**1. Introduction**

The initial planning of any Radio Access Network begins with a Radio Link Budget. As the name suggests, a link budget is simply the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. In this page, we will briefly discuss link budget calculations for LTE.

**2. LTE Radio Link Budgeting**

**2.1. Typical Parameter Values**

The link budget calculations estimate the maximum allowed signal attenuation g between the mobile and the base station antenna. The maximum path loss allows the maximum cell range to be estimated with a suitable propagation model. The cell range gives the number of base station sites required to cover the target geographical area.The following table shows typical (practical) parameter values used for doing an LTE Radio Link Budget.

|  |  |  |
| --- | --- | --- |
|  | **Parameter** | **Typical Value** |
| **a** | Base Station maximum transmission power. A typical value for macro cell base station is 20-69 W at the antenna connector. | 43 – 48 dBm |
| **b** | Base Station Antenna Gain | Manufacturer Dependent |
| **c** | Cable loss between the base station antenna connector and the antenna. The cable loss value depends on the cable length, cable thickness and frequency band. Many installations today use RF heads where the power amplifiers are close to the antenna making the cable loss very small. | 1 – 6 dB |
| **d** | Base Station EIRP, Calculated as A + B - C |  |
| **e** | UE RF noise figure. Depends on the frequency band. Duplex separation and on the allocated bandwidth. | 6 – 11 dB |
| **f** | Terminal noise can be calculated as:“***K (Boltzmann constant) x T (290K) x bandwidth***”.The bandwidth depends on bit rate, which defines the number of resource blocks. We assume 50 resource blocks, equal 9 MHz, transmission for 1 Mbps downlink. | -104.5 dBm for 50 resource blocks (9 MHz) |
| **g** | Calculated as E + F |  |
| **h** | Signal-to-noise ratio from link simulations or measurements. The value depends on the modulation and coding schemes, which again depend on the data rate and the number of resource blocks allocated. | -9 to -7 dB  |
| **i** | Calculated as G + H |  |
| **j** | Interference margin accounts for the increase in the terminal noise level caused by the other cell. If we assume a minimum G-factor of -4 dB, that corresponds to 10\*Log10(1+10^(4/10)) = 5.5 dB interference margin. | 3 – 8 dB |
| **k** | Control channel overhead includes the overhead from reference signals,PBCH, PDCCH and PHICH. | 10 – 25 %***=***0.4 – 1.0 dB |
| **L** | UE antenna gain. | Manufacturer Dependent |
| **M** | Body loss |  Device Dependent |

**2.2. Uplink Budget**

The table below shows an example LTE link budget for the uplink from [1], assuming a 64 kbps data rate and two resource block allocation (giving a 360 kHz transmission bandwidth). The UE terminal power is assumed to be 24 dBm (without any body loss for a data connection). It is assumed that the eNode B receiver has a noise figure of 2.0 dB, and the required Signal to Noise and Interference Ratio (SINR) has been taken from link level simulations performed in [1]. An interference margin of 2.0 dB is assumed. A cable loss of 2 dB is considered, which is compensated by assuming a masthead amplifier (MHA) that introduces a gain of 2.0 dB. An RX antenna gain of 18.0 is assumed considering a 3-sector macro-cell (with 65-degree antennas). In conclusion the maximum allowed path loss becomes 163.4 dB.

Uplink Link Budget for 64 kbps with dual-antenna receiver base station

|  |  |
| --- | --- |
| **Data rate (kbps)** | **64** |
| ***Transmitter – UE*** |  |
| **a** | Max. TX power (dBm) | 24.0 |
| **b** | TX antenna gain (dBi) | 0.0 |
| **c** | Body loss (dB) | 0.0 |
| **d** | EIRP (dBm) | 24.0 = a + b + c |
|  |  |  |
| ***Receiver – eNode B*** |  |
| **e** | Node B noise figure (dB) | 2.0 |
| **f** | Thermal noise (dBm) | -118.4 = *k(*Boltzmann*) \**T*(*290K*)\**B*(*360kHz*)* |
| **g** | Receiver noise floor (dBm) | -116.4 = e + f |
| **h** | SINR (dB) | -7.0 From Simulations performed in [1] |
| **i** | Receiver sensitivity (dBm) | -123.4 = g + h |
| **j** | Interference Margin (dB) | 2.0 |
| **k** | Cable Loss (dB) | 2.0 |
| **l** | RX antenna gain (dBi) | 18.0 |
| **m** | MHA gain (dB) | 2.0 |
|  |  |  |
| ***Maximum path loss*** | **163.4 = d – i – j – k + l - m** |

The table below shows an example LTE link budget

**2.3. Downlink Budget**

The table below shows an example LTE link budget for the downlink from [1], assuming a 1 Mbps data rate (assuming antenna diversity) and 10 MHz bandwidth. The eNode B power is assumed to be 46 dBm, a value typical among most manufacturers. Again the SINR value is taken from link level simulations performed in [1]. A 3 dB interference margin and a 1 dB control channel overhead are assumed, and the maximum allowed path loss becomes 165.5 dB.

Downlink Link Budget for 1 Mbps with dual-antenna receiver terminal

|  |  |
| --- | --- |
| **Data rate (Mbps)** | **1** |
| ***Transmitter – eNode B*** |  |
| **a** | HS-DSCH power (dBm) | 46.0 |
| **b** | TX antenna gain (dBi) | 18.0 |
| **c** | Cable loss (dB) | 2.0 |
| **d** | EIRP (dBm) | 62.0 = a + b + c |
|  |  |  |
| ***Receiver – UE*** |  |
| **e** | UE noise figure (dB) | 7.0 |
| **f** | Thermal noise (dBm) | -104.5 = *k(*Boltzmann*) \**T*(*290K*)\**B*(*360kHz*)* |
| **g** | Receiver noise floor (dBm) | -97.5 = e + f |
| **h** | SINR (dB) | -10.0 From Simulations performed in [1] |
| **i** | Receiver sensitivity (dBm) | -107.5 = g + h |
| **j** | Interference Margin (dB) | 3.0 |
| **k** | Control Channel Overhead (dB) | 1.0 |
| **l** | RX antenna gain (dBi) | 0.0 |
| **m** | Body Loss (dB) | 0.0 |
|  |  |  |
| ***Maximum path loss*** | **165.5 = d – i – j – k + l - m** |

The table below shows an example LTE link budget

**2.4. Propagation (Path Loss) Models**

A propagation model describes the average signal propagation, and it converts the maximum allowed propagation loss to the maximum cell range. It depends on:

* Environment : urban, rural, dense urban, suburban, open, forest, sea…
* Distance
* Frequency
* atmospheric conditions
* Indoor/outdoor

Common examples include Free space, Walfish–Ikegami, Okumura–Hata, Longley–Rice, Lee and Young's models. The most commonly used model in urban environments is the Okumura-Hata model as described below:

For Urban Areas:

 

For Small and Medium-sized cities:



For Large cities:



where:

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**2.5. Mapping of Path Losses to Cell Sizes**

For a path loss of 164 dB, based on the assumptions shown in the table below the following cell ranges can be attained with LTE. The cell range is shown for 900, 1800, 2100 and 2500 MHz frequency bands.

**Assumptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Okumura–Hata parameter** | **Urban Indoor** | **Suburban Indoor** | **Rural Indoor** | **Rural outdoor fixed** |
| Base station antenna height (m) | 30 | 50 | 80 | 80 |
| Mobile antenna height (m) | 1.5 | 1.5 | 1.5 | 5 |
| Mobile antenna gain (dBi) 0 | 0.0 | 0.0 | 0.0 | 5.0 |
| Slow fading standard deviation (dB) | 8.0 | 8.0 | 8.0 | 8.0 |
| Location probability (%) | 95 | 95 | 95 | 95 |
| Correction factor (dB) | 0 | -5 | -15 | -15 |
| Indoor loss (dB) | 20 | 15 | 0 | 0 |
| Slow fading margin (dB) | 8.8 | 8.8 | 8.8 | 8.8 |

**Cell Size in Km**



**2.6. Comparison to Other Radio Access Technologies**

In comparison to other Radio Access Technologies such as GSM or UMTS, LTE does not provide a significant increase in cell size or path loss measurements, however, the data rate (services) provided is much superior. In contrast to HSPA link budgets, the LTE Link budgets show up to roughly 2 dB higher values, which is mainly a result of low interference margins that can be achieved with orthogonal modulation. For a detailed comparison please refer to [LTE Link Budget Comparison](https://sites.google.com/site/lteencyclopedia/lte-radio-link-budgeting-and-rf-planning/lte-link-budget-comparison).

**3. References**

[1] H.Holma & A.Toskala, “WCDMA for UMTS: HSPA Evolution and LTE”, John Wiley & Sons, 2010

[2] H.Holma & A.Toskala, “LTE for UMTS: OFDMA and SC-FDMA based radio access”, John Wiley & Sons, 2009