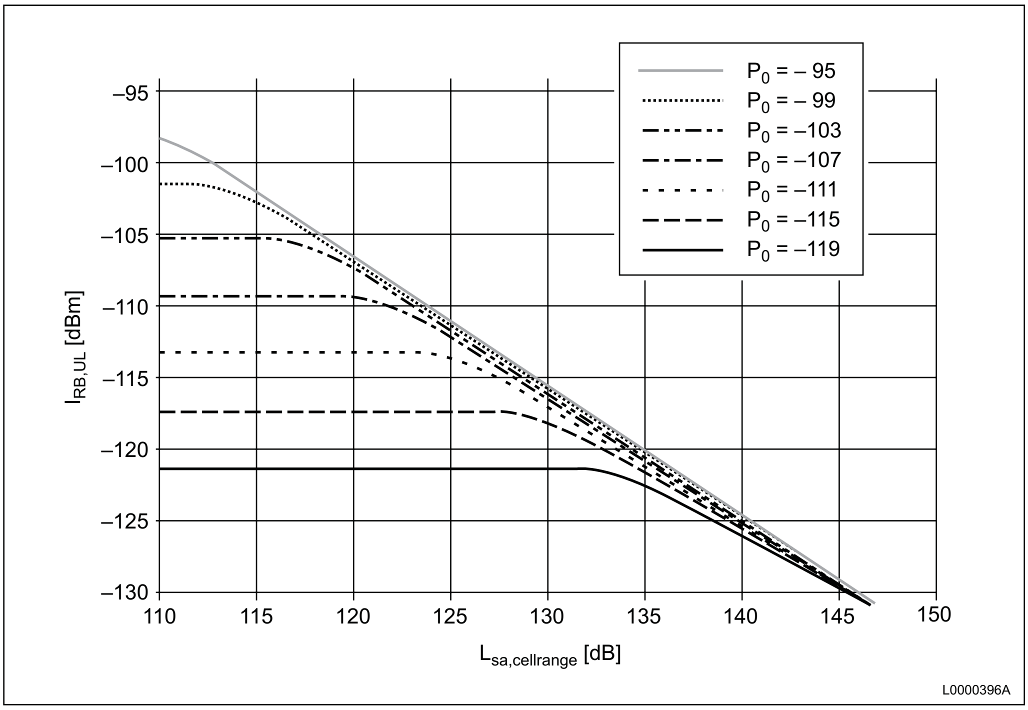

Figure 5 Interference per Resource Block for Different Settings of the Power Control Target P0 with alpha=1

For a quantitative analysis of the noise rise more refined methods must be used. Such methods can be based on network simulations or the "Uplink ring method", see Section 7.2 on page 44.

Uplink Noise Rise with Interference Rejection Combining

Interference Rejection Combining (IRC) is a method to enhance the capacity by suppressing the undesirable inter-cell interference and when activated, it replaces the Maximum Ratio Combining (MRC) algorithm. The reduced interference can be described by an interference cancellation efficiency factor β. β is between 0 and 1 where 0 means no cancellation and 1 means perfect cancellation. With IRC, the uplink interference margin is expressed as:

$$B_{IUL,IRC} = 10 \log \left[1 + \frac{Q_{PUSCH} (1 - \beta) I_{RB,UL}}{N_{RB,UL}} \right]$$

Equation 5 Noise Rise with IRC

This reduced noise rise can be used either to increase the coverage by G_{IRC} dB, where $G_{IRC} = B_{IUL} - B_{IUL,IRC}$, or to obtain a higher throughput (capacity) at the same cell range.

4.4.4 Resource Block Allocation

To calculate the bitrates in later steps, it is required to know how many resource blocks n'_{RB} that a UE is allocated as a function of the signal attenuation. For this purpose the following approximative formula can be used:

$$n'_{RB} = \max \left\{ n'_{RB,min}; \min \left[n'_{RB,max}; 10^{(P_{UE} - L_{sa} - N_{RB,UL} - B_{IUL} - \gamma_0)/10} \right] \right\}$$

Equation 6 Resource Block Allocation

where

$\boldsymbol{n'_{RB,min}}$ is the minimum number of resource blocks a UE can be allocated (in the current release equal to 2)

$\boldsymbol{n'_{RB,max}}$ is the maximum number of resource blocks a UE can be allocated. Typically $n'_{RB,max} = n_{RB,PUSCH}$ where $n_{RB,PUSCH}$ is the resource blocks available for PUSCH, see Section 4.5.4 on page 25.

$\boldsymbol{P_{UE}}$ is the maximum UE output power, typically 23 dBm.

$\boldsymbol{L_{sa}}$ is the signal attenuation between the UE and the RBS RX reference point [dB]

γ_0 is a parameter used to model the link adaptation behavior at low SINR values. The value can be seen as the minimum desired SINR level at the RBS. The recommended values are found in Table 5.

The γ_0 values in Table 5 have been obtained by link level simulation.

Table 5 Recommended γ0 values

Propagation Model	**EPA5**	**EVA70**	**ETU300**
1.4 MHz bandwidth	-2.0 dB	2.8 dB	2.0 dB
All bandwidths except 1.4 MHz	-4.0 dB	-1.4 dB	-1.4 dB

When dimensioning for networks deployed with base stations configured with 4 or 8 receive antennas, the γ_0 values are modified according to Table 6.

Table 6 Modification of γ0 values for 4 and 8 receive antennas

Number of antennas	**4**	**8**
Value to be added to γ_0	-4.0 dB	-7.0 dB

The equation for resource block allocation tries to capture the link adaptation behavior to select n'_{RB} as the largest possible number not forcing the SINR to fall below the minimum desired level γ_0.

To allocate resource blocks so that $\gamma < \gamma_0$ is not useful since the achievable bitrate will not increase. Resource blocks that are not allocated can be used by other UE to increase cell throughput.

In the figure below the equation for resource block allocation is plotted as a function of signal attenuation. A 10 MHz scenario with $n'_{RB,max}$ = 47.4, γ_0 = -2dB, $N_{RB,UL}$ = -120 dBm and B_{IUL} = 4 dB is assumed.

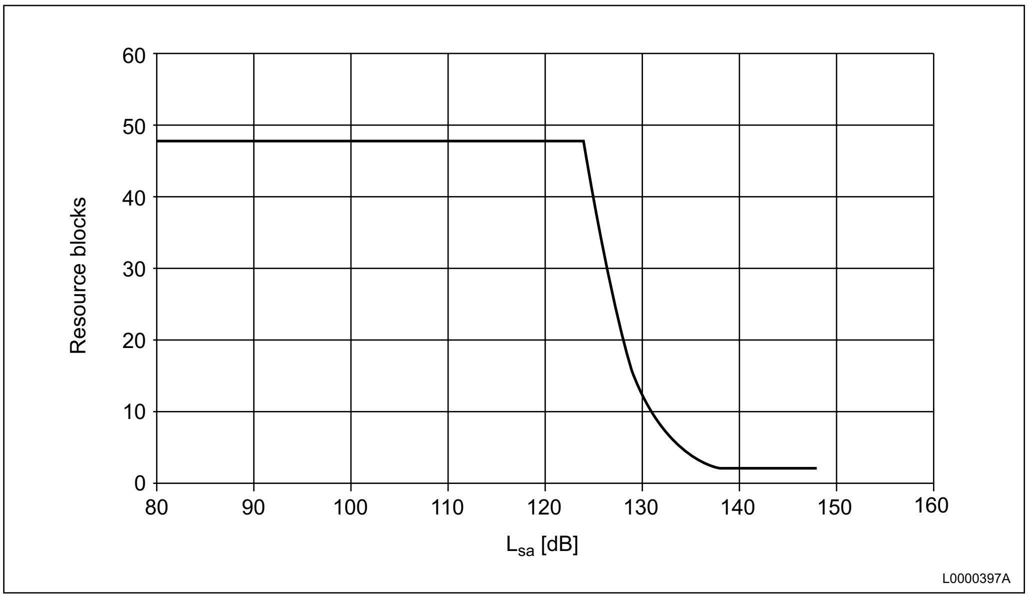

Figure 6 Example of the Relationship Between Signal Attenuation and Number of Resource Blocks

4.4.5 Power Level

To calculate the bitrates it is not only required to know the number of resource blocks that UE is allocated but also at what SINR these resource blocks are received. This is governed by the power control settings.

For dimensioning purposes the following equation can be used to model the TX power used per resource block:

$$P_{UE,RB} = \min\left[P_{UE} - 10\log\left(n'_{RB}\right); P_0 + \alpha L_{sa}\right]$$

Equation 7 TX Power per resource block

Here P_0 is the power control target and α is the path loss compensation factor.

Knowing the TX power, the RX power level per resource block is simply given as in the following equation:

$$P_{rx,RB} = P_{UE,RB} - L_{sa}$$

Equation 8 RX Power Per RB

Finally the achieved SINR, γ can be calculated as in the following equation:

$$\gamma = P_{rx,RB} - N_{RB,UL} - B_{IUL}$$

Equation 9 SINR

To illustrate the behavior of power control, $P_{UE,RB}$, $P_{rx,RB}$ and γ are plotted for P_0 = -103 dBm and α = 1. The remaining parameters have the same values as in the example in Figure 6.

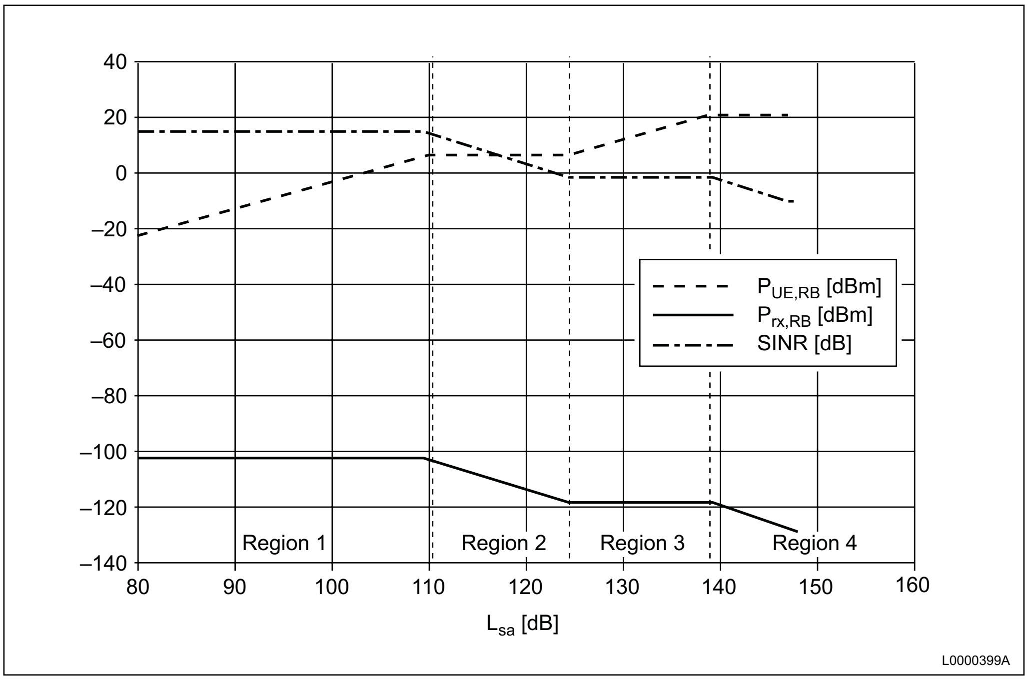

Figure 7 Illustration of Power Levels

The figure can be divided into four regions with different characteristics:

- Region 1: Here UE power control is working within the dynamic range. The power control target P_0 is met and γ is constant.
- Region 2: Here the UE is transmitting at the maximum power. $P_{rx,RB}$ and γ decreases with a higher signal attenuation until $\gamma = \gamma_0$.
- Region 3: Here $P_{rx,RB}$ and γ are constant even though the signal attenuation increases. The number of allocated resource blocks decreases, see Figure 6.
- Region 4: The number of allocated resource blocks has reached its minimum, $n'_{RB,min}$. γ decreases with a higher signal attenuation.

4.4.6 Bitrates

When the number of allocated resource blocks (Equation 6) and the SINR (Equation 9) are known, the achieved bitrate R_{UL} can be calculated as the number of resource blocks times the rate per resource block $R_{RB}(\gamma)$, as in the following equation:

$$R_{UL} = n'_{RB} R_{RB}(\gamma)$$

Equation 10 Bitrate

$R_{RB}(\gamma)$ is the following function of SINR:

$$\begin{aligned} &R_{RB}(\gamma) = \max\left[0, a_3 + (a_0 - a_3)\, e^{-\ln(2)[(\gamma - a_1)/a_2]^{a_4}}\right]; \quad \gamma < a_1 \\ &R_{RB}(\gamma) = a_0; \qquad \gamma \geq a_1 \end{aligned}$$

Equation 11 Bitrate per Resource Block

Information about the coefficients a_0, a_1, a_2, a_3, a_4 can be found in Section 10 on page 57.

Using the equation above, the achieved bitrate can be calculated for an arbitrary signal attenuation.

4.4.7 Cell Edge Bitrate

The median signal attenuation at the cell border is given by $L_{sa,cellrange}$. The relation between $L_{sa,cellrange}$ and the attenuation to the cell edge user (defined by the required coverage probability) is given as in the following equation:

$$L_{sa,celledge} = L_{sa,cellrange} + B_{LNF}$$

Equation 12 Signal Attenuation at Cell Edge where B_{LNF} is the log-normal fading margin. The following table lists fading margins in dB for varying standard deviation σ of the log-normal fading process and different coverage probabilities:

Table 7 Fading Margins for Varying Standard Deviation of Log-Normal Fading

Environment	**σ [dB]**	**Coverage Probability**				
		98%	**95%**	**90%**	**85%**	**75%**
Rural, Suburban	6	5.5	2.9	0.5	-1.2	-3.7
Urban	8	8.1	4.9	1.8	-0.2	-3.4
Dense urban and Suburban indoor	10	10.6	6.7	3.1	0.6	-3.1
Urban indoor	12	13.1	8.4	4.2	1.3	-3.1
Dense urban indoor	14	15.3	9.9	5.1	1.8	-3.1

When the signal attenuation at the cell edge is known, the number of resource blocks and the SINR at the cell edge can be calculated as in the following equations:

$$n'_{RB,celledge} = \max\left\{n'_{RB,min}; \min\left[n'_{RB,max}; 10^{(P_{UE}-L_{sa,celledge}-N_{RB,UL}-B_{IUL}-\gamma_0)/10}\right]\right\}$$

Equation 13 Resource Block Allocation at Cell Edge

$$\gamma_{celledge} = \min\left(P_{UE} - 10\log\left(n'_{RB,celledge}\right); P_0 + \alpha L_{sa,celledge}\right) - \\ - L_{sa,celledge} - N_{RB,UL} - B_{IUL}$$

Equation 14 SINR at Cell Edge

These values can then be used to calculate the cell edge bitrate as (using Equation 10):

$$R_{celledge,UL} = n'_{RB,celledge} R_{RB,celledge}$$

Equation 15 Cell Edge Bitrate

The cell edge bitrate is compared to the required cell edge bitrate $R_{req,UL}$.

4.4.8 High Bitrate

The high bitrate requirement is evaluated for a UE close to the site, for example, with $L_{sa} = 70dB$. Here it can be assumed that the maximum number of resource blocks is allocated and that the SINR (γ_h) is given by:

$$\gamma_h = P_{rx,RB} - N_{RB,UL} - B_{IUL} = P_0 - (1-\alpha)\, L_{sa} - N_{RB,UL} - B_{IUL}$$

Equation 16 SINR for UE close to Site

The bitrate for a UE close to site, $R_{h,UL}$ is calculated as:

$$R_{h,UL} = n'_{RB,max} R_{RB,h}$$

Equation 17 High Bitrate

$R_{h,UL}$ is compared to the high bitrate quality requirement $R_{h,req,UL}$.

4.4.9 Uplink Link Budget

This section describes how to convert from $L_{sa,cellrange}$ to air propagation loss. For the conversion the following link budget equation can be used:

$$L_{pmax} = L_{sa,cellrange} - L_{BL} - L_{CPL} - L_{BPL} + G_a - L_j$$

Equation 18 Uplink Link Budget

where

$\boldsymbol{L_{pmax}}$ is the maximum path loss due to propagation in the air [dB]

$\boldsymbol{L_{BL}}$ is the body loss [dB]

$\boldsymbol{L_{CPL}}$ is the car penetration loss [dB]

$\boldsymbol{L_{BPL}}$ is the building penetration loss [dB]

$\boldsymbol{G_a}$ is the sum of the maximum gain in the forward direction of the RBS antenna, and UE antenna gain [dBi]

$\boldsymbol{L_j}$ is any losses due to jumpers installed between the antenna and the RX reference point [dB]

Maximum air propagation loss can then be converted to a cell range, site-to-site distance and cell size using the equations in Section 11 on page 71.

Sometimes it is desired to base the link budget on the receiver sensitivity. If this is the case, the following alternative link budget equation can be used:

$$L_{pmax} = P_{UE,RB} - S_{RBS} - B_{IUL} - B_{LNF} - L_{BL} - L_{CPL} - L_{BPL} + G_a - L_j$$

Equation 19 Uplink Link Budget Based on Receiver Sensitivity

where S_{RBS} is the RBS receiver sensitivity corresponding to the required RX power per resource block to support a certain bitrate assuming zero noise rise. For the cell edge bitrate, assuming that the UE uses maximum power, the receiver sensitivity can be calculated as:

$$S_{RBS} = P_{UE} - L_{sa,cellrange} - B_{LNF} - 10\log\left(n'_{RB}\right) - B_{IUL}$$

Equation 20 Receiver Sensitivity

4.5 Capacity Calculation

This section describes an approach facilitating an approximative pen and paper analysis of LTE capacity for a given combination of $L_{sa,cellrange}$, P_0, α and Q_{PUSCH}.

4.5.1 Calculation Flow

The calculation involves the following three steps:

1. Average RX power
2. Average SINR
3. Cell throughput

For a quantitative analysis of LTE capacity, simulation-based approaches or the uplink ring method described in section Section 7.2 on page 44 must be used.

4.5.2 Average RX Power

The following graph shows how approximate levels of the average received power per resource block, $P_{rx,RB,ave}$, depends on the power control target P_0, path loss compensation factor α and $L_{sa,cellrange}$.

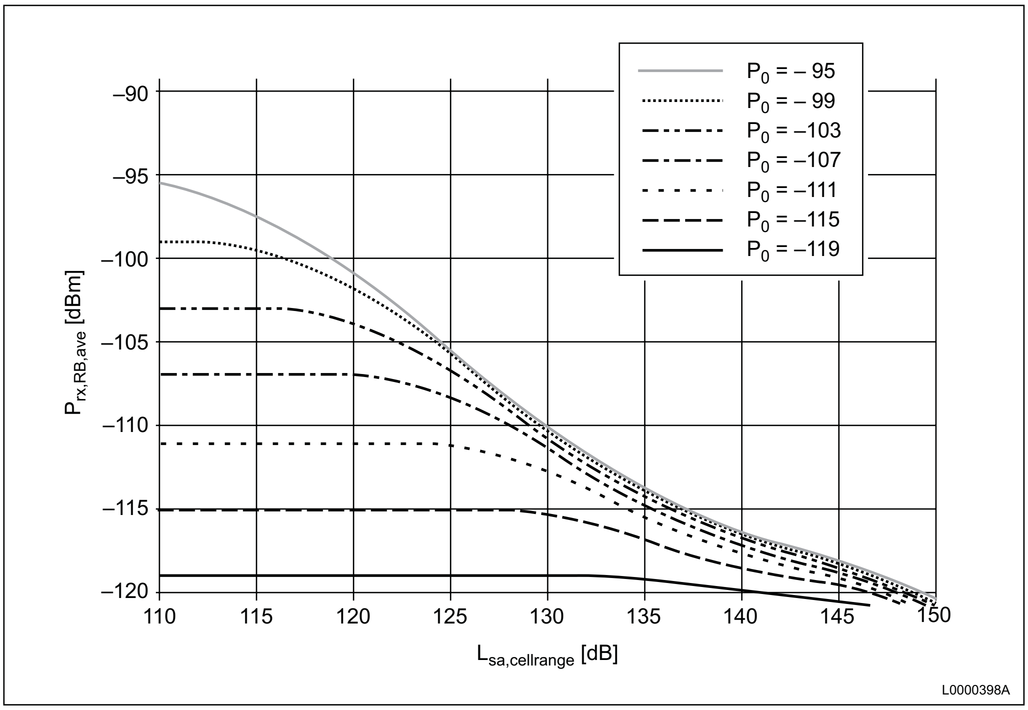

Figure 8 RX Power per Resource Block with alpha=1

As can be seen, $P_{rx,RB,ave}$ increases with a higher setting of P_0 and decreases with the $L_{sa,cellrange}$. The region to the left where the average RX power does not change with the attenuation represent cells in which all UE reach the power control target and are received with the same SINR.

4.5.3 Average SINR

Based on $P_{rx,RB,ave}$ an average SINR can be calculated:

$$\gamma_{ave} = P_{rx,RB,ave} - N_{RB,UL} - B_{IUL}$$

Equation 21 Average SINR

where the $N_{RB,UL}$ and B_{IUL} are calculated in Section 4.4.2 on page 16 and Section 4.4.3 on page 16.

4.5.4 Cell Throughput

Based on γ_{ave} the average bitrate per resource block, $R_{RB,UL,ave}$ can be calculated using Equation 10. The cell throughput can be estimated as:

$$T_{cell,UL} = Q_{PUSCH} n_{RB,PUSCH} R_{RB,UL,ave}$$

Equation 22 Uplink Cell Throughput

where $n_{RB,PUSCH}$ is the average number of resource blocks available for PUSCH. $n_{RB,PUSCH}$ is calculated as:

$$n_{RB,PUSCH} = n_{RB} - n_{RB,PUCCH} - n_{RB,PRACH}$$

Equation 23 Average Number of Resource Blocks Available for PUSCH

where $n_{RB,PUCCH}$ and $n_{RB,PRACH}$ are the average number of resource blocks allocated to PUCCH and PRACH respectively.

The number of resource blocks allocated for PUCCH is dependent on the bandwidth. Suitable values can be found in *Control Channel Guideline*.

The value of $n_{RB,PRACH}$ is 0.6 for cell ranges up to 15 km. For cell ranges larger than 15 km, the Maximum Cell Range feature is required and the value of $n_{RB,PRACH}$ is 1.2.

The achieved value of $T_{cell,UL}$ is compared with the quality requirements $T_{cell,req,UL}$. If the requirement is based on cell throughput per area unit, $T_{cell,UL}$ is divided by the cell area (section Section 4.4.9 on page 23) and compared with $T_{area,req,UL}$.

4.6 Optimizing Power Control and PUSCH Load

The power control settings P_0, α, and PUSCH load Q_{PUSCH} can be adjusted to improve coverage and capacity.

The following general rules apply:

- If the cell edge bitrate quality requirement is the bottleneck, consider reducing P_0, α, and or Q_{PUSCH}. The effect is a lower noise rise which can increase the cell edge bitrate.
- If the capacity quality requirement is the bottleneck, consider increasing P_0, α, and or Q_{PUSCH}.
- If the high bitrate quality requirement is the bottleneck, consider increasing P_0 to increase received power of cell center UEs, and decrease Q_{PUSCH}.

4.7 Special Cases

In the previous sections, calculations of coverage and capacity for arbitrary combinations of P_0, α, $L_{sa,cellrange}$ and Q_{PUSCH} are given. This section describes special cases.

4.7.1 Maximum Signal Attenuation

In large parts of the cell, UE will operate at their maximum power. In this case, the TX power per resource block is simply given by:

$$P_{UE,RB} = P_{UE} - 10\log\left(n'_{RB}\right)$$

Equation 24 UE TX Power Per Resource Block when at Maximum Power

If the number of resource blocks that a UE uses is known, Equation 10 can be re-arranged to give the maximum L_{sa} supporting a certain rate R_{UL} as:

$$\begin{aligned} L_{sa} = P_{UE} - 10\log\left(n'_{RB}\right) - N_{RB,UL} - B_{IUL} - a_1 + \\ + a_2\left[\ln\left(\frac{a_0 - a_3}{R_{UL}/n'_{RB} - a_3}\right)/\ln 2\right]^{1/a_4}; \\ 0 \le R_{UL}/n'_{RB} \le a_0 \end{aligned}$$

Equation 25 Signal Attenuation for Certain Rate

For large cells, the cell edge UE is typically allocated the minimum number of resource blocks $n'_{RB} = n'_{RB,min}$. With the assumption that the minimum number of resource blocks are used for the cell edge rate, this means that $L_{sa,celledge}$ is given by:

$$
\begin{aligned}
L_{sa,celledge} &= L_{sa,cellrange} + B_{LNF} = \\
&= P_{UE} - 10\log\left(n'_{RB,min}\right) - N_{RB,UL} - B_{IUL} - a_1 + \\
&+ a_2\left[\ln\left(\frac{a_0 - a_3}{R_{req,UL}/n'_{RB} - a_3}\right)/\ln 2\right]^{1/a_4}; \\
&0 \le R_{req,UL}/n'_{RB,min} \le a_0
\end{aligned}
$$

Equation 26 Signal Attenuation at Cell Border for Quality Requirement

The noise rise in the equations above depends on the PUSCH load (Equation 4). By increasing the PUSCH load level until the desired capacity is reached the lowest possible cell range can be found. Note that for large cells the noise rise is almost independent on the power control target P_0.

4.7.2 Power Control Target

If the noise rise is known, the required power control target $P_{0,h,req}$ to achieve the high rate quality requirement (see Section 4.4.8 on page 22) is calculated as:

$$
\begin{aligned}
P_{0,h,req} = N_{RB,UL} + B_{IUL} + a_1 - a_2\left[\ln\left(\frac{a_0 - a_3}{R_{h,UL,req}/n'_{RB} - a_3}\right)/\ln 2\right]^{1/a_4} + \\
+ (1-\alpha)\,L_{sa}; \\
0 \le R_{h,req,UL}/n'_{RB,max} \le a_0
\end{aligned}
$$

Equation 27 Required Power Control Target

When $\alpha < 1$, the resulting $P_{0,h,req}$ depends on the value of α and L_{sa}. Since the high rate requirement is for UEs close to the site, a typical value for L_{sa} can be 70dB. Defining the high bitrate requirement at a larger L_{sa} (larger distance from the site) will yield a higher$P_{0,h,req}$ by Equation 27 . This leads to a larger noise rise.

5 Downlink Dimensioning

This section describes the downlink dimensioning method.

5.1 Downlink Coverage

The downlink link budget is calculated for the following purposes:

- To determine the limiting link
- To determine the bitrate that can be supported in the downlink at the uplink cell range limit

5.1.1 Calculation Flow

The calculations are performed using the following steps:

1. Maximum air path loss from uplink
2. Bitrate requirement
3. Power per resource block
4. Downlink noise rise (interference margin)
5. Downlink link budget
6. Receiver sensitivity, UE
7. Bitrate at the cell edge
8. Concluding the link budget

5.1.2 Path Loss from Uplink

L_{pmax} from the uplink link budget calculations is the starting point of the downlink calculations and is used to obtain a downlink noise rise estimate. At the end of the link budget calculation process, if the downlink L_{pmax} is less than the uplink L_{pmax}, both the uplink and downlink link budgets can be recalculated (including the noise rise) using the new L_{pmax}.

5.1.3 Bitrate Requirement

The bitrate requirement $R_{req,DL}$ is divided by n_{RB} to obtain the required bitrate per resource block $R_{req,RB,DL}$, as shown in the following equation:

$$R_{req,RB,DL} = \frac{R_{req,DL}}{n_{RB}\left(k_{subf,DL} - k_{subf,PRS}\right)}$$

Equation 28 Bitrate Requirement per Resource Block

Unlike the uplink, the downlink scheduler can allocate resource blocks without requiring them to be consecutive. It can be shown that it is always favorable to spread the transmission across as many resource blocks as possible. Assuming this, the number of allocated resource blocks n_{RB} in the downlink for dimensioning is set to the total number of resource blocks for the deployed bandwidth.

In this process, the obtained bitrate requirement per resource block is not used directly to calculate power per resource block, but to compare with the rate that can be obtained at the cell edge given by the uplink link budget. Alternatively, it can be used as a starting point for link budget calculations.

5.1.4 Power per Resource Block

The power in LTE is shared by all resource blocks. It is assumed that all resource blocks are allocated an equal amount of power.

The power per resource block at the TX reference point is:

$$P_{tx,RB} = 10\log\left(P_{nom,ref}\right) - L_f - 10\log\left(n_{RB}\right) \quad [dB]$$

Equation 29 Power per Resource Block at the TX Reference Point

where

$\boldsymbol{P_{nom,ref}}$ is the sum of nominal power from all radio units in a cell [W]. This means that if two radio units of 20 W each are used, $P_{nom,ref}$ is equal to 40 W.

$\boldsymbol{L_f}$ is the feeder loss in dB between the radio unit connector and the TX reference point.

5.1.5 Downlink Noise Rise at the Cell Edge

The downlink noise rise $B_{IDL,celledge}$ on the cell edge is needed for the link budget and is calculated using the following equation (all quantities linear):

$$B_{IDL,celledge} = 1 + \frac{P_{tx,RB}F_c\left[\rho_{CCH} + \left(1 - \rho_{CCH}\right)Q_{PDSCH}\right]}{N_{RB,DL}L_{sa,celledge}}$$

Equation 30 Calculation of Downlink Noise Rise

where

$\boldsymbol{Q_{PDSCH}}$ is the PDSCH load, defined as the fraction of occasions a PDSCH resource is carrying data

$\boldsymbol{\rho_{CCH}}$ is the fraction of PDSCH resources interfered by control channels

$\boldsymbol{F_c}$ is the average ratio between the received power from other cells to that of own cell at cell edge locations

$\boldsymbol{N_{RB,DL}}$ is the thermal noise per resource block in the downlink, defined by $N_t + N_{f,UE} + 10\log(W_{RB})$ similar to Equation 2. The assumed noise figure $N_{f,UE}$ for a typical UE receiver is 7 dB.

An estimate of ρ_{CCH} per bandwidth is given in Table 8 for non time synchronized networks, and in Table 9 for time synchronized networks. The PDSCH load is modeled with Q_{PDSCH}. Usually, one design goal is to determine the PDSCH load for which the required coverage is fulfilled.

Table 8 Interference due to Control Channels for Non Time Synchronized Networks

Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
ρ_{CCH}	23.2%	17.1%	16.5%	16.1%	12.0%	11.8%

Table 9 Interference due to Control Channels for Time Synchronized Networks

Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
ρ_{CCH}	9.7%	8.3%	8.3%	8.3%	7.7%	7.7%

The cell plan quality is modeled with the factor F_c. F_c describes the ratio of received power from all other cells to that received from own cell at a location near the cell edge.

Table 10 provides values for F_c values at varying tilt with 30 meter antenna height, and 3-sector sites. The values are based on system simulations. The recommended tilt is given by the table row with the numbers in bold face. For dimensioning with other antenna heights or cell ranges, see Section 7.1.2 on page 42. For dimensioning of six-sector sites it is recommended to multiply the values in the table by a factor of 1.2. For dimensioning of omni-sites it is recommended to multiply the values in the table by a factor of 0.8.

Table 10 Examples of Fc at Cell Edge for Varying Tilt Angle

Cell range	5000 m	2000 m	1000 m	500 m	F_c
Tilt Angle	0.0	0.0	0.0	0.0	2.8
	0.2	0.5	1.0	2.0	2.7
	0.4	1.0	2.0	4.0	2.5
	0.6	1.5	3.0	6.0	2.3
	0.8	2.0	4.0	8.0	2.1
	1.0	***2.5***	***5.0***	***9.9***	***1.8***
	1.2	3.0	6.0	11.9	1.6
	1.4	3.5	7.0	13.8	1.5
	1.6	4.0	8.0	15.7	1.4

$L_{sa,cellrange}$ for downlink is calculated in the logarithmic scale from the maximum air path loss L_{pmax} by the following equation:

$$L_{sa,cellrange} = L_{pmax} + L_{BL} + L_{CPL} + L_{BPL} - G_a + L_j \ \ [\mathrm{dB}]$$

Equation 31 Calculation of Downlink Signal Attenuation at the Cell Range

5.1.6 Downlink Link Budget

The downlink link budget, L_{pmax}, is calculated by the following equation:

$$L_{pmax} = P_{tx,RB} - S_{UE} - B_{IDL,celledge} - B_{LNF} - \\ - L_{BL} - L_{CPL} - L_{BPL} + G_a - L_j \ \ [\mathrm{dB}]$$

Equation 32 Downlink Budget Calculation

where

$\boldsymbol{P_{tx,RB}}$ is the transmitter power per resource block at the TX reference point [dBm]

$\boldsymbol{S_{UE}}$ is the UE sensitivity [dBm]

5.1.7 UE Receiver Sensitivity

The only unknown variable in Equation 32 is the UE sensitivity S_{UE}. S_{UE} is the signal power at the UE reference point required to achieve a certain bitrate in the absence of inter-cell interference.

The following relation describes the receiver sensitivity per resource block:

$$S_{UE} = N_t + N_{f,UE} + 10\log\left(W_{RB}\right) + \gamma = N_{RB,DL} + \gamma \, [\text{dB}]$$

Equation 33 UE Receiver Sensitivity

5.1.8 Bitrate at Cell Edge

Solving Equation 32 and Equation 33 for downlink SINR yield an SINR estimate on the edge of a cell with the size given by L_{pmax}.

The calculation of SINR on cell edge is given by the following equation:

$$\begin{aligned}\gamma_{celledge} = P_{tx,RB} - L_{pmax} - N_{RB,DL} - B_{IDL,celledge} - B_{LNF} - \\ - L_{BL} - L_{CPL} - L_{BPL} + G_a - L_j \ \ [\text{dB}]\end{aligned}$$

Equation 34 Calculation of SINR at Cell Edge

The cell edge SINR estimate is transformed into a cell edge bitrate per resource block, $R_{RB,celledge}$, by mapping SINR to throughput using link simulation curves, see Section 10 on page 57.

$R_{RB,celledge}$ is used to obtain the cell edge bitrate $R_{celledge,DL}$ by:

$$R_{celledge,DL} = R_{RB,celledge} n_{RB} \left(k_{subf,DL} - k_{subf,PRS}\right)$$

Equation 35 Bitrate at Cell Edge

5.1.9 Concluding Link Budget

If the uplink is really the limiting link, as in the initial assumption, the bitrate at the cell edge R should be larger than the required bitrate $R_{req,DL}$. The link budget is concluded. L_{pmax}, Equation 32, is used as a measure of cell size. It is converted to geographical distance by a suitable wave propagation expression as described in Section 11 on page 71.

5.1.10 Downlink Limited Link Budget

If the resulting bitrate $R_{celledge,DL}$ is lower than the required bitrate $R_{req,DL}$, the downlink is the limiting link. In that case, the true maximum cell range must be determined by backtracking the following downlink link budget calculations:

- $R_{req,RB,DL}$, derived using Equation 28 , is transformed into a SINR requirement as described in to Section 10 on page 57

- The SINR requirement is used to derive a UE sensitivity S_{UE} at the cell edge, see Equation 33

- The UE sensitivity S_{UE} is used in the link budget, see Equation 32, initially with the same noise rise $B_{IDL,celledge}$ as before
- A new signal attenuation $L_{sa,cellrange}$ is derived using Equation 31
- The new $L_{sa,cellrange}$ is applied in Equation 30 to obtain a new $B_{IDL,celledge}$
- Equation 32, is iterated until $L_{sa,cellrange}$ and $B_{IDL,celledge}$ are constant

The new $L_{sa,cellrange}$ converted to L_{pmax} is now used to calculate the true cell range, as described in Section 5.1.9 on page 33.

A downlink limited system means that the uplink quality exceeds the requirement. If the bitrate on the cell edge for the uplink is required for reporting, the uplink link budget calculations also must be backtracked. This is done by recalculating the uplink dimensioning process with $L_{sa,cellrange}$ set to the value found to fulfill the downlink requirements.

5.2 Downlink Capacity

The following downlink capacity calculations are performed:

- SINR
- Cell throughput

5.2.1 SINR

The downlink capacity is based on the SINR at the average location within a cell, denoted $\gamma_{DL,ave}$ as a linear ratio. The average SINR is based on the average noise rise which can be calculated as in the following equation:

$$B_{IDL,ave} = 1 + \frac{P_{tx,RB} F \left[\rho_{CCH} + (1 - \rho_{CCH}) Q_{PDSCH}\right]}{N_{RB,DL} L_{sa,cellrange}}$$

Equation 36 Average Downlink Noise Rise

where

F is the average ratio of path gains for interfering cells to those of the serving cell.

The following table gives values for F at varying tilt with 30 meter antenna height and 3-sector sites. The values are based on system simulations. The recommended tilt is given by the table row with the numbers in bold face. For dimensioning of other antenna heights or cell ranges see Section 7.1.2 on page 42. For dimensioning of six-sector sites it is recommended to multiply the values in the table by a factor of 1.2. For dimensioning of omni-sites it is recommended to multiply the values in the table by a factor of 0.8.

Table 11 Examples of F for Varying Tilt Angle

Cell range	5000 m	2000 m	1000 m	500 m	F
Tilt Angle	0.0	0.0	0.0	0.0	1.1
	0.2	0.5	1.0	2.0	0.9
	0.4	1.0	2.0	4.0	0.8
	0.6	1.5	3.0	6.0	0.7
	0.8	2.0	4.0	8.0	0.7
	1.0	***2.5***	***5.0***	***9.9***	***0.6***
	1.2	3.0	6.0	11.9	0.5
	1.4	3.5	7.0	13.8	0.4
	1.6	4.0	8.0	15.7	0.4

The resulting average SINR, γ_{ave} is shown in the following equation:

$$\gamma_{ave} = \frac{P_{tx,RB}}{B_{IDL,ave} N_{RB,DL} H L_{sa,cellrange}}$$

Equation 37 Average Downlink SINR

In the equation, H is the average attenuation factor. It is the ratio between the (linear) signal attenuation that gives an average SINR in the cell and the (linear) signal attenuation at the cell range distance from the antenna. H depends on the site geometry, antenna pattern, wave propagation exponent, and base station antenna height. A value of 0.36 is recommended for dimensioning.

5.2.2 Cell Throughput

The average SINR (converted to a logarithmic value) yields an average bitrate by way of Section 10 on page 57 and R_{RB} is the bitrate per resource block. The average user bitrate per cell is scaled proportionately with the number of resource blocks n_{RB}, see Table 2:

$$R_{ave,DL} = n_{RB} R_{RB} \left(k_{subf,DL} - k_{subf,PRS} \right)$$

Equation 38 Average Downlink User Bitrate per Cell

The cell throughput is shown in the following equation:

$$T_{cell,DL} = Q_{PDSCH} R_{ave,DL}$$

Equation 39 Downlink Cell Throughput

The achieved value of $T_{cell,DL}$ is compared with the quality requirements $T_{cell,req,DL}$. If the requirement is based on cell throughput per area unit, $T_{cell,DL}$ divided by the cell area and compared with $T_{area,req,DL}$, where requirements are defined analogous to Section 4.3.2 on page 15.

6 Control Channel Coverage

This section describes the process for evaluating control channel coverage.

6.1 Downlink Control Channel Coverage

UE must be able to decode downlink control channels to be able to reach the calculated cell edge performance. In downlink, the limiting channel is PDCCH, which both have to be correctly decoded by the UE to be able to receive and transmit data.

6.1.1 Downlink Control Channel SINR for Non Time Synchronized Network

In a non time synchronized network, PDCCH is interfered by both PDSCH and control channels in other cells. Therefore SINR on control channels at the cell edge can be assumed to be equal to the calculated cell edge SINR in Equation 34.

6.1.2 Downlink Control Channel SINR for Time Synchronized Network

In a time synchronized network, PDCCH is only interfered by control channels in other cells. The downlink control channel noise rise is calculated as:

$$B_{IDL,celledge,PDCCH} = 1 + \frac{P_{tx,RB} F_c Q_{PDCCH}}{N_{RB,DL} L_{sa,celledge}}$$

Equation 40 Calculation of Downlink Control Channel Noise Rise

where Q_{PDCCH} is the PDCCH load, defined as the fraction of occasions a PDCCH resource is used. By setting Q_{PDCCH} to 100% the extreme case of fully loaded PDCCH can be calculated.

By replacing $B_{IDL,celledge}$ with $B_{IDL,celledge,PDCCH}$ in Equation 34 control channel cell edge SINR is calculated.

6.1.3 Downlink Control Channel SINR Requirements

For the control channel performance not to limit the cell edge bitrate, the calculated control channel cell edge SINR must be higher than the SINR requirement given in Table 12. If the calculated cell edge SINR is lower, the cell edge throughput will degrade gracefully. If the SINR is substantially lower than the requirement in the table, the site-to-site distance needs to be decreased.

Table 12 Downlink Control Channel SINR Requirements. In case of 4 RX Antennas in the UE the Requirements are Reduced by 3 dB

SINR [dB]	SIMO 1x2			Tx Div 2x2		
Bandwidth	**EPA 5**	**EVA 70**	**ETU 300**	**EPA 5**	**EVA 70**	**ETU 300**
> 3 MHZ	-4.5	-5.5	-4.5	-6	-6.5	-5.5
≤ 3 MHZ	-1.5	-3	-2	-3.5	-4	-3

6.2 Uplink Control Channel Coverage

In uplink the limiting control signalling is ACK/NACK transmitted on PUCCH. If the decoding of the signalling repeatedly is unsuccessful this could lead to decreased downlink cell edge throughput.

The PUCCH power control algorithm adjusts the received signal strength towards the target $P_{0,pucch}$ is defined by:

$$P_{0,pucch} = \texttt{pZeroNominalPucch}$$

Equation 41 Power Control Target for PUCCH

where `pZeroNominalPucch` is an operator parameter.

UE transmitting ACK/NACK are multiplexed on the same resource block. Therefore PUCCH ACK/NACK is interfered by both intra-cell and inter-cell signalling. Intra-cell interference is modeled by a non-orthogonality factor and inter-cell interference is modeled using the F value. The PUCCH ACK/NACK SINR at cell edge, $\gamma_{PUCCH,A/N}$, is calculated by:

$$\begin{aligned}\gamma_{PUCCH,A/N} =& min\left(P_{0,pucch}; P_{UE} - L_{sa,celledge}\right) - \\ & - 10\log\left[10^{N_{RB,UL}/10} + Q_{PUCCH,A/N}\left(\mu + F\right)10^{P_{0,pucch}/10}\right]\end{aligned}$$

Equation 42 Cell Edge PUCCH ACK/NACK SINR

where

$Q_{PUCCH,A/N}$ is the number of simultaneously transmitted ACK/NACK on PUCCH in a cell. In the current release a value of 2 is recommended for dimensioning.

μ is the non-orthogonality factor to model intra-cell PUCCH interference. A value of 0.2 is recommended for dimensioning.

F is the average ratio of path gains for interfering cells to those of the serving cell, as given in Table 11.

For the ACK/NACK performance not to limit the downlink cell edge bitrate, $\gamma_{PUCCH,A/N}$ must be higher than the PUCCH ACK/NACK SINR requirement given in Table 13. If $\gamma_{PUCCH,A/N}$ is lower, the cell edge throughput will degrade gracefully. If the SINR is substantially lower than the requirement in the table, the site-to-site distance needs to be decreased.

Table 13 PUCCH ACK/NACK SINR Requirements. In case of 4 RX diversity the requirements are reduced by 3 dB

SINR [dB]	EPA 5	EVA 70	ETU 300
SINR limit for PUCCH ACK/NACK	-8	-8	-7.5

7 Ring Methods

This section describes dimensioning based on successive calculations for defined ring-shaped regions of the cell.

7.1 Downlink Ring Method

The downlink ring method creates curves of throughput versus path loss, and provides an alternative method of calculating cell throughput. The method involves averaging throughput over the cell area.

The required input is the maximum air path loss L_{pmax} from the uplink or downlink link budget calculations. Antenna tilt θ and PDSCH load Q_{PDSCH} are required as inputs for the dimensioning calculations.

The calculations are performed in the following stages:

1 Signal attenuation $L_{sa,i}$ for each ring

2 Calculation of equivalent tilt angle

3 SINR for each ring

4 Average cell throughput

5 Throughput for each ring

7.1.1 Cell Rings

The cell area is modeled as a hexagon. The hexagonal cell area is divided into N rings, each with an area proportional to $d_i^2 - d_{i-1}^2$, where d_i is the outer range of ring *i*. The path losses $L_{p,i}$ to all positions in ring *i* are modeled to be equal. The same is valid for the signal attenuations $L_{sa,i}$.

Figure 9 depicts a target cell with the area of ring number *i* shaded.

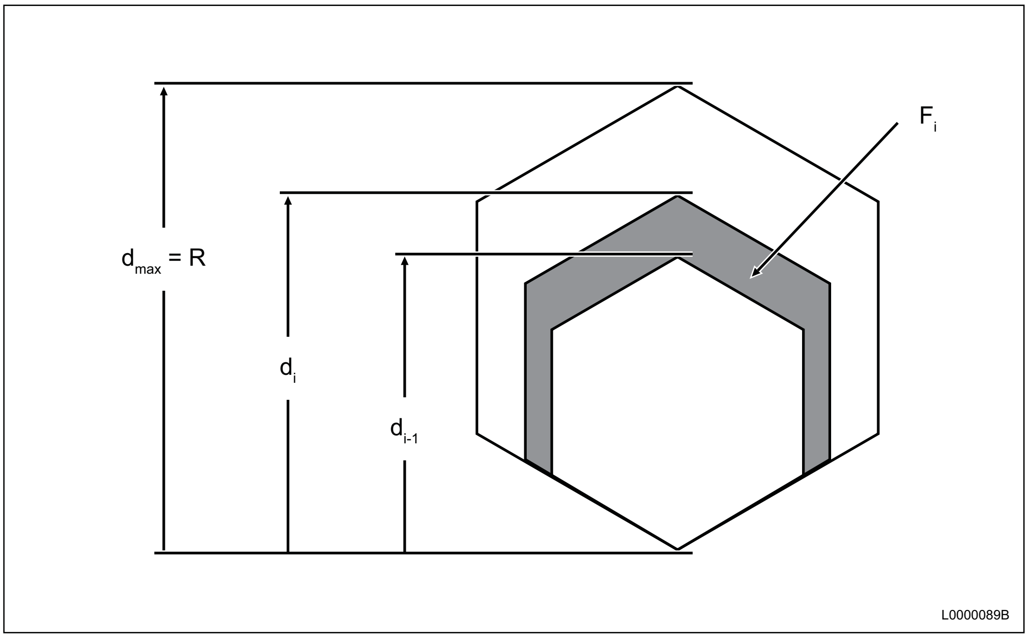

Figure 9 Target Cell Showing Area of Ring

Signal attenuation at the cell border (last *i*) $L_{sa,cellrange}$ is calculated from L_{pmax} as described in Equation 31. Maximum air path loss L_{pmax} is taken either from uplink or downlink coverage calculation.

The signal attenuation in ring *i*, $L_{sa,i}$, can be calculated from a distance ratio using the following equation:

$$L_{sa,i} = L_{sa,cellrange} + 10m\log\left(d_i/d_{max}\right)\ [\mathrm{dB}]$$

Equation 43 Signal Attenuation in Ring i

m is the path loss exponent (typically 3.5).

$L_{sa,cellrange}$ and $L_{sa,i}$ are expressed in dB.

7.1.2 Calculation of Equivalent Tilt Angle

The F values to use in the ring method have been obtained by simulations with a cell range of 1000 m and an antenna height of 30 m. The simulation results have been aggregated into average F values for each ring. If the cell range differs from 1000 m, the same F values can be used after a modification of the tilt value, to an effective tilt θ_{eq} using Equation 44.

Equivalent tilt θ_{eq} is approximately given by the following equation:

$$\theta_{eq} = \theta\frac{d_{max}}{1000}\frac{30}{h_b}$$

Equation 44 Calculation of Equivalent Tilt

The cell range d_{max} corresponding to the path loss L_{pmax} value is calculated by the appropriate wave propagation model, see Section 11 on page 71 or *Radio Wave Propagation Guideline*, and θ is the tilt for the dimensioned cell.

Equivalent tilt angle θ_{eq} is used to select the appropriate F values in Section 12 on page 73.

7.1.3 SINR in Each Ring

As signal attenuation $L_{sa,i}$ and F_i are modeled to be constant within a ring, the resulting SINR γ is also constant.

The SINR in ring *i*, γ_i is given by the following equation (all quantities linear):

$$\gamma_i = \frac{1}{\left[\rho_{CCH} + \left(1 - \rho_{CCH}\right) Q_{PDSCH}\right] F_i + \left(N_{RB,DL} L_{sa,i}\right) / P_{tx,RB}}$$

Equation 45 SINR in Ring i

where

$\boldsymbol{P_{tx,RB}}$ is the transmitter power per resource block at the TX reference point

$\boldsymbol{Q_{PDSCH}}$ is the PDSCH load, defined as the fraction of the PDSCH resource blocks carrying user data.

$\boldsymbol{\rho_{CCH}}$ is the fraction of PDSCH resources interfered by control channels

$\boldsymbol{F_i}$ is the F value in ring *i*

$\boldsymbol{N_{RB,DL}}$ is the thermal noise per resource block in downlink

With SINR, γ_i, from Equation 45 as an input, the bitrate in ring *i*, $R_{RB,i}$ can be calculated, see Section 10 on page 57.

7.1.4 Average Cell Throughput

If users are modeled to be uniformly distributed over the cell area, the number of users in ring *i* is directly proportional to the area of ring *i*.

The proportion of users in ring *i* $p_{user,i}$ is calculated by the following equation:

$$p_{user,i} = \frac{d_i^2 - d_{i-1}^2}{d_{max}^2}$$

Equation 46 Proportion of Users in Ring i

The average bitrate per resource block $R_{RB,ave}$ is as in the following equation:

$$R_{RB,ave} = \sum_i p_{user,i} R_{RB,i}$$

Equation 47 Average Bitrate per Resource Block

The average user bitrate is calculated as in the following equation:

$$R_{ave} = n_{RB} R_{RB,ave} \left(k_{subf,DL} - k_{subf,PRS}\right)$$

Equation 48 Average User Bitrate

n_{RB} is the number of resource blocks allocated.

The cell throughput is as in the following equation:

$$T_{cell,DL} = Q_{PDSCH} R_{ave}$$

Equation 49 Cell Throughput

7.2 Uplink Ring Method

A ring method can also be created for the uplink coverage and capacity dimensioning with the purpose of facilitating accurate calculations of cell throughput, noise rise and to provide user throughput distributions. Similar to the downlink, the cell area is divided into hexagonal rings. In each ring the supported number of resource blocks, SINR, bitrate and generated interference is calculated using the equations presented in Section 4.4 on page 15.

8 Additional Features Impacting Capacity and Coverage

This section describes features improving capacity and coverage which are not included the dimensioning process.

8.1 Minimum Rate Proportional Fair

The Minimum Rate Proportional Fair feature provides a trade-off between user fairness and system performance in both uplink and downlink. By prioritizing users experiencing good channel quality, a higher throughput can be achieved, compared to the Resource Fair algorithm. In many scenarios, cell capacity can be increased by using the low fairness versions of the proportional fair scheduling algorithms. These algorithms increase the share of the resources given to users with good channel conditions. This leads to an overall increase in capacity.

A cell throughput gain of 20% to 30%, while still maintaining cell edge user throughput, is possible in favorable conditions with many users per cell and a less time dispersive channel.

8.2 Uplink Frequency-Selective Scheduling

Variations in attenuation and interference in different parts of the system bandwidth, can introduce opportunities when performing uplink scheduling for a UE transmission. By using frequency-selective scheduling in uplink, that is, preferentially allocating channel resources of high quality to the UEs, both coverage and capacity will be improved. Uplink Frequency-Selective Scheduling provides improvements in cell edge throughput as well as in average cell throughput.

The frequency-selective scheduling algorithm utilizes the same basic trade-off and mechanisms as the proportional fair scheduling algorithms. The addition of the frequency selectivity makes uplink capacity gains of up to 15% - while maintaining the same cell edge coverage - possible in very favorable conditions, as compared with the Resource Fair algorithm.

If Frequency-Selective Uplink Scheduling is used as a coverage enhancing feature, coverage can be extended up to 2 dB in favorable conditions, without losing capacity. The gain include the impact from introducing Sounding Reference Symbols, see *Control Channel Guideline*.

8.3 Downlink Frequency-Selective Scheduling

The introduction of the downlink frequency selectivity makes downlink capacity gains of up to 15% possible in very favorable conditions, while maintaining the same cell edge coverage. In this case, the Resource Fair algorithm is used as a reference.

8.4 Carrier Aggregation

Carrier aggregation makes it possible to aggregate several LTE carriers with the purpose of reaching higher peak bitrates. On a high level, the impact of coverage and capacity dimensioning can be summarized as follows:

- Downlink bitrates are increased with increased spectrum.
- For non power limited UE, uplink bitrates are increased with increased spectrum.
- Downlink and uplink capacity are increased with increased spectrum.
- Common control channel coverage and bitrates for power limited UE are unchanged.

8.5 Antenna Integrated Radio

Antenna Integrated Radio (AIR) consists of two RUs integrated with an antenna. It is intended to be used in a Main-Remote configuration in the same fashion as conventional RRUs. Compared to an equivalent RRU of the same power class and with an antenna of the same form factor, the uplink and downlink performance are improved. A link budget for AIR can be made in the same way as a link budget for an RRU of the same power class with the following modifications:

- The RBS noise figure is reduced by 1.2 dB, $\Delta N_{f,RBS} = -1.2$.
- The jumper loss accounting for the loss between the RRU and the antenna is set to zero, $L_j = 0$.
- The antenna gain can be increased by 0.3 dB compared to a conventional antenna of the same form factor, $\Delta G_a = 0.3$. The reason is low internal losses in the AIR antenna.

Compared to an RRU configuration with a jumper loss of 0.5 dB, AIR will provide an improvement of the uplink sensitivity by 2 dB and an increase of the downlink TX power by 0.8 dB.

More information about AIR can be found in the document *Antenna Integrated Radio*.

8.6 Uplink Coordinated Multi-point Reception

Uplink Coordinated Multi-Point Reception (UL CoMP) is a feature that combines antenna signals from multiple cells/sectors to decode transport blocks from a UE. The purpose of UL CoMP is to improve uplink throughput by utilizing increased received UE signal power and interference suppression of one or several interferers.

UL CoMP can be performed within a site or between different sites. The first release of UL CoMP is only available for intra-eNodeB cells/sectors. The maximum number of antennas for combining is six and only applied for PUSCH.

For a 3 sectors macro site, the average uplink throughput gain by applying UL CoMP is up to 5%. Users that are close to another sector of the same site can experience an improved SINR by up to 3 dB.

9 LTE Mobile Broadband Design Example

This section describes an example of an LTE mobile broadband design using the input criteria, uplink coverage calculation, downlink coverage calculation, and downlink throughput calculation.

9.1 Input Criteria

The example network is designed with the following cell edge criteria:

- Uplink cell edge bitrate 500 kbps at 95% area coverage probability
- Uplink high rate of 10 Mbps
- Uplink cell throughput 6 Mbps
- Downlink cell edge bitrate 8 Mbps at 95% area coverage probability
- Downlink cell throughput 15 Mbps

9.1.1 Prerequisites

The prerequisites are as follows:

- RBS capability: 40 W output power; 2x2 MIMO (TM3)
- Number of resource blocks allocated for the PUCCHs: 4
- Number of OFDM symbols allocated for the PDCCHs: 1
- Maximum modulation for uplink: 16 QAM
- Terminal capability: 23 dBm output power; receive diversity
- Bandwidth: 20 MHz
- Frequency band: 2600 MHz

9.1.2 Additional Calculation Assumptions

The following additional assumptions have been made for the calculations:

- The major part of traffic in the network conforms to the mobile broadband traffic model (coverage, noise rise, and capacity determined for the same service and traffic model)
- A Remote Radio Unit and no feeder loss

- 18 dB indoor penetration loss
- 3 dB additional loss due to jumpers, body attenuation, and so forth
- 18.5 dB antennas, tilt angle equivalent to 5° tilt angle for a cell range of 1000 m.
- Channel model EPA at 5 Hz Doppler frequency
- Urban area
- No positioning is assumed
- Power control strategy: $\alpha = 1$

9.2 Desired Output

The desired output is as follows:

- Cell range and site-to-site distance
- Capacity and expected user bitrate distribution
- Setting for P_0 maximizing the cell range

9.3 Uplink Coverage and Capacity

In this section the dimensioning process for uplink coverage and capacity is described. The iteration steps are described in Section 4.1 on page 13.

Three iterations are shown:

1. The first iteration corresponds to initial assumptions for $L_{sa,cellrange}$, P_0 and Q_{PUSCH}.
2. In the second iteration, $L_{sa,cellrange}$ is increased to the maximum, with the initial assumptions for the P_0 and Q_{PUSCH} fulfilling the quality requirements.
3. The third iteration corresponds to the final $L_{sa,cellrange}$ with optimized values for P_0 and Q_{PUSCH}.

Table 14 Uplink Link Budget Example

Link Budget					
Assumptions		**Iteration 1**	**Iteration 2**	**Iteration 3**	
Signal attenuation at cell range	$L_{sa,cellrange}$	115	120	128	dB
Power control target	P_0	-106	-106	-103	dBm/ RB

Table 14 Uplink Link Budget Example

Link Budget					
PUSCH load	Q_{PUSCH}	100%	100%	25%	
Noise Rise					
Thermal noise	$N_{RB,UL}$	-119.5	-119.5	-119.5	dBm/ RB
Interference per resource block	$I_{RB,UL}$	-108.2	-108.5	-114.3	dBm
Noise rise	B_{IUL}	11.5	11.3	2.6	dB
Cell Edge Bitrate					
Log normal fading margin	B_{LNF}	4.9	4.9	4.9	dB
Signal attenuation at cell edge	$L_{sa,celledge}$	119.9	124.9	132.9	dB
Allocated resource blocks	$n'_{RB,celledge}$	31.7	10.6	12.4	
TX power per resource block	$P_{UE,RB,celledge}$	8.0	12.7	12.1	dBm
RX power per resource block	$P_{rx,RB,celledge}$	-111.9	-112.2	-120.8	dBm
SINR	$\gamma_{celledge}$	-4.0	-4.0	-4.0	dB
Bitrate per resource block	$R_{RB,celledge}$	42	42	42	kbps
Cell edge bitrate	$R_{celledge,UL}$	1330	450	520	kbps
High Bitrate					
Allocated resource blocks	$n'_{RB,h}$	95.4	95.4	95.4	
SINR	γ_h	1.9	2.2	13.8	dB
High bitrate	$R_{h,UL}$	12800	13300	38600	kbps
Capacity					
Average received power per resource block	$P_{rx,RB,ave}$	-106	-106	-109.0	dBm
Average SINR	γ_{ave}	1.9	2.1	7.8	dB
Cell throughput	$T_{cell,UL}$	12800	13200	6500	kbps
Cell Size					
Body loss	L_{BL}	3	3	3	dB
Building penetration loss	L_{BPL}	18	18	18	dB
Car penetration loss	L_{CPL}	0	0	0	dB
Antenna gain	G_a	18.5	18.5	18.5	dBi

Table 14 Uplink Link Budget Example

Link Budget					
Max uplink air path loss	L_{pmax}	112.5	117.5	125.5	dB
Range	d_{max}	200	278	469	m

9.4 Downlink Coverage and Capacity

The maximum air path loss L_{pmax} from the uplink is used to find the maximum sustainable bitrate per resource block in the downlink, see Table 15.

The following table presents a downlink link budget example:

Table 15 Downlink Link Budget Example

Link Budget			
Max uplink air path loss	L_{pmax}	125.5	dB
Fading margin	B_{LNF}	4.9	dB
Body loss	L_{BL}	3	dB
Building penetration loss	L_{BPL}	18	dB
Car penetration loss	L_{CPL}	0	dB
Antenna gain	G_a	18.5	dBi
Jumper and TMA insertion loss	L_J	0	dB
Signal attenuation at cell edge	$L_{sa,celledge}$	132.9	dB
Average RBS power at TX reference point	P_{tx}	40	W
Average RBS power at TX reference point per resource block	$P_{tx,RB}$	0.40	W
Cell edge F factor	F_c	1.8	
PDSCH load	Q_{PDSCH}	55%	
Interference due to control channels	ρ_{CCH}	11.8%	
Interference margin	$B_{IDL,celledge}$	8.6	dB
UE sensitivity	S_{UE}	-115.5	dBm
Noise figure UE	$N_{f,UE}$	7	dB
Thermal noise floor per resource block	$N_{RB,DL}$	-114.4	dBm

Link Budget			
Cell edge SINR	$\gamma_{celledge}$	-1.0	dB
Cell edge bitrate per resource block	$R_{RB,celledge}$	91.3	kbps
Number of resource blocks	n_{RB}	100	
Total user bitrate at cell edge	$R_{celledge,DL}$	9.1	Mbps
Capacity			
Attenuation factor, target cell	H	0.36	
Average F factor	F	0.6	
Average noise rise	$B_{IDL,ave}$	8.7	dB
Average SINR	$\gamma_{DL,ave}$	8.2	dB
Bitrate per resource block	$R_{RB,DL}$	342	kbps
Average user bitrate per cell	$R_{ave,DL}$	34.2	Mbps
Cell throughput	$T_{cell,DL}$	18.8	Mbps

The input requirements are satisfied. The PDSCH load was selected at a reasonable value. With the input requirements given in this example, PDSCH load can be selected within a wide range while still satisfying the requirements.

9.5 Downlink Throughput Using Ring Method

The maximum path loss from the uplink is used in this example as an input and obtained from the calculation for uplink coverage in Section 9.3 on page 50.

The following table provides the factors used to adjust input to the dimensioning process and the calculation according to Equation 31 and Equation 44:

Table 16 Adjusting Input

Used Inputs			
Max uplink air path loss	L_{pmax}	125.5	dB
Equivalent tilt	θ_{eq}	5°	
PDSCH load	Q_{PDSCH}	55%	
Interference due to control channels	ρ_{CCH}	11.8%	
Calculation of $L_{sa,max}$ and cell range d_{max}			
Max uplink air path loss	L_{pmax}	125.5	dB
Body loss	L_{BL}	3	dB
Building penetration loss	L_{BPL}	18	dB

Used Inputs			
Car penetration loss	L_{CPL}	0	dB
Antenna gain	G_a	18.5	dBi
Jumper and TMA insertion loss	L_J	0	dB
Signal attenuation at cell edge	$L_{sa,celledge}$	128.0	dB
Range	d_{max}	469	m

F_i is obtained by interpolating between the columns for 2° and 3° in Section 12 on page 73.

The following table provides the bitrate per resource block and ring using the calculation in Equation 43 and Equation 45 using the input in Table 16:

Table 17 Bitrate per Resource Block and Ring Example

d_i/d_{max}	Area or Proportion of Users $p_{user,i}$	$L_{sa,i}$ [dB]	F_i	SINR γ_i [dB]	$R_{RB,i}$ [kbps]
1%	0.01%	58.00	0	82.91	1442
2%	0.03%	68.54	0	72.31	1442
3%	0.05%	74.70	0	66.11	1442
4%	0.07%	79.07	0	61.71	1442
5%	0.09%	82.46	0	58.29	1442
6%	0.11%	85.24	0	55.50	1442
7%	0.13%	87.58	0	53.14	1442
8%	0.15%	89.61	0	51.10	1442
9%	0.17%	91.40	0	49.30	1442
10%	0.19%	93.00	0	47.69	1441
. .					
91%	1.81%	126.57	1.070	1.64	150
92%	1.83%	126.73	1.158	1.30	150
93%	1.85%	126.90	1.223	1.08	150
94%	1.87%	127.06	1.341	0.99	128
95%	1.89%	127.22	1.445	0.35	128
96%	1.91%	127.38	1.645	-0.19	110
97%	1.93%	127.54	1.796	-0.56	110

Table 17 Bitrate per Resource Block and Ring Example

d_i/d_{max}	Area or Proportion of Users $p_{user,i}$	$L_{sa,i}$ [dB]	F_i	SINRγ_i [dB]	$R_{RB,i}$ [kbps]
98%	1.95%	127.69	1.955	-0.92	110
99%	1.97%	127.85	2.504	-1.94	91
100%	1.99%	128.00	3.330	-3.15	63

With Table 17 calculation of cell capacity according to the equations in Section 7.1.4 on page 43 can be performed. The result is presented in the table below:

Table 18 Cell Capacity Calculation Example

Output			
Average bitrate per resource block	R_{RB}	375.5	kbps
Average user bitrate	$R_{ave,DL}$	37.5	Mbps
Cell throughput	$T_{cell,DL}$	20.6	Mbps

10 Relationship of Bitrate to SINR

The relationship between bitrate per resource block, R_{RB}, and SINR, γ, has been determined by a set of link simulations. The bitrate is referring to the Medium Access Control (MAC) layer including the MAC headers.

The downlink cases simulated include the following:

- Transmission modes: TM1, TM3, TM4 and TM9.
- Modulation schemes: QPSK, 16-QAM, 64-QAM and 256-QAM
- Channel models: EPA 5 Hz, EVA 70 Hz, ETU 300 Hz
- Number of antennas (TX x RX): 1 x 2, 2 x 2, 4 x 2, 4 x 4 and 8 x 2
- Number of CRS antenna ports are 1 (for TM 1x2), 2 (for TM3 2x2, TM4 2x2, TM9 2x2, TM9 8x2), and 4 (for TM3 4x2, TM3 4x4, TM4 4x2, TM4 4x4, TM9 4x2)
- Bandwidth: 1.4 MHz and 10 MHz (representing all bandwidths except 1.4 MHz by scaling)

The uplink cases simulated include the following:

- Antenna techniques: 2-branch RX diversity
- Modulation schemes: 16-QAM, 64-QAM
- Channel models: EPA 5 Hz, EVA 70 Hz, ETU 300 Hz
- Bandwidth: 1.4 MHz and 10 MHz (representing all bandwidths except 1.4 MHz by scaling)

TM 7 is described and prepared for in this section, but the actual link simulations are not included.

Two different methods are used to map calculated SINR to bitrate per resource block.

For downlink the relationship between bitrate per resource block and SINR is plotted in graphs. The graphs are then used to map calculated SINR to bitrate per resource block. All downlink simulation curves are given with the assumption that all downlink REs in the given bandwidth are used for PDSCH. The throughput given by these curves is then reduced by the total control channel overhead valid per configuration.

For uplink the relationship between bitrate and SINR has been modelled with parameterized link curves, where coefficients are used to curve-fit simulated values. The link curve coefficients can be modified to extend the use to all antenna configurations. Estimates of these modifications are presented. For capacity calculations, they have to be complemented with correction factors to capture correctly and in a simple way the difference between the link curves of the different antenna configuration cases. The link curve coefficient modifications as well as the correction factors have also been determined by simulations.

10.1 Downlink Link Performance

10.1.1 Simulation Parameters

In this section link simulation curves, stating throughput per RB, are given.

All downlink simulation curves are given with the assumption that all downlink REs in the given bandwidth are used for PDSCH. Therefore, the throughput given by these curves needs to be adjusted depending on control channel overhead. The adjustment is described in the formula:

$$R_{RB} = R_{RB,sim}\,[1-\Delta]$$

Equation 50 Adjustment of Throughput per RB Due to Control Channel Configuration

where

$$1-\Delta = [1-\frac{n_{PDCCH}}{14}-\frac{n_{CRS}+n_{UERS}+\frac{n_{CSIRS}}{20}}{168}- -\frac{n_{PBCH}+n_{PSS/SSS}+n_{BF,loss}}{n_{RB}1680}]$$

$$n_{BF,loss}=\begin{cases}2n_{lim,RB}\,(168-12n_{pdcch}-n_{CRS}-n_{UERS}) & ;if\ TM9\\ 0 & ;otherwise\end{cases}$$

Equation 51 Calculation of Control Channel Adjustment Factor

To explain the equation above, it is split into three terms, handling different aspects. The first term accounts for the share of REs allocated to PDCCH, i.e. the PDCCH overhead. The dimension is subframe.

Term number two considers the overhead due to the cell-specific Reference Signals and the UE-specific Reference Signals plus the CSI Reference Signals applicable to TM9. The dimension is PRB, considering the periodicity of CSI Reference Signals. The third term, excluding beamforming loss $n_{BF,loss}$, accounts for the REs allocated to PBCH and PSS/SSS. The dimension is a radioframe times the whole bandwidth.

The complementary $n_{BF,loss}$ differs from zero, when TM9 is chosen. It accounts for REs where PDSCH is not sent at all due to conflicts between UE-specific Reference Signals and PBCH, and also conflicts between

UE-specific Reference Signals and PSS/SSS in case of TM9. The latter terms in $n_{BF,loss}$ make sure that no REs previously removed in terms one or two are removed twice.

$R_{RB,sim}$ is the simulated throughput per RB without control channel overhead. This value is found in the simulation graphs.

n_{PDCCH} is the number of allocated symbols for PDCCH, 1 to 3 for bandwidths larger than 1.4 MHz and 2 to 4 for 1.4 MHz

n_{CRS} is the number of cell-specific Reference Signals multiplexed with PDSCH per RB. This value depends on the number of PDCCH symbols per RB, and number of configured antenna ports $n_{ant,CRS}$. n_{CRS} is set according to

n_{UERS} is the number of UE-specific Reference Signals multiplexed with PDSCH per RB. n_{UERS} is 12 for TM9, and equals 0 for all other transmission modes

n_{CSIRS} is the number of CSI Reference Signals multiplexed with PDSCH per RB. n_{CSIRS} is 24 for TM9, and equals 0 for all other transmission modes

n_{PBCH} is the amount of PDSCH RE lost due to PBCH. n_{PBCH} is 0 for TM9, but dependent on $n_{ant,CRS}$ for all other transmission modes. n_{PBCH} equals 276, 264 and 240 when $n_{ant,CRS}$ equals 1, 2 and 4, respectively

$n_{PSS/SSS}$ is the amount of resources lost due to PSS and SSS. $n_{PSS/SSS}$ is 0 for TM9, and 288 for all other transmission modes

$n_{lim,RB}$ is the amount of RB not used for PDSCH. Depending on bandwidth, PRBs are sent in PRB groups of different size. The PRB group size varies in 3 steps from 2 to 4 PRBs. Some margin $n_{lim,RB}$ is needed to be certain that the PRB groups are not overlapping with the 72 mid subcarriers. $n_{lim,RB}$ is set according Table 21

Table 19 Number of Configured CRS Antenna Ports

Antenna Configuration	Transmission Mode	$n_{ant,CRS}$
1x2	TM1	1
2x2	TM3, TM4, TM9	2
4x2, 4x4	TM3, TM4, TM9	4
8x2	TM7, TM8, TM9	2

Table 20 Number of Cell Reference Signals Multiplexed with PDSCH per RB

Configuration	n_{CRS}
$n_{ant,CRS} = 1$	6
$n_{ant,CRS} = 2$	12
$n_{ant,CRS} = 4$ and $n_{PDCCH} = 1$	20
$n_{ant,CRS} = 4$ and $n_{PDCCH} > 1$	16

Table 21 Number of RB not Used for PDSCH

Bandwidth [MHz]	$n_{lim,RB}$
5	8
10	9
15, 20	12

Information on control channel dimensioning can be found in *Control Channel Dimensioning*.

10.1.2 Simulated curves for TM1, TM3 and TM4

Link simulations are provided in this section in the form of link curves for TM1, TM3 and TM4. The link curves show throughput per Resource Block vs. SINR for selected channel models and for 1.4 MHz or 10 MHz bandwidth. No control channel overhead is included in these curves.

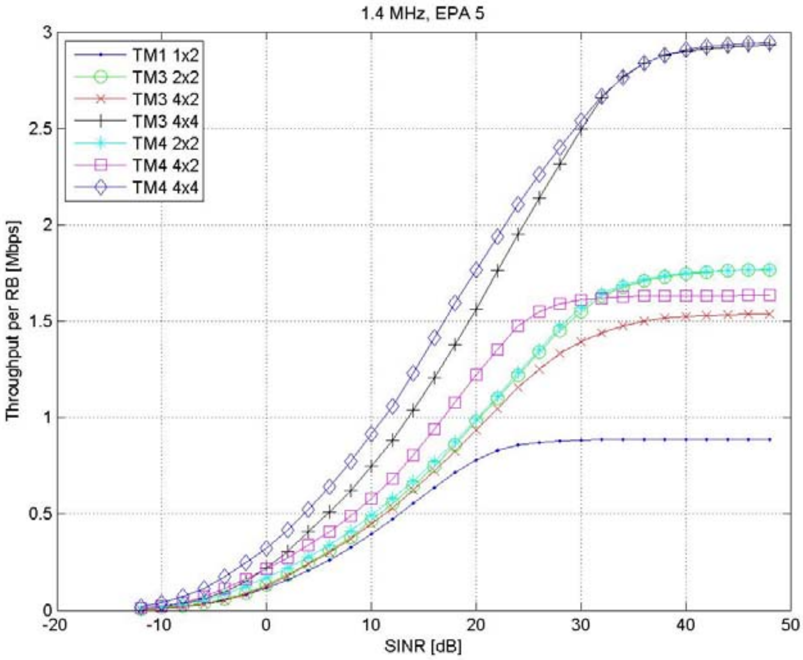

Figure 10 TM1, TM3 and TM4 throughput per Resource Block for EPA5 channel model, 1.4 MHz bandwidth.

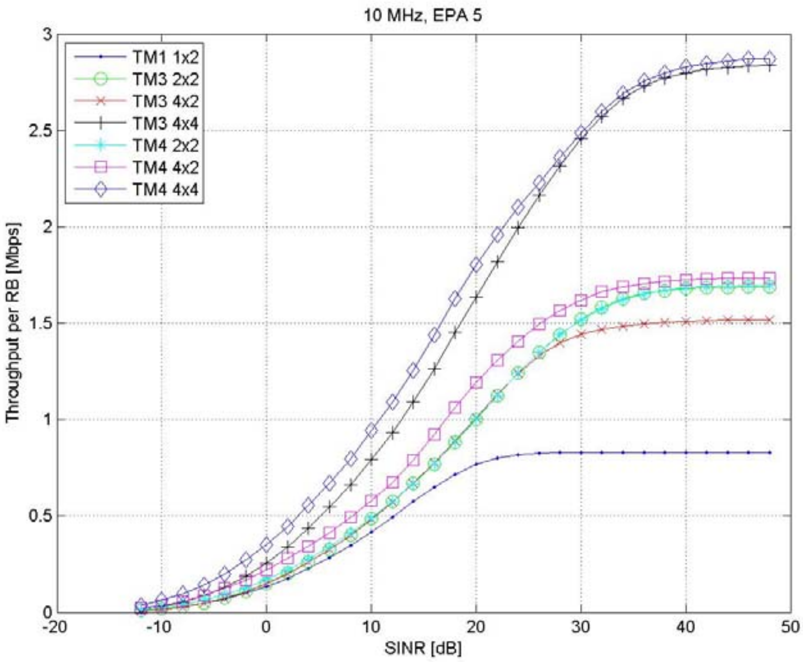

Figure 11 TM1, TM3 and TM4 throughput per Resource Block for EPA5 channel model, 10 MHz bandwidth.

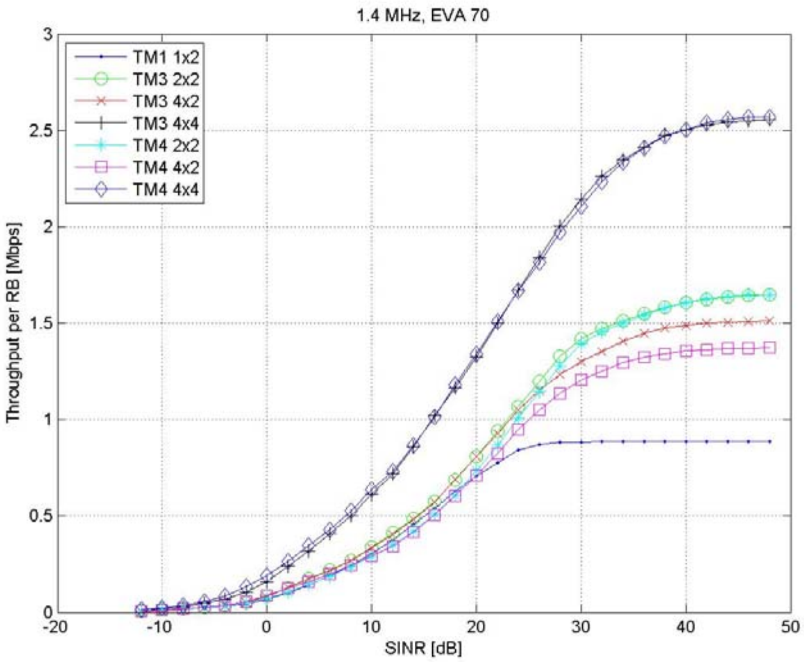

Figure 12 TM1, TM3 and TM4 throughput per Resource Block for EVA70 channel model, 1.4 MHz bandwidth.

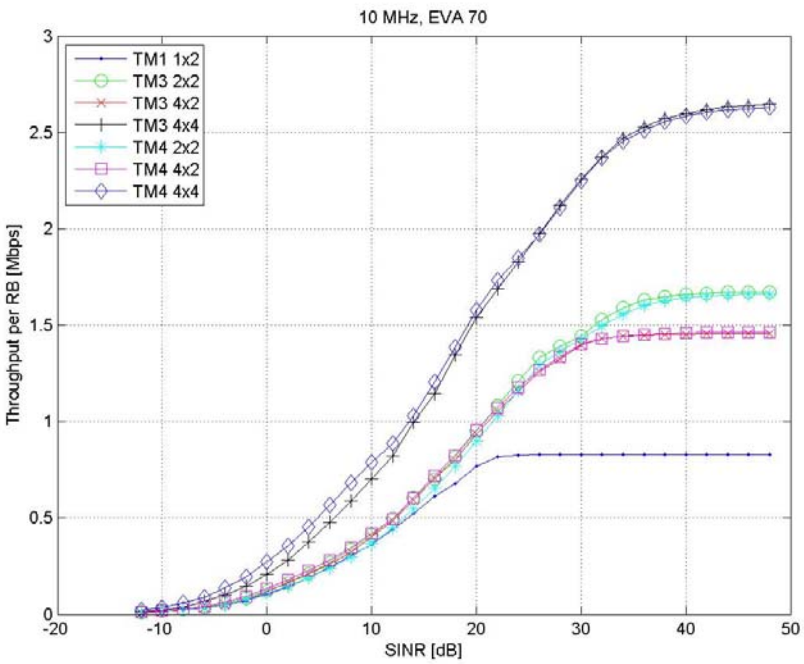

Figure 13 TM1, TM3 and TM4 throughput per Resource Block for EVA70 channel model, 10 MHz bandwidth.

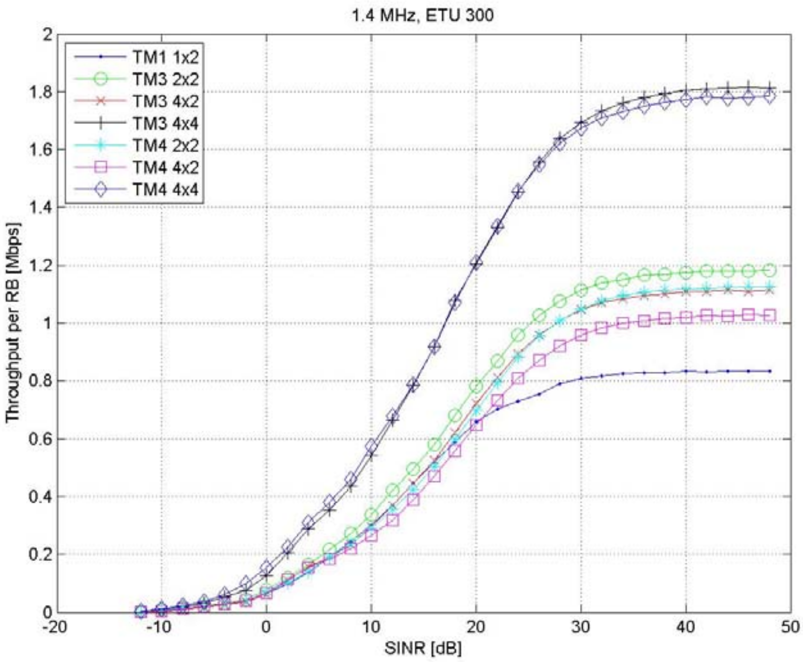

Figure 14 TM1, TM3 and TM4 throughput per Resource Block for ETU300 channel model, 1.4 MHz bandwidth.

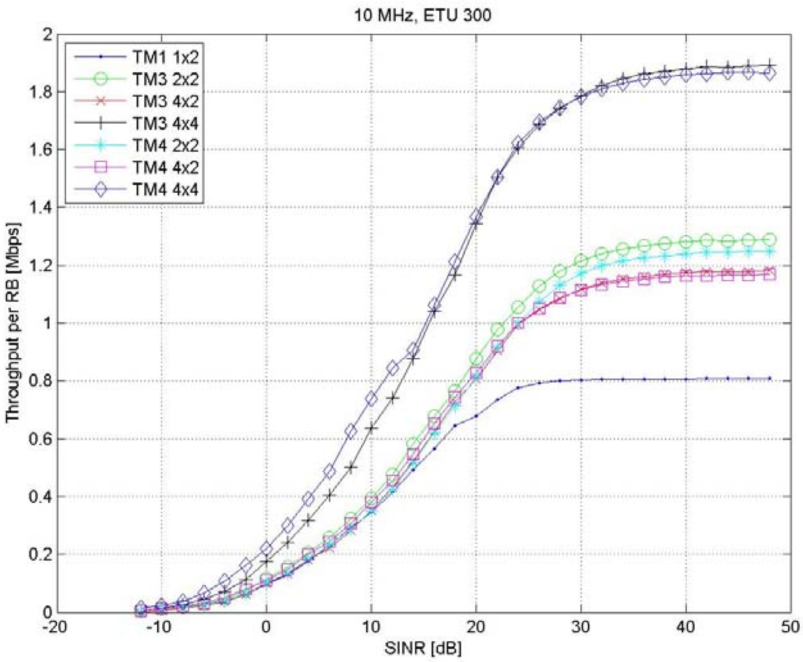

Figure 15 TM1, TM3 and TM4 throughput per Resource Block for ETU300 channel model, 10 MHz bandwidth.

10.1.3 Simulated curves for TM9

Link simulations are provided in this section in the form of link curves for TM9. Link curves for TM3 and TM4 are included as reference. The link curves show throughput per Resource Block vs. SINR for selected channel models and for 1.4 MHz or 10 MHz bandwidth. No control channel overhead is included in these curves.

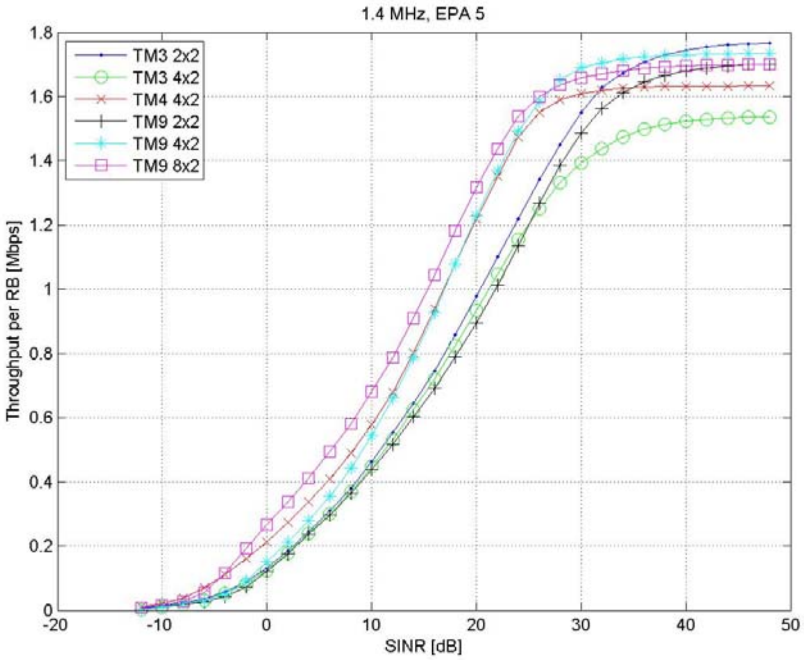

Figure 16 TM3, TM4 and TM9 throughput per Resource Block for EPA5 channel model, 1.4 MHz bandwidth.

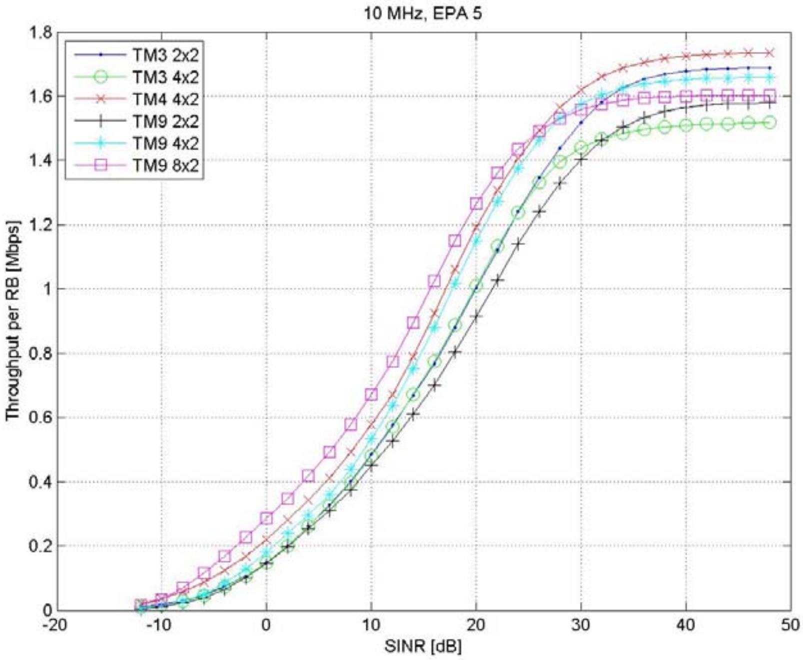

Figure 17 TM3, TM4 and TM9 throughput per Resource Block for EPA5 channel model, 10 MHz bandwidth.

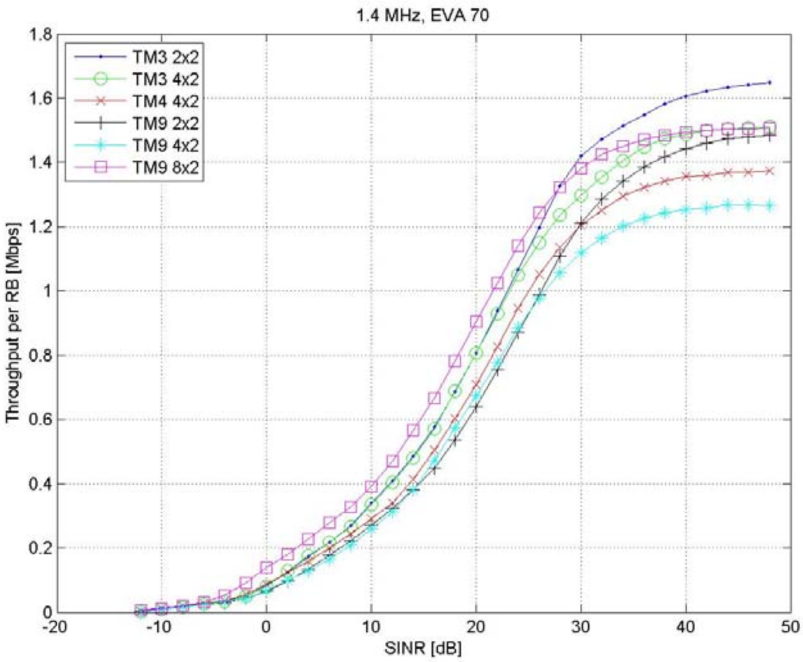

Figure 18 TM3, TM4 and TM9 throughput per Resource Block for EVA70 channel model, 1.4 MHz bandwidth.

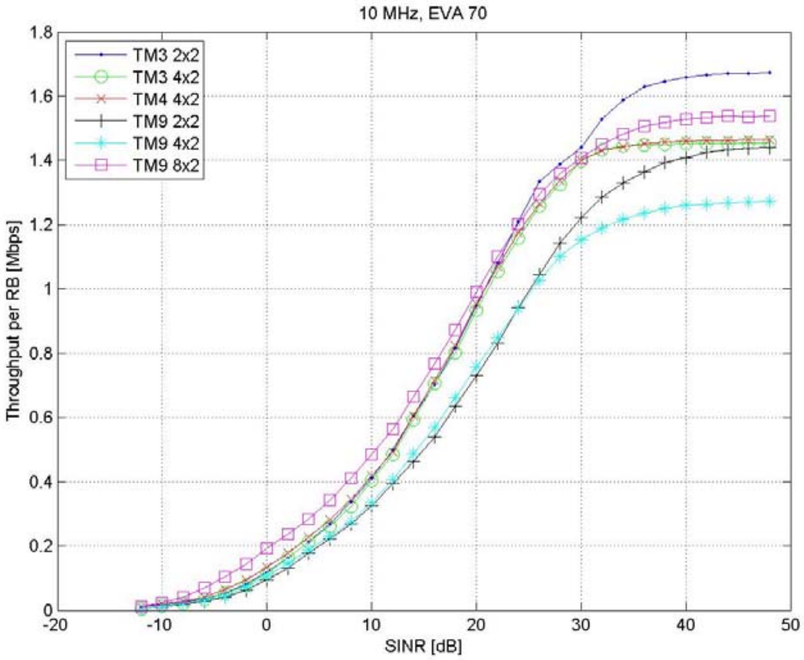

Figure 19 TM3, TM4 and TM9 throughput per Resource Block for EVA70 channel model, 10 MHz bandwidth.

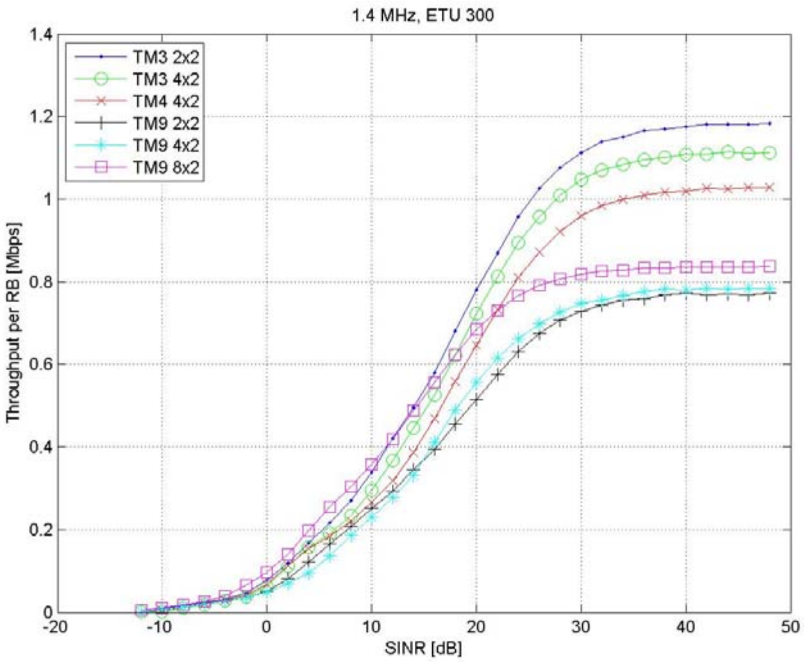

Figure 20 TM3, TM4 and TM9 throughput per Resource Block for ETU300 channel model, 1.4 MHz bandwidth.

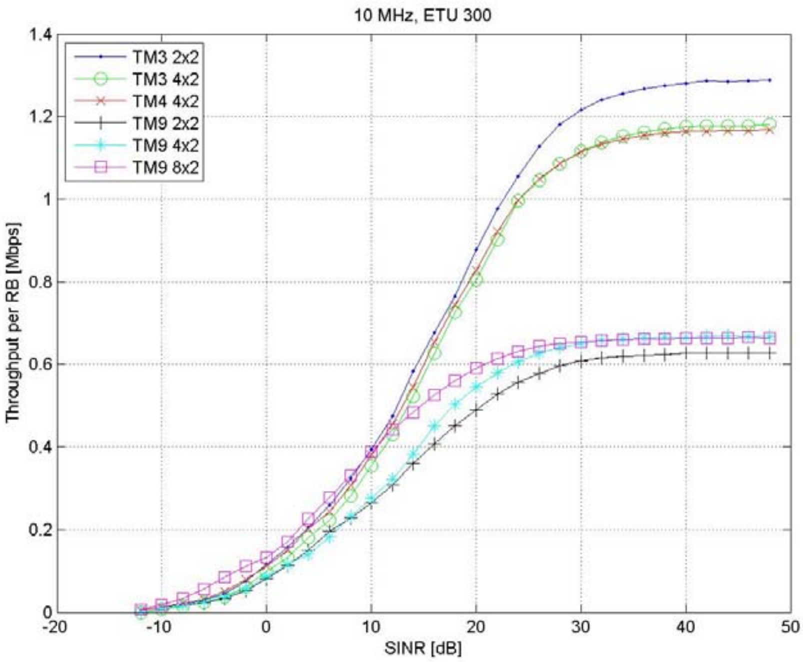

Figure 21 TM3, TM4 and TM9 throughput per Resource Block for ETU300 channel model, 10 MHz bandwidth.

10.1.4 Simulated curves for 256QAM

Link simulations are provided in this section in the form of link curves for 256QAM modulation, and only for EPA5. The link curves show throughput per Resource Block vs. SINR for selected channel models, transmission modes and for 10 MHz bandwidth. Link curves for 64QAM are included as reference. No control channel overhead is included in these curves.

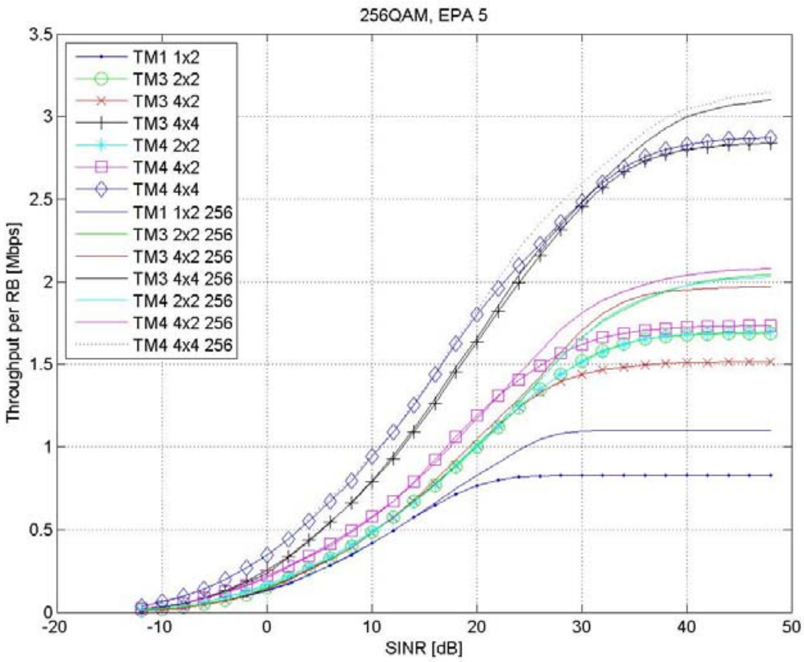

Figure 22 Throughput per Resource Block for 256QAM, EPA5 channel model and 10 MHz bandwidth.

10.2 Uplink Link Performance

10.2.1 Link Performance Model

The results, including an implementation margin, have been fitted to a semi-empirical parameterized expression as in the following equation:

$$R_{RB} = max\left[0, a_3 + (a_0 - a_3)\, e^{-\ln(2)[(\gamma - a_1)/a_2]^{a_4}}\right]; \quad \gamma < a_1$$
$$R_{RB} = a_0; \quad \gamma \geq a_1$$

Equation 52 Bitrate Calculation

The inverse relationship, between γ and R_{RB}, is as in the following equation:

$$\gamma = a_1 - a_2\left[\ln\left(\frac{a_0 - a_3}{R_{RB} - a_3}\right)/\ln 2\right]^{1/a_4} \quad ; \quad 0 \leq R_{RB} \leq a_0 \quad [\mathrm{dB}]$$

Equation 53 SINR Calculation

a_0, a_1, a_2, a_3 and a_4 are fitted coefficients and the SINR γ is expressed in dB. The semi-empirical coefficientsa_0 represents the maximum obtainable bitrate in one resource block.

For FDD configurations all bandwidths are relevant in the following sections, whereas only the bandwidths wider than 1.4 MHz are relevant for TDD configurations.

10.2.2 Link Curves

The basic set of semi-empirical coefficients for 1x2 uplink is given in Table 22.

Table 22 Semi-Empirical Link Curve Coefficients for Uplink

Max modulation	Bandwidth	Channel model/ Doppler frequency	a_0 [kbps]	a_1 [dB]	a_2 [dB]	a_3 [kbps]	a_4
16 qam	1.4 MHz	EPA 5	529.2	35.3	28.2	0	4
		EVA 70	528.6	23.8	12.5	0	2
		ETU 300	379.0	21.5	12.2	0	2
	All bandwidths except 1.4 MHz	EPA 5	519.7	37.0	29.7	0	4
		EVA 70	519.7	37.4	27.8	0	4
		ETU 300	388.3	32.2	24.7	0	4
64 qam	1.4 MHz	EPA 5	717.4	43.4	33.2	0	4
		EVA 70	711.2	28.8	14.5	0	2
		ETU 300	394.6	22.1	12.4	0	2
	All bandwidths except 1.4 MHz	EPA 5	719.2	45.9	35.2	0	4
		EVA 70	718.2	47.8	34.5	0	4
		ETU 300	400.7	33.0	25.2	0	4

The basic set of semi-empirical coefficients for 1x4 uplink is given in Table 23.

Table 23 Semi-Empirical Link Curve Coefficients for Uplink

Max modulation	Bandwidth	Channel model/ Doppler frequency	a_0 [kbps]	a_1 [dB]	a_2 [dB]	a_3 [kbps]	a_4
16 qam	1.4 MHz	EPA 5	529.2	28.7	25,5	0	4
		EVA 70	529.2	17.4	11.4	0	2
		ETU 300	500.9	17.5	11.4	0	2
	All bandwidths except 1.4 MHz	EPA 5	519.7	30.1	27.0	0	4
		EVA 70	519.7	29.6	25.0	0	4
		ETU 300	511.0	29.1	24.3	0	4

Table 23 Semi-Empirical Link Curve Coefficients for Uplink

Max modulation	Bandwidth	Channel model/ Doppler frequency	a_0 [kbps]	a_1 [dB]	a_2 [dB]	a_3 [kbps]	a_4
64 qam	1.4 MHz	EPA 5	717.3	37.4	31.1	0	4
		EVA 70	711.3	39.6	30.7	0	4
		ETU 300	580.6	35.4	28.0	0	4
	All bandwidths except 1.4 MHz	EPA 5	719.2	39.1	32.6	0	4
		EVA 70	719.2	39.2	31.2	0	4
		ETU 300	580.8	33.1	27.0	0	4

The basic set of semi-empirical coefficients for 1x8 uplink is given in Table 24.

Table 24 Semi-Empirical Link Curve Coefficients for Uplink

Max modulation	Bandwidth	Channel model/ Doppler frequency	a_0 [kbps]	a_1 [dB]	a_2 [dB]	a_3 [kbps]	a_4
16 qam	1.4 MHz	EPA 5	529.2	23.1	23.4	0	4
		EVA 70	529.2	25.5	23.7	0	4
		ETU 300	529.1	25.3	23.1	0	4
	All bandwidths except 1.4 MHz	EPA 5	519.7	24.3	24.9	0	4
		EVA 70	519.7	23.9	23.2	0	4
		ETU 300	519.7	23.6	22.5	0	4
64 qam	1.4 MHz	EPA 5	717.3	31.4	28.8	0	4
		EVA 70	717.3	33.4	28.8	0	4
		ETU 300	706.0	33.9	28.9	0	4
	All bandwidths except 1.4 MHz	EPA 5	719.2	33.5	30.7	0	4
		EVA 70	719.2	33.1	29.2	0	4
		ETU 300	717.5	33.2	28.8	0	4

11 Wave Propagation

This section describes wave propagation characteristics.

The distance in kilometers d can be calculated as in the following equation:

$$d = 10^{\alpha}$$

Equation 54 Calculation of Distance in Kilometers

where:

$$\alpha = \frac{L_p - A + 13.82\log h_b + a\left(h_m\right)}{44.9 - 6.55\log h_b}$$

Equation 55 Exponent for Calculation Distance

where

$\boldsymbol{L_p}$ is the air path loss

$\boldsymbol{A}$ is the frequency-dependent fixed attenuation value, see Table 25,

$\boldsymbol{h_b}$ is the base station height [m]

$\boldsymbol{h_m}$ is the height of the UE antenna [m]

$a\left(h_m\right)$ [dB] is a correction factor for the vehicular antenna height h_m (*a* is fixed at 0 dB for h_m = 1.5 m). It is calculated by:

$$a\left(h_m\right) = 3.2\left[\log\left(11.75\, h_m\right)\right]^2 - 4.97$$

Equation 56 Correction Factor for Mobile Antenna Height

The inverse relationship to Equation 55 is written as follows:

$$L_p = A - 13.82\log h_b - a\left(h_m\right) + \left(44.9 - 6.55\log h_b\right)\log R$$

Equation 57 Ericsson Variant Okumura-Hata Model

The following table shows the attenuation value A as a function of frequency and environment:

Table 25 Fixed Attenuation A in Okumura-Hata Propagation Model

Environment	**Frequency [MHz]**									
	700	**800**	**850**	**900**	**1700**	**1800**	**1900**	**2100**	**2300**	**2600**
Urban	144.3	145.6	146.2	146.8	153.2	153.8	154.3	155.1	156.3	157.5
Suburban	133.5	135.3	136.1	136.9	145.4	146.2	146.9	147.9	149.5	151.1

Table 25 Fixed Attenuation A in Okumura-Hata Propagation Model

Environment	Frequency [MHz]									
	700	800	850	900	1700	1800	1900	2100	2300	2600
Rural	125.1	126.4	127.0	127.5	133.6	134.1	134.6	135.3	136.4	137.6
Open	116.1	117.3	117.8	118.3	123.8	124.3	124.8	125.4	126.4	127.5

Additional information can be found in *Radio Wave Propagation Guideline*.

12 F Table

The following table provides F values for a cell range of 1000 m and antenna heights of 30 m. For other cell ranges or antenna heights, the F values below can be used after modifying the tilt by using Equation 44.

Table 26 F values for Cell Range

d_i/d_{max}	A_i/A_{max}	Antenna Down-Tilt Angle								
		0°	**1°**	**2°**	**3°**	**4°**	***5°***	**6°**	**7°**	**8°**
0%	0%	0.000	0.000	0.000	0.000	0.000	***0.000***	0.000	0.000	0.000
1%	0.01%	0.000	0.000	0.000	0.000	0.000	***0.000***	0.000	0.000	0.000
2%	0.03%	0.000	0.000	0.000	0.000	0.000	***0.000***	0.000	0.000	0.000
3%	0.05%	0.000	0.000	0.000	0.000	0.000	***0.000***	0.000	0.000	0.000
4%	0.07%	0.000	0.001	0.001	0.001	0.000	***0.000***	0.000	0.000	0.000
5%	0.09%	0.002	0.003	0.002	0.001	0.000	***0.000***	0.000	0.000	0.000
6%	0.11%	0.004	0.004	0.003	0.002	0.001	***0.000***	0.000	0.000	0.000
7%	0.13%	0.006	0.005	0.004	0.002	0.001	***0.000***	0.000	0.000	0.000
8%	0.15%	0.010	0.008	0.005	0.002	0.001	***0.000***	0.000	0.000	0.000
9%	0.17%	0.011	0.009	0.007	0.003	0.001	***0.000***	0.000	0.000	0.000
10%	0.19%	0.012	0.011	0.008	0.003	0.001	***0.000***	0.000	0.000	0.000
11%	0.21%	0.017	0.013	0.009	0.004	0.001	***0.000***	0.000	0.000	0.000
12%	0.23%	0.021	0.016	0.010	0.006	0.002	***0.001***	0.000	0.000	0.000
13%	0.25%	0.022	0.018	0.011	0.008	0.003	***0.001***	0.000	0.000	0.000
14%	0.27%	0.026	0.020	0.013	0.008	0.004	***0.002***	0.000	0.000	0.000
15%	0.29%	0.029	0.022	0.014	0.010	0.006	***0.003***	0.001	0.000	0.000
16%	0.31%	0.034	0.024	0.015	0.010	0.006	***0.003***	0.001	0.000	0.000
17%	0.33%	0.037	0.026	0.016	0.011	0.006	***0.004***	0.001	0.000	0.000
18%	0.35%	0.042	0.029	0.018	0.013	0.007	***0.004***	0.001	0.000	0.000
19%	0.37%	0.047	0.038	0.021	0.014	0.008	***0.004***	0.002	0.000	0.000
20%	0.39%	0.056	0.043	0.025	0.015	0.008	***0.005***	0.002	0.000	0.000
21%	0.41%	0.058	0.045	0.031	0.016	0.010	***0.005***	0.002	0.001	0.000
22%	0.43%	0.060	0.045	0.034	0.017	0.013	***0.005***	0.003	0.001	0.000
23%	0.45%	0.063	0.049	0.035	0.023	0.015	***0.007***	0.003	0.001	0.000
24%	0.47%	0.068	0.058	0.038	0.026	0.015	***0.007***	0.003	0.001	0.000

Table 26 F values for Cell Range

d_i/d_{max}	A_i/A_{max}	Antenna Down-Tilt Angle								
		0°	1°	2°	3°	4°	*5°*	6°	7°	8°
25%	0.49%	0.079	0.064	0.040	0.027	0.017	***0.008***	0.004	0.001	0.000
26%	0.51%	0.090	0.066	0.046	0.029	0.019	***0.009***	0.004	0.002	0.001
27%	0.53%	0.097	0.075	0.052	0.033	0.020	***0.010***	0.005	0.002	0.001
28%	0.55%	0.107	0.083	0.055	0.037	0.022	***0.012***	0.006	0.003	0.001
29%	0.57%	0.116	0.087	0.059	0.039	0.025	***0.014***	0.007	0.003	0.001
30%	0.59%	0.128	0.097	0.063	0.040	0.028	***0.015***	0.008	0.004	0.002
31%	0.61%	0.146	0.102	0.068	0.045	0.030	***0.017***	0.009	0.004	0.002
32%	0.63%	0.159	0.110	0.072	0.049	0.032	***0.020***	0.011	0.005	0.003
33%	0.65%	0.170	0.117	0.083	0.055	0.035	***0.021***	0.012	0.006	0.003
34%	0.67%	0.174	0.127	0.090	0.058	0.039	***0.024***	0.014	0.007	0.004
35%	0.69%	0.179	0.134	0.097	0.065	0.043	***0.027***	0.016	0.009	0.004
36%	0.71%	0.194	0.146	0.105	0.072	0.047	***0.029***	0.018	0.010	0.006
37%	0.73%	0.212	0.161	0.113	0.077	0.054	***0.033***	0.021	0.012	0.007
38%	0.75%	0.221	0.170	0.117	0.087	0.057	***0.036***	0.023	0.013	0.008
39%	0.77%	0.236	0.181	0.127	0.093	0.061	***0.041***	0.025	0.016	0.011
40%	0.79%	0.243	0.187	0.139	0.097	0.068	***0.044***	0.029	0.019	0.013
41%	0.81%	0.262	0.198	0.148	0.103	0.071	***0.047***	0.033	0.021	0.014
42%	0.83%	0.277	0.208	0.155	0.106	0.077	***0.052***	0.036	0.023	0.017
43%	0.85%	0.285	0.219	0.163	0.114	0.083	***0.058***	0.040	0.026	0.019
44%	0.87%	0.300	0.231	0.166	0.122	0.090	***0.062***	0.044	0.030	0.021
45%	0.89%	0.310	0.241	0.175	0.132	0.098	***0.070***	0.047	0.032	0.024
46%	0.91%	0.320	0.249	0.186	0.139	0.104	***0.074***	0.050	0.034	0.025
47%	0.93%	0.337	0.259	0.193	0.146	0.109	***0.075***	0.054	0.036	0.027
48%	0.95%	0.353	0.269	0.201	0.153	0.117	***0.084***	0.058	0.039	0.030
49%	0.97%	0.363	0.280	0.217	0.159	0.124	***0.088***	0.062	0.042	0.032
50%	0.99%	0.371	0.290	0.231	0.168	0.130	***0.097***	0.068	0.044	0.037
51%	1.01%	0.378	0.311	0.241	0.175	0.137	***0.105***	0.070	0.048	0.039
52%	1.03%	0.397	0.324	0.251	0.186	0.145	***0.108***	0.075	0.054	0.041
53%	1.05%	0.411	0.332	0.261	0.197	0.153	***0.115***	0.079	0.057	0.045
54%	1.07%	0.432	0.343	0.275	0.210	0.160	***0.117***	0.082	0.062	0.048
55%	1.09%	0.451	0.359	0.287	0.218	0.172	***0.127***	0.090	0.067	0.053

Table 26 F values for Cell Range

d_i/d_{max}	A_i/A_{max}	Antenna Down-Tilt Angle								
		0°	**1°**	**2°**	**3°**	**4°**	***5°***	**6°**	**7°**	**8°**
56%	1.11%	0.462	0.370	0.298	0.230	0.186	***0.137***	0.095	0.074	0.061
57%	1.13%	0.478	0.379	0.309	0.242	0.195	***0.144***	0.100	0.078	0.065
58%	1.15%	0.499	0.389	0.318	0.255	0.204	***0.152***	0.113	0.083	0.072
59%	1.17%	0.525	0.406	0.334	0.270	0.211	***0.159***	0.119	0.091	0.077
60%	1.19%	0.538	0.421	0.342	0.287	0.223	***0.172***	0.129	0.100	0.084
61%	1.21%	0.553	0.435	0.354	0.294	0.238	***0.181***	0.136	0.107	0.092
62%	1.23%	0.581	0.460	0.369	0.308	0.249	***0.191***	0.145	0.166	0.100
63%	1.25%	0.606	0.488	0.387	0.319	0.259	***0.200***	0.156	0.125	0.111
64%	1.27%	0.642	0.503	0.405	0.330	0.276	***0.210***	0.160	0.134	0.118
65%	1.29%	0.667	0.528	0.431	0.346	0.291	***0.221***	0.174	0.144	0.124
66%	1.31%	0.688	0.553	0.453	0.360	0.304	***0.239***	0.181	0.153	0.133
67%	1.33%	0.714	0.581	0.485	0.383	0.318	***0.250***	0.200	0.163	0.148
68%	1.35%	0.745	0.621	0.518	0.406	0.344	***0.266***	0.221	0.180	0.158
69%	1.37%	0.774	0.652	0.538	0.436	0.369	***0.289***	0.231	0.195	0.167
70%	1.39%	0.802	0.670	0.580	0.470	0.402	***0.310***	0.251	0.209	0.183
71%	1.41%	0.841	0.688	0.614	0.504	0.431	***0.330***	0.266	0.225	0.197
72%	1.43%	0.886	0.729	0.631	0.538	0.466	***0.362***	0.281	0.237	0.216
73%	1.45%	0.913	0.772	0.673	0.567	0.486	***0.376***	0.309	0.257	0.236
74%	1.47%	0.941	0.796	0.700	0.598	0.508	***0.401***	0.334	0.275	0.255
75%	1.49%	0.987	0.830	0.739	0.633	0.531	***0.423***	0.354	0.298	0.272
76%	1.51%	1.041	0.875	0.770	0.660	0.569	***0.461***	0.379	0.325	0.295
77%	1.53%	1.096	0.902	0.808	0.691	0.596	***0.503***	0.411	0.343	0.317
78%	1.55%	1.131	0.940	0.833	0.725	0.633	***0.530***	0.448	0.378	0.342
79%	1.57%	1.152	0.976	0.871	0.753	0.662	***0.571***	0.481	0.414	0.382
80%	1.59%	1.191	1.029	0.907	0.777	0.695	***0.595***	0.507	0.446	0.416
81%	1.61%	1.244	1.067	0.941	0.830	0.738	***0.620***	0.530	0.472	0.441
82%	1.63%	1.288	1.105	0.988	0.867	0.766	***0.658***	0.567	0.508	0.468
83%	1.65%	1.339	1.155	1.027	0.917	0.819	***0.707***	0.600	0.542	0.509
84%	1.67%	1.398	1.204	1.073	0.963	0.861	***0.741***	0.641	0.574	0.533
85%	1.69%	1.445	1.280	1.123	1.009	0.905	***0.798***	0.689	0.616	0.566
86%	1.71%	1.486	1.331	1.172	1.062	0.962	***0.834***	0.733	0.664	0.602

Table 26 F values for Cell Range

d_i/d_{max}	A_i/A_{max}	Antenna Down-Tilt Angle								
		0°	1°	2°	3°	4°	*5°*	6°	7°	8°
87%	1.73%	1.539	1.376	1.212	1.110	1.004	***0.873***	0.782	0.696	0.642
88%	1.75%	1.598	1.428	1.257	1.159	1.049	***0.927***	0.833	0.747	0.680
89%	1.77%	1.680	1.485	1.348	1.214	1.095	***0.979***	0.874	0.782	0.735
90%	1.79%	1.779	1.556	1.433	1.292	1.135	***1.019***	0.920	0.827	0.788
91%	1.81%	1.843	1.614	1.507	1.353	1.201	***1.070***	0.994	0.884	0.830
92%	1.83%	1.897	1.732	1.603	1.454	1.269	***1.158***	1.036	0.954	0.862
93%	1.85%	2.016	1.842	1.678	1.543	1.359	***1.223***	1.088	1.001	0.925
94%	1.87%	2.155	1.976	1.832	1.675	1.518	***1.341***	1.203	1.083	1.004
95%	1.89%	2.327	2.131	2.022	1.858	1.706	***1.445***	1.312	1.132	1.082
96%	1.91%	2.501	2.302	2.222	2.086	1.903	***1.645***	1.404	1.237	1.185
97%	1.93%	2.711	2.548	2.422	2.244	2.031	***1.796***	1.561	1.399	1.321
98%	1.95%	2.884	2.764	2.684	2.499	2.240	***1.955***	1.771	1.575	1.507
99%	1.97%	3.360	3.258	3.128	2.909	2.798	***2.504***	2.210	1.973	1.860
100%	1.99%	4.080	4.000	3.790	3.520	3.630	***3.330***	2.870	2.570	2.390

13 Link Curves

In this section full link simulation curves, stating throughput versus SINR for all Resource Blocks, are given for 1.4 MHz and 10 MHz. This set of curves is not used in the dimensioning method, but are only provided to visualize link curves when control channel overhead is included.

13.1 Link simulations for TM1, TM3 and TM4

Link simulations are provided in this section in the form of link curves for TM1, TM3 and TM4. The link curves show throughput vs. SINR for selected channel models and for 1.4 MHz or 10 MHz bandwidth.

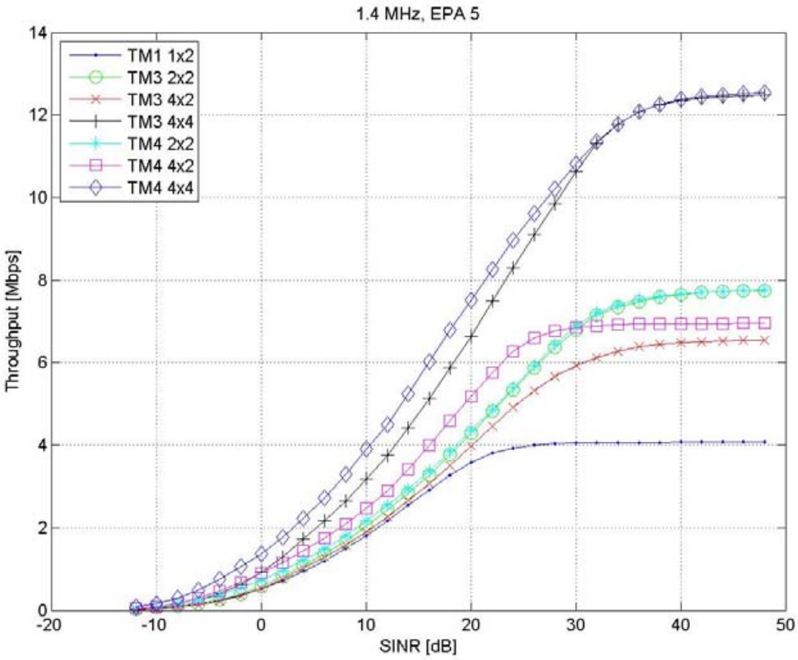

Figure 23 TM1, TM3 and TM4 throughput for EPA5 channel model, 1.4 MHz bandwidth.

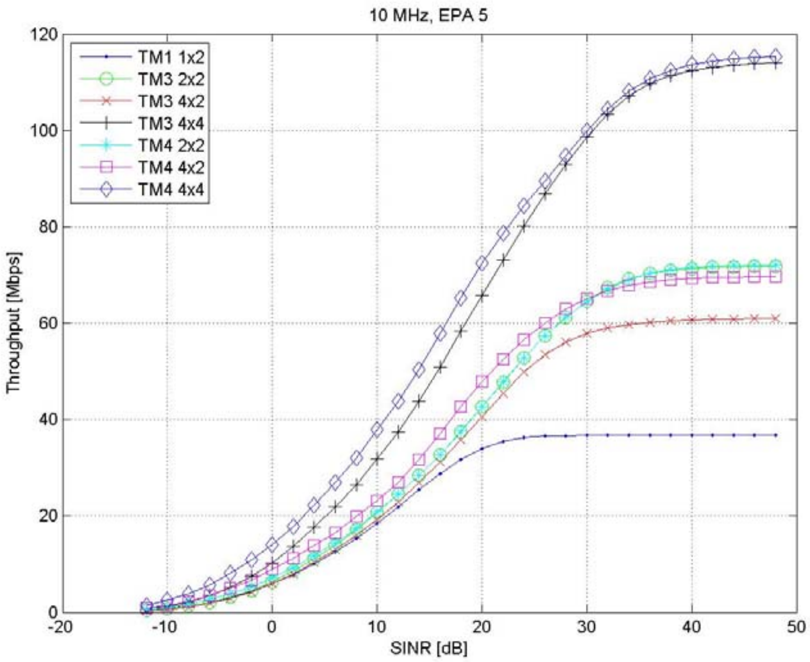

Figure 24 TM1, TM3 and TM4 throughput for EPA5 channel model, 10 MHz bandwidth.

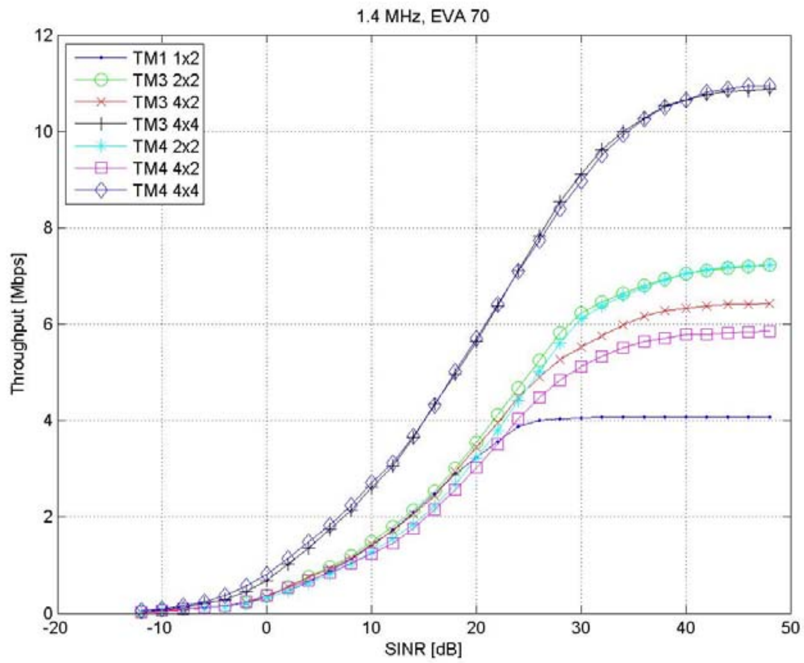

Figure 25 TM1, TM3 and TM4 throughput for EVA70 channel model, 1.4 MHz bandwidth.

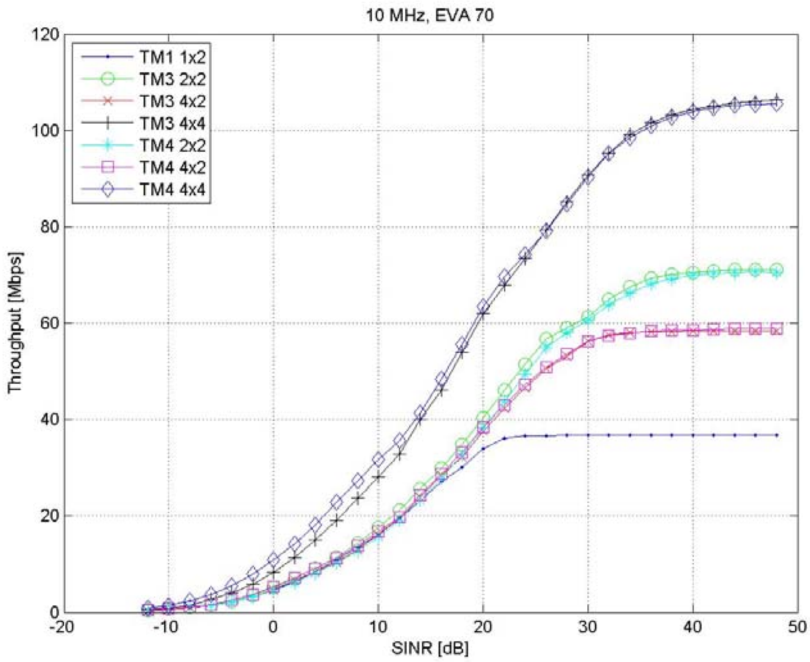

Figure 26 TM1, TM3 and TM4 throughput for EVA70 channel model, 10 MHz bandwidth.

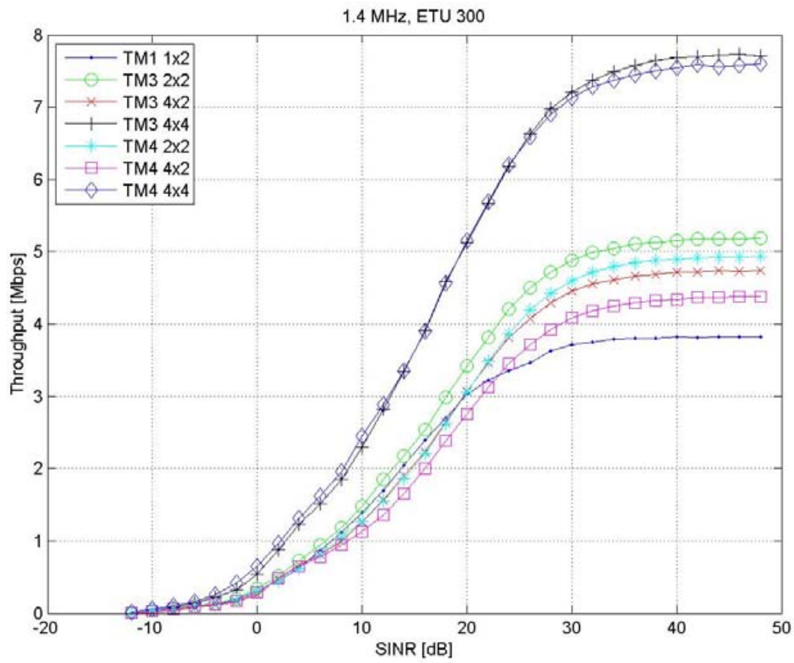

Figure 27 TM1, TM3 and TM4 throughput for ETU300 channel model, 1.4 MHz bandwidth.

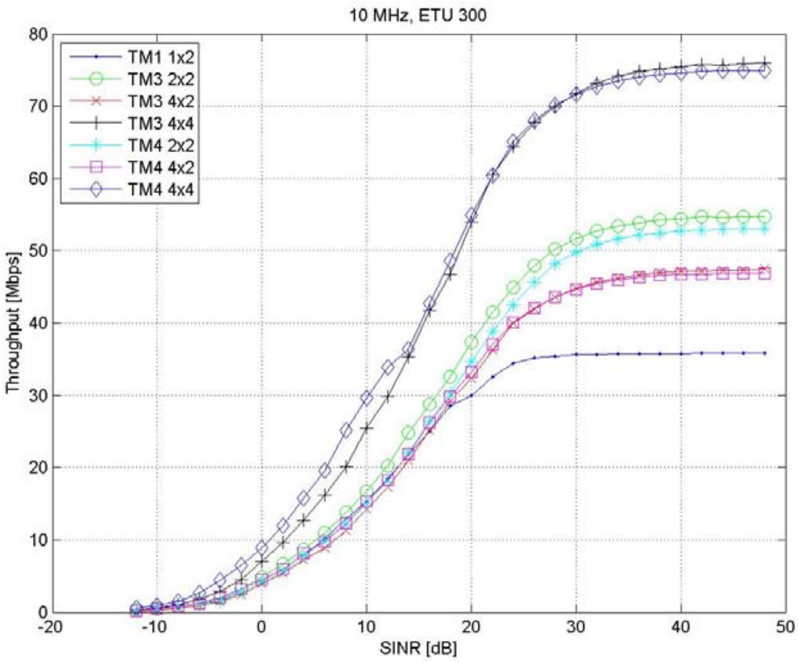

Figure 28 TM1, TM3 and TM4 throughput for ETU300 channel model, 10 MHz bandwidth.

13.2 Link simulations for TM9

Link simulations are provided in this section in the form of link curves for TM9. Link curves for TM3 and TM4 are included as reference. The link curves show throughput vs. SINR for selected channel models and for 1.4 MHz or 10 MHz bandwidth.

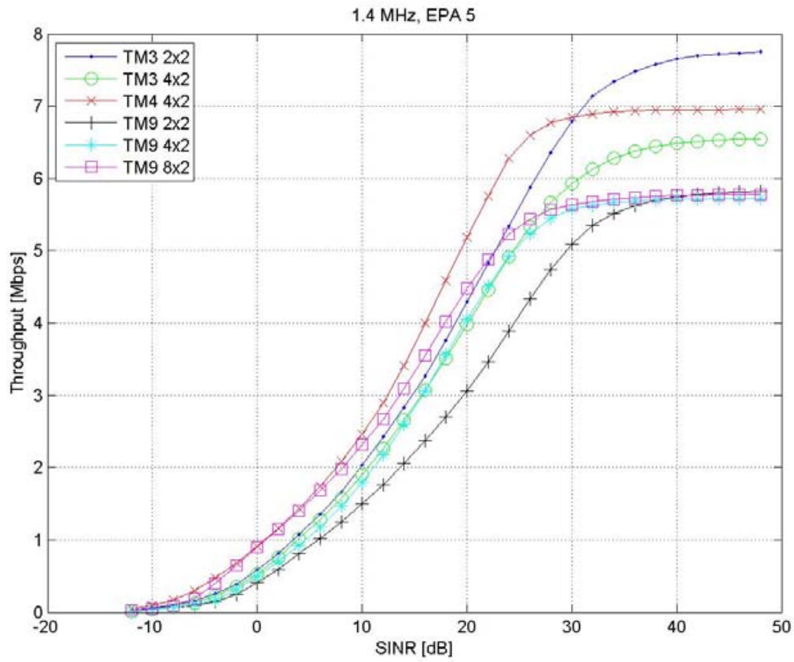

Figure 29 TM3, TM4 and TM9 throughput for EPA5 channel model, 1.4 MHz bandwidth.

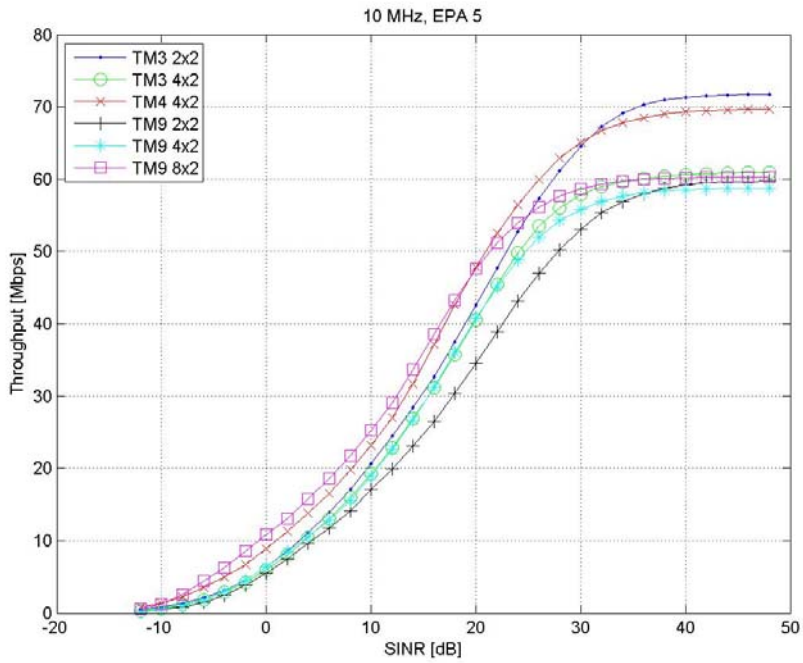

Figure 30 TM3, TM4 and TM9 throughput for EPA5 channel model, 10 MHz bandwidth.

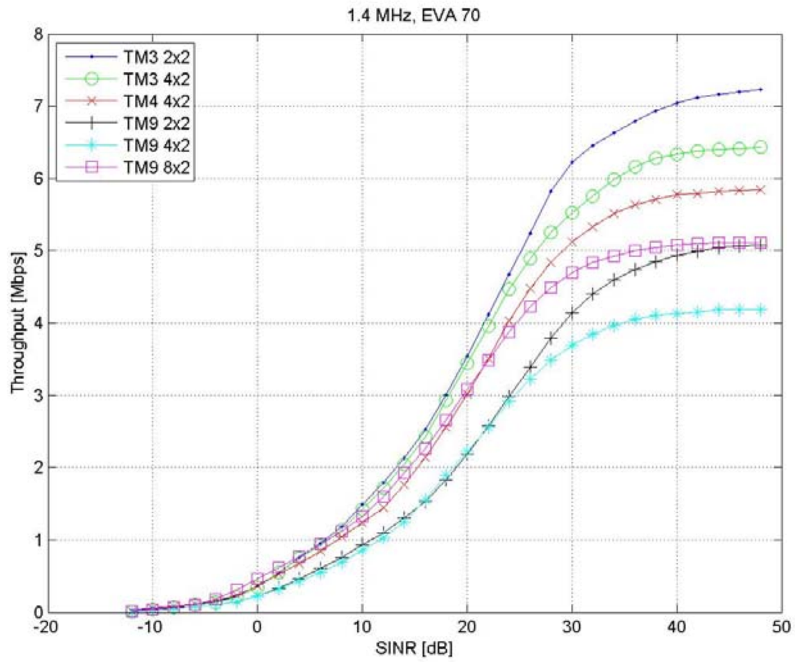

Figure 31 TM3, TM4 and TM9 throughput for EVA70 channel model, 1.4 MHz bandwidth.

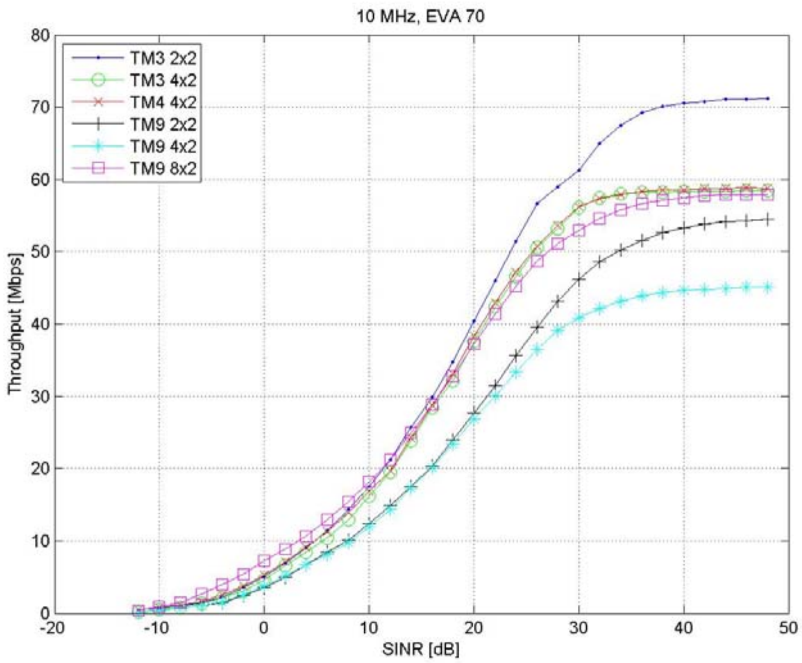

Figure 32 TM3, TM4 and TM9 throughput for EVA70 channel model, 10 MHz bandwidth.

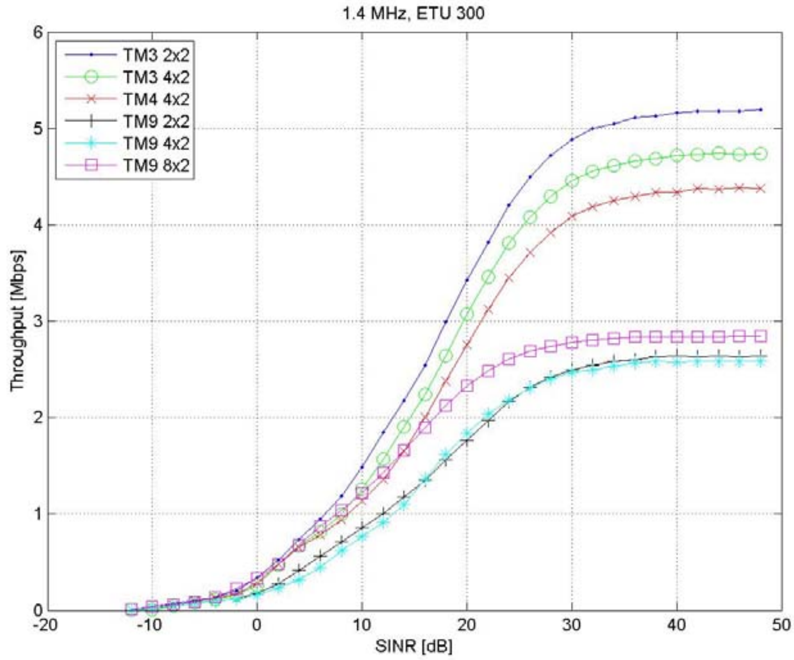

Figure 33 TM3, TM4 and TM9 throughput for ETU300 channel model, 1.4 MHz bandwidth.

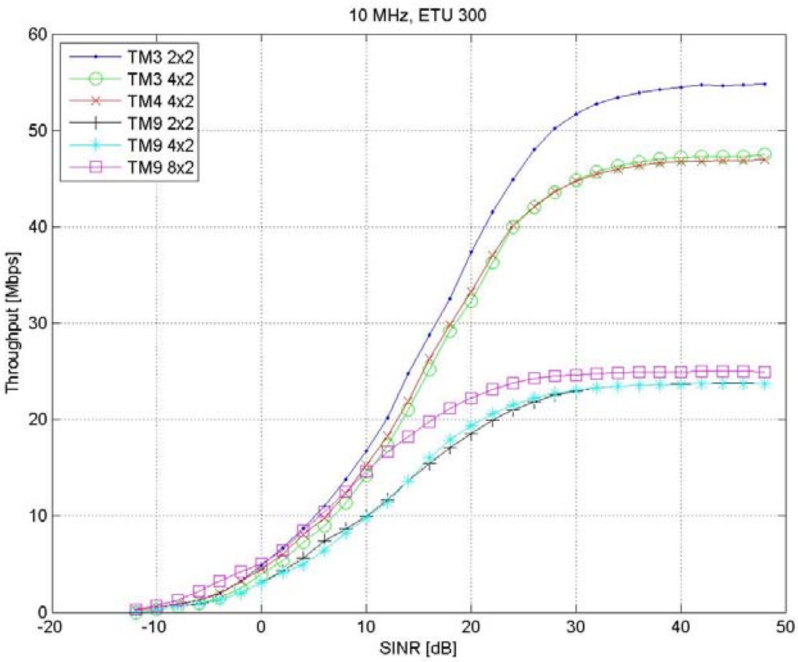

Figure 34 TM3, TM4 and TM9 throughput for ETU300 channel model, 10 MHz bandwidth.

13.3 Link simulations for 256QAM

Link simulations are provided in this section in the form of link curves for 256QAM modulation, and only for EPA5. The link curves show throughput vs. SINR for selected channel models, transmission modes and for 10 MHz bandwidth. Link curves for 64QAM are included as reference.

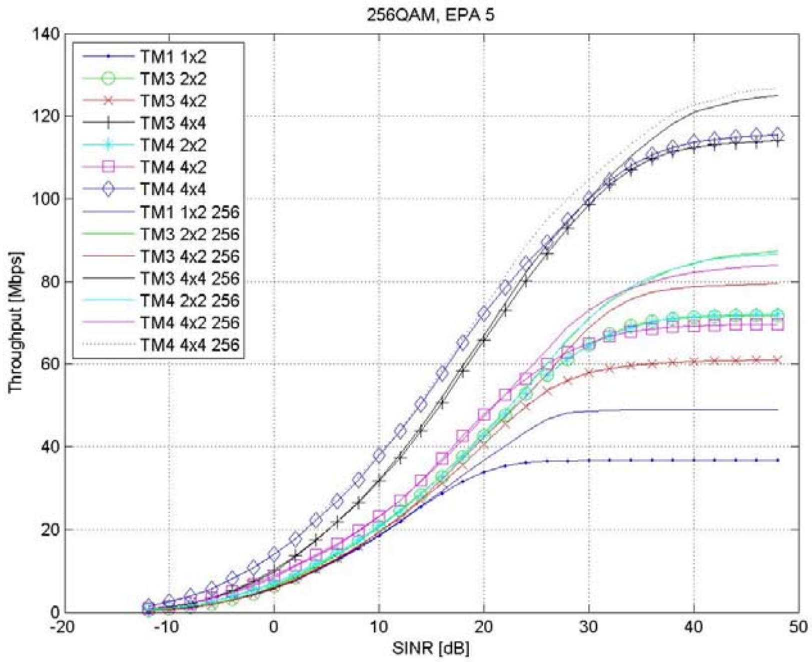

Figure 35 Throughput for 256QAM, EPA5 channel model and 10 MHz bandwidth.