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**Environmental Engineering (EE);**
**Measurement method for energy efficiency of**
**wireless access network equipment**

Reference

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# Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

# Introduction

Energy efficiency is one of the critical factor of the modern telecommunication systems. The energy consumption of the access network is the dominating part of the wireless telecom network energy consumption. Hence the core network and the service network are not considered in the present document. In the access network, the power consumption of the Radio Base Station node sites (later referred as RBS sites) is dominating and the power consumption of Radio Network Control nodes (RNC or BSC) are not considered in the present document.

The present document defines harmonized methods to evaluate the energy efficiency of wireless access networks. In order to do that, the present document provides definitions for the following indicators:

- Average power consumption of RBS equipment in clause 5.1: The RBS average power consumption is based on measured RBS power consumption under reference configuration, reference environment and under reference load levels.

- Average power consumption of RBS site in clause 5.2: The RBS site level power consumption is calculated based on RBS equipment power consumption for reference RBS site configuration using correction factors for different power supply, cooling and site solutions.

- Performance indicators for network level energy efficiency for wireless systems in clause 5.3: The network level performance indicators are calculated based on RBS site level reference power consumption as well as based on RBS coverage area for rural area and RBS capacity for urban area.

# 1 Scope

The present document defines a method to analyse the energy efficiency of wireless access network equipment.

The present document version covers the following radio access technologies:

- GSM.
- LTE.
- WCDMA.
- WiMAX$^{TM}$.

As the RBS power consumption is the dominant part of total power consumption of wireless access network, the present document covers methods which take into account only the RBS site power consumption when defining the total power consumption of wireless access networks. In the dynamic measurement, functionalities located in RNC or BSC node, which may have a significant impact on power consumption of base station nodes, are also considered.

The methodology described in the present document to measure energy efficiency consists of two parts. Within the present document they are referred to as static and dynamic measurements.

The results based on "static" measurements of the RBS power consumption provide a power consumption figure for RBS under static load and without radio network features activated. The results based on "dynamic" measurements of the RBS power consumption provide a power consumption figure for RBS with dynamic load and with radio network features activated, i.e. including the functionalities located in the radio network controller e.g. BSC/RNC.

Energy consumption of terminal (end-user) equipment is outside the scope of the present document.

The scope of the present document is not to define target values for the energy efficiency of equipment or networks.

The results should only be used to assess and compare the efficiency of mobile radio network equipment from different vendors featuring the same mobile radio standard and frequency band.

The present document does not cover multi RAT. Only Wide Area Base Stations are covered in this version. Other type of RBS will be considered in a future version of the present document.

# 2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

## 2.1 Normative references

The following referenced documents are necessary for the application of the present document.

[1] Void.

[2] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".

[3] CENELEC EN 50160: "Voltage characteristics of electricity supplied by public electricity networks".

[4] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 2: Operated by -48 V direct current (dc)".

[5] Void.

[6] Void.

[7] ETSI TS 125 141: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) conformance testing (FDD) (3GPP TS 25.141)".

[8] ETSI TS 125 101: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (FDD) (3GPP TS 25.101)".

[9] ETSI TS 136 101: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101)".

[10] ETSI TS 136 211: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211)".

[11] ETSI TS 136 141 (V8.6.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) conformance testing (3GPP TS 36.141)".

[12] ETSI TS 136 104: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104)".

[13] IEEE 802.16e: "IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands".

NOTE: WiMAX™ Technologies and Standards.

## 2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] NIST Technical Note 1297: "Guidance for evaluating and expressing the uncertainty of NIST measurement results".

[i.2] ISO/IEC Guide 98: 1995: "Guide to the expression of uncertainty in measurement (GUM)".

[i.3] ETSI TS 145 005: "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception (3GPP TS 45.005)".

[i.4] ISO/IEC 17025: "General requirements for the competence of testing and calibration laboratories".

[i.5] ETSI TS 151 021: "Digital cellular telecommunications system (Phase 2+); Base Station System (BSS) equipment specification; Radio aspects (3GPP TS 51.021)".

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**activity level:** traffic model in dynamic measurement is divided into three activity levels corresponding to low-, medium- and busy hour traffic

**activity time:** time to generate data from the server to at least one UE (in the scenario for dynamic measurement this corresponds to the transmission time for the UE group with highest path loss)

**busy hour:** period during which occurs the maximum total load in a given 24-hour period

**busy hour load:** in static measurement it is the highest measurement level of radio resource configuration and in dynamic measurement is the highest activity level

**distributed RBS:** RBS architecture which contains remote radio heads (RRH) close to antenna element and a central element connecting RBS to network infrastructure

**dynamic measurement:** power consumption measurement performed with different activity levels and path losses

**energy efficiency:** relation between the useful output and energy/power consumption

**integrated RBS:** RBS architecture in which all RBS elements are located close to each other for example in one or two cabinets

NOTE: The integrated RBS architecture may include Tower Mount Amplifier (TMA) close to antenna.

**IPERF:** allows the user to set various parameters that can be used for testing a network, or alternately for optimizing or tuning a network

NOTE: IPERF has a client and server functionality, and can measure the throughput between the two ends, either unidirectonally or bi-directionally. It is open source software and runs on various platforms including Linux, Unix and Windows. It is supported by the National Laboratory for Applied Network Research.

**low load:** in static measurement it is the lowest measurement level of radio resource configuration and in dynamic measurement is the lowest activity level

**medium load:** in static measurement it is the medium measurement level of radio resource configuration and in dynamic measurement is the medium activity level

**power consumption:** power consumed by a device to achieve an intended application performance

**power saving feature:** feature which contributes to decreasing power consumption compared to the case when the feature is not implemented

**Radio Base Station (RBS):** network component which serves one or more cells and interfaces the user terminal (through air interface) and a wireless network infrastructure

**RBS test control unit:** unit which can be used to control and manage RBS locally

**site correction factor:** scaling factor to scale the RBS equipment power consumption for reference site configuration taking into account different power supply solutions, different cooling solutions and power supply losses

**static measurement:** power consumption measurement performed with different radio resource configurations

**telecommunication network:** network which provides telecommunications between Network Termination Points (NTPs)

**UE group:** group of UEs whose pathlosses to the RBS are identical

**Wide Area Base stations:** Base Stations that are characterized by requirements derived from Macro Cell scenarios with a BS to UE minimum coupling loss equals to 70 dB according to 3GPP standardization

**wireless access network:** telecommunications network in which the access to the network (connection between user terminal and network) is implemented without the use of wires

## 3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| AC | Alternating Current |
| AMR | Adaptive Multi Rate |
| BCCH | Broadcast Control CHannel |
| BER | Bit Error Rate |
| BH | Busy Hour |
| BS | Base Station |
| BSC | Base Station Controller |

| | |
|---|---|
| BTS | Base Transceiver Station |
| BW | Bandwidth |
| CCH | Common CHannel |
| CCPCH | Common Control Physical Channel |
| CF | Cooling Factor |
| CFC | Cooling Factor for Central part |
| CFRRH | Cooling Factor for Remote Radio Head |
| CPICH | Common PIlot CHannel |
| CS | Circuit Switched |
| DC | Direct Current |
| DL | DownLink |
| DPCH | Dedicated Physical CHannel |
| EC | Energy for Central part |
| EDGE | Enhanced Datarate GSM Evolution |
| ERRH | Energy for Remote Radio Part |
| FCH | Frequency Correction Channel |
| GERAN | GSM/EDGE Radio Access Network |
| GSM | Global System for Mobile communication |
| GUM | Guide to the expression of Uncertainty in Measurement |
| HSPA | High Speed Packet Access |
| HW | HardWare |
| IPERF | See the definition part |
| KPI | Key Performance Indicator |
| LTE | Long Term Evolution |
| MAP | Media Access Protocol |
| MCPA | Multi Carrier Power Amplifier |
| MIMO | Multiple Input Multiple Output |
| NA | Not Applicable |
| NIST | National Institute of Standards and Technology |
| NTP | Network Termination Point |
| OFDM | Orthogonal Frequency Division Multiplex |
| PA | Power Amplifier |
| PBCH | Packet Broadcast Control Channel |
| PBH | Power during Busy Hour |
| PC | Power for Central Part |
| PCFICH | Physical Control Format Indicator CHannel |
| PCH | Paging Channel |
| PCM | Pulse Code Modulation |
| PDCCH | Physical Downlink Control CHannel |
| PDF | Proportional Distribution Function |
| PDSCH | Physical Downlink Shared CHannel |
| PFF | Power Feeding Factor |
| PHICH | Physical Hybrid ARQ Indicator CHannel |
| PICH | Paging Indicator Channel |
| PRB | Physical Resource Block |
| PRRH | Power for Remote Radio Head |
| PSF | Power Supply Factor |
| PSFC | Power Supply correction Factor for Central part |
| PSFRRH | Power Supply correction Factor for Remote Radio Head |
| RAT | Radio Access Technology |
| RBS | Radio Base Station |
| RF | Radio Frequency |
| RNC | Radio Network Controller |
| RRBS | Reference models for RBS sites |
| RRH | Remote Radio Head |
| RS | Reference Signals |
| RSS | Root Sum of Squares |
| RX | Receiver |
| SAE | System Architecture Evolution |
| SCH | Synchronization Channel |
| SDH | Synchronous Digital Hierarchy |
| SIMO | Single Input Multiple Output |

| | |
|---|---|
| SN | Signal-to-Noise |
| SW | SoftWare |
| TD | Time during one Duty cycle |
| TF | Tolerance Factor |
| TMA | Tower Mount Amplifier |
| TP | ThroughPut |
| TRX | Transceiver |
| TS | Time Slot |
| TX | Transmitter |
| UDP | User Data Protocol |
| UE | User Equipment |
| UL | UpLink |
| UL/DL | Uplink/Downlink |
| WCDMA | Wideband Code Division Multiple Access |
| WiMAX$^{TM}$ | Worldwide interoperability for Microwave Access |

# 4 Assessment method

## 4.1 Assessment levels

The present document defines a three level assessment method to be used to evaluate energy efficiency of wireless access networks. The three levels are:

- RBS equipment average power consumption for which the present document defines reference RBS equipment configurations and reference load levels to be used when measuring RBS power consumption.
- RBS site average power consumption which is based on measured RBS equipment power consumption and site level correction factors defined in the present document. The RBS site power consumption can be used to compare different equipment at site level.
- Network level performance indicators which are based on RBS site energy consumption as well as site coverage, site capacity. These indicators provide a means to evaluate the energy efficiency at network level taking into account not only site level energy consumption but also features to improve network coverage and capacity.

## 4.2 Assessment procedure

The assessment procedure contains the following tasks:

- Identify RBS basic parameters (table A.1 in annex A).
- List RBS configuration and traffic load(s) for measurements (annexes D to H).
- Measure RBS equipment power consumption for required load levels. (see clause 6).
- KPI calculation procedure according to:

  1) Calculate RBS equipment average power consumption according to equations 5.1 to 5.4 (see clause 5.1).

  2) List required RBS site level correction factors (annex B).

For GSM undertake the following:

8G. Calculate cell coverage area for 3 sectors as done in annex C formula (C.6).

9G. Define cell capacity and energy consumption (annex D).

10G. Calculate the KPI for EE performance indicators.

For WCDMA undertake the following:

8W. Calculate cell coverage area for 3 sectors as done in annex C formula (C.6).

9W. Define cell capacity and energy consumption (For static method annex E, for dynamic method annex H).

10W. Calculate the KPI for EE performance indicators.

For LTE undertake the following:

8L. Calculate cell coverage area for 3 sectors as done in annex C formula (C.6).

9L. Measure cell capacity and energy consumption (For static method annex F, for dynamic method annex H).

10L. Calculate the KPI for EE performance indicators.

For WiMAX™ undertake the following:

8WM. Calculate cell coverage area for 3 sectors as done in annex C formula (C.6).

9WM. Define cell capacity and energy consumption (annex G).

10WM. Calculate the KPI for EE performance indicators.

Collect and report the measurement results.

# 5 Calculation method for energy efficiency

## 5.1 RBS equipment energy consumption

The RBS equipment is a network component which serves one or more cells and interfaces the mobile station (through air interface) and a wireless network infrastructure (BSC or RNC), i.e. within the present document a RBS is defined as one or more BTS or one Node B ([i.3] and [2]).

Appropriate transmission e.g. a transport function for E1/T1/Gbit Ethernet or other providing capacity corresponding to the RBS capacity, shall be included in the RBS configuration during testing.

Static as well as dynamic energy consumption measurements are defined.

### 5.1.1 Reference configurations for Static energy consumption

For static RBS equipment power consumption measurements the following items are specified for each system in annexes D to G:

- Reference configuration(s).
- Frequency bands.
- Load levels.

Power Savings features implemented independently in RBS i.e. not requiring any other network element (for example BSC, RNC) to run the feature except activation and deactivation can be used during testing. Such features shall be listed in the measurement report.

### 5.1.2 Reference configurations for Dynamic energy consumption

For dynamic RBS equipment energy consumption measurements the following items are specified for each system in annexes E to H:

- Reference configuration(annexes E and F).
- Frequency bands (annexes E and F).
- Traffic load levels (annex H).
- Traffic case (annex H).

Power Savings features and other radio and traffic related features implemented in BSC/RNC and RBS can be used during the testing. Such features shall be listed in the measurement report.

## 5.2 Calculation method for integrated RBS

### 5.2.1 Definition of power consumption in static method

The power consumption of integrated RBS equipment in static method is defined for three different load levels as follows:

- $P_{BH}$ is the power consumption [W] with busy hour load.
- $P_{med}$ is the power consumption [W] with medium term load.
- $P_{low}$ is the power consumption [W] with low load.

The loads are defined for a given system. The model covers voice and/or data hour per hour. The models are provided in the annexes D to G.

The average power consumption [W] of integrated RBS equipment in static method is defined as:

$$P_{equipement,static} = \frac{P_{BH} \cdot t_{BH} + P_{med} \cdot t_{med} + P_{low} \cdot t_{low}}{t_{BH} + t_{med} + t_{low}} \qquad (5.1)$$

in which $t_{BH}$, $t_{med}$ and $t_{low}$ [hour] are duration of different load levels (for details for each different access system see annexes D to G).

### 5.2.2 Definition of power consumption in dynamic method

The power consumption of integrated RBS equipment in dynamic method is defined for three different activity levels as follows:

- $P^{AL10}$ is the power consumption [W] with 10 % activity level.
- $P^{AL40}$ is the power consumption [W] with 40 % activity level.
- $P^{AL70}$ is the power consumption [W] with 70 % activity level.

The activity levels are defined for a given system. The models are provided in annex H.

# 5.3 Calculation method for distributed RBS

## 5.3.1 Definition of power consumption for distributed RBS in static method

The power consumption of distributed RBS equipment in static method is defined for three different load levels as follows (for details of load levels see the annexes D to G):

- $P_{BH,C}$ and $P_{BH,RRH}$ are the power consumption [W] of central and remote parts of RBS with busy hour load.
- $P_{med,C}$ and $P_{med,RRH}$ are the power consumption [W] of central and remote parts of RBS with medium term load.
- $P_{low,C}$ and $P_{low,RRH}$ are the power consumption [W] of central and remote parts of RBS with low load.

The average power consumption [W] of distributed RBS equipment is defined as:

$$P_{equipement,static} = P_{c,static} + P_{RRH,static,} \quad (5.2)$$

in which $P_{C,\ static}$ and $P_{RRH,\ static}$ [W] are average power consumption of central and remote parts in static method defined as:

$$P_{c,static} = \frac{P_{BH,C} \cdot t_{BH} + P_{med,C} \cdot t_{med} + P_{low,C} \cdot t_{low}}{t_{BH} + t_{med} + t_{low}} \quad (5.3)$$

$$P_{RRH,static} = \frac{P_{BH,RRH} \cdot t_{BH} + P_{med,RRH} \cdot t_{med} + P_{low,RRH} \cdot t_{low}}{t_{BH} + t_{med} + t_{low}} \quad (5.4)$$

in which $t_{BH}$ , $t_{med}$ and $t_{low}$ [hour] are duration of different load levels (for details for each different access system see annexes D to F). This average power consumption of distributed RBS equipment does not include the DC feeder loss for remote parts. The DC feeder loss is on the other hand included in the site level power consumption defined in clause 5.4.

## 5.3.2 Definition of power consumption for distributed RBS in dynamic method

The power consumption of distributed RBS equipment in dynamic method is defined for three different activity levels as follows (for details of activity levels see annex G):

- $P^{AL10}{}_{,C}$ and $P^{AL10}{}_{,RRH}$ are the power consumption [W] of central and remote parts of RBS with 10 % activity level.
- $P^{AL40}{}_{,C}$ and $P^{AL40}{}_{,RRH}$ are the power consumption [W] of central and remote parts of RBS with 40 % activity level.
- $P^{AL70}{}_{,C}$ and $P^{AL70}{}_{,RRH}$ are the power consumption [W] of central and remote parts of RBS with 70 % activity level.

# 5.4 RBS site power consumption

Figures 1 to 3 show examples of reference models for RBS sites. The RBS site includes the RBS equipment, but may also include different infrastructure support systems and/or auxiliary cabinets. The power consumption and losses of support parts needed as a complementary to the site parts that are not included in the RBS product will be considered by using reference values for those complementary parts.

Following parts shall be included in the site power consumption value:

- RBS equipment and auxiliary cabinets, as defined for the product.
- Rectifiers.
- Climate unit.
- Power distribution losses. All power distribution losses between units shall be included for integrated indoor and outdoor RBS. For distributed base station the defined model has to be used (extra 5 % considering remote head power consumption, for details see annex B).
- Other auxiliary equipment and cabinets.

Functionalities excluded from site reference models are:

- Battery charge power.
- Cooling for batteries (if batteries are integrated part of RBS site solution, the power consumption measurement should be done with batteries separated from RBS for example by switch off battery breakers).

In the following RBS site level power consumption is defined for the purpose of making it possible to compare power consumption of different RBS. For this purpose scaling factors are used to scale the RBS equipment power consumption for reference site configuration taking into account:

- Power supply solutions. The power supply for reference RBS site is 230 V AC.
- Different cooling solutions. For the reference RBS site ambient air temperature for static measurement is +25 °C and +40 °C and for dynamic measurement is +25 °C.
- Power supply losses. For distributed BTS a reference loss for RRH power supply is included.

The site average power consumption [W] for integrated RBS is defined as:

$$P_{site} = PSF \cdot CF \cdot P_{equipment} \quad (5.5)$$

in which *PSF* is power supply correction factor [unit less] and *CF* is cooling factor [unit less], values of which are given in annex B.

The site average power consumption [W] for distributed RBS is defined as:

$$P_{site} = PSF_C \cdot CF_C \cdot P_C + PSF_{RRH} \cdot CF_{RRH} \cdot PFF \cdot P_{RRH}, \quad (5.6)$$

in which $PSF_C$ and $PSF_{RRH}$ are power supply correction factors for central and remote parts, $CF_C$ and $CF_{RRH}$ are cooling factors for central and remote parts and *PFF* is power feeding factor [unit less] for remote units as given in annex B.

Based on the concepts and measurements described in clause 5.1 the site efficiency can be calculated as the ratio between output power measured at the antenna connector and the total site power consumption, see annex A, table A.4.

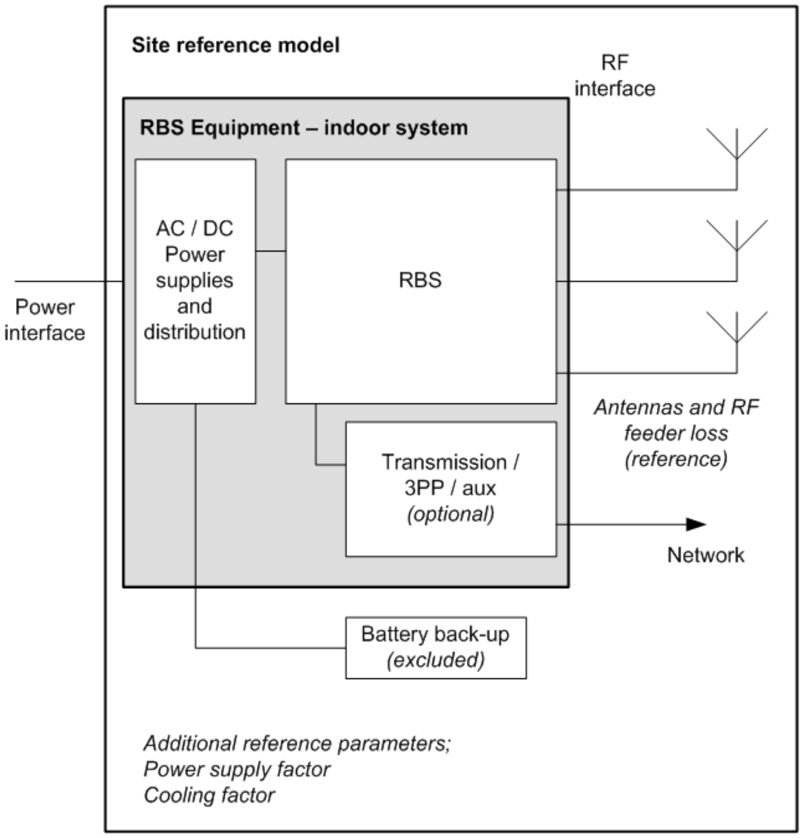


**Figure 1: Indoor RBS site model showing RBS equipment and support system infrastructure**

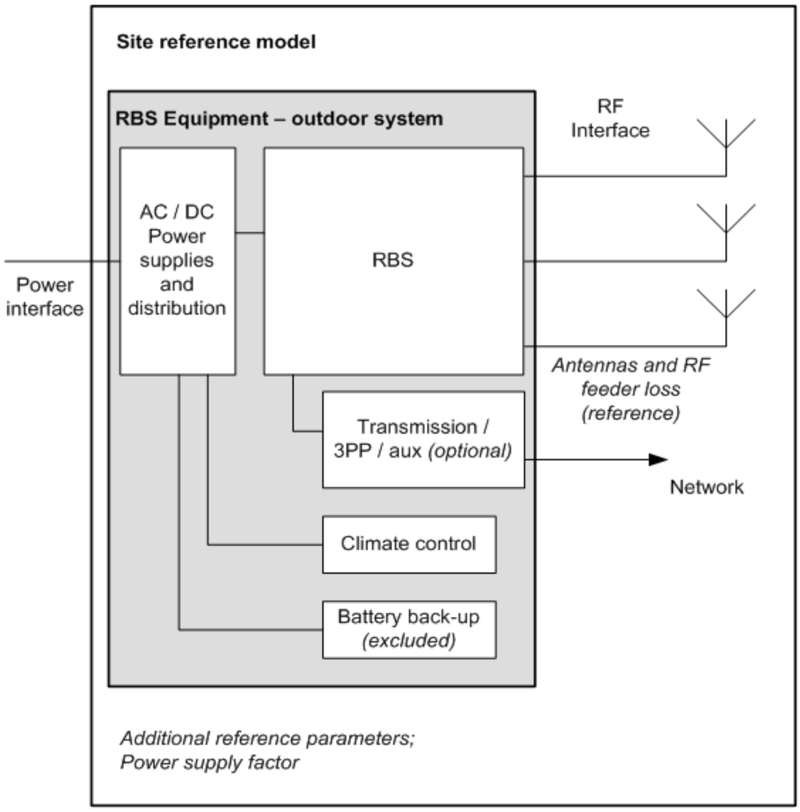


**Figure 2: Outdoor RBS site model showing RBS equipment and support system infrastructure**

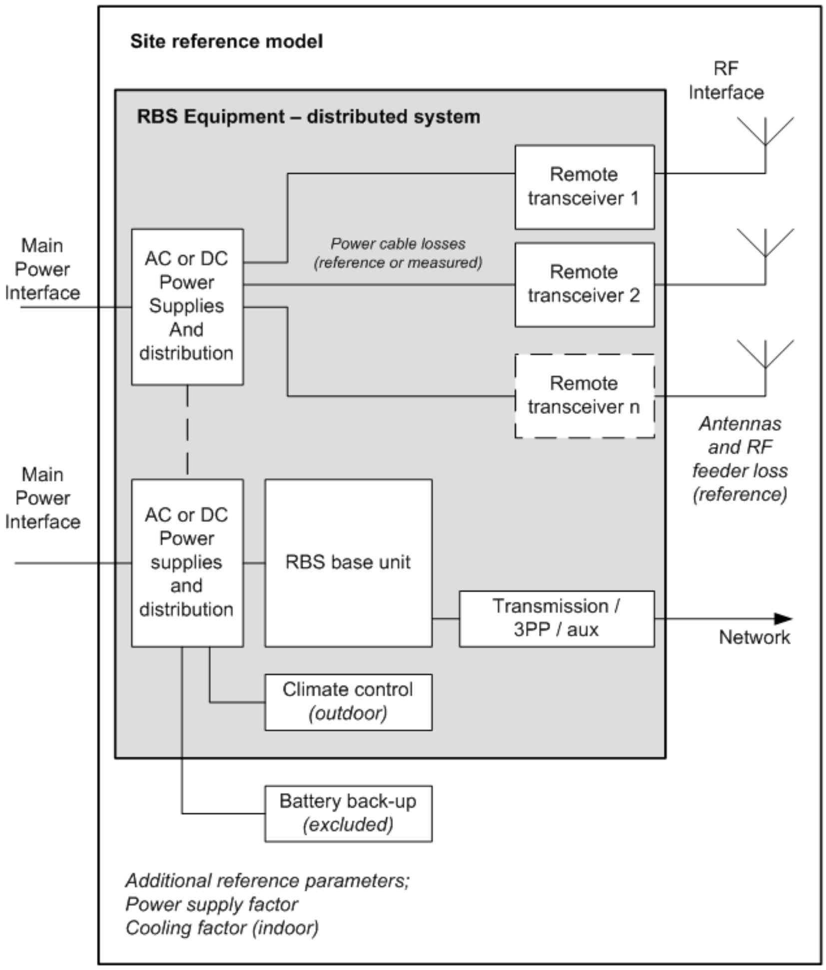


**Figure 3: Distributed RBS site model showing RBS equipment and support system infrastructure**

## 5.5 Energy efficiency

The energy efficiency provides a mean to evaluate the energy efficiency of wireless access network at RBS node level thus taking into account aspects targeting not only the RBS site energy consumption but also to features and properties related to capacity and coverage of the network.

### 5.5.1 Energy efficiency for GSM

In rural areas, the dominant factor for the dimensioning of a network is the coverage area. The traffic demand is typically smaller than the maximum possible capacity of the RBS and thus the cell size is defined by the propagation model. Thus, the energy efficiency for rural area is defined as the following where the *KPI* in the formula (5.7) is the area the RBS can cover from radio coverage point of view:

$$EE_{\mathrm{coverage}} = \frac{A_{\mathrm{coverage}}}{P_{site}} \qquad (5.7)$$

$A_{coverage}$ is the RBS coverage area [km$^2$] for rural area. The coverage area is calculated based on both uplink and downlink systems values (for details on how to calculate system values and cell radius see annex C). The limiting value of uplink and downlink coverage areas shall be used. Both coverage areas are calculated under low traffic load situation. For downlink calculation the RBS BCCH signal power level and UE receiver sensitivity and traffic type defined in annex D shall be used. For uplink calculation the measured RBS receiver sensitivity with UE transmission power and traffic type defined in annex D shall be used.

In urban areas, the dominant factor for the dimensioning of a network is the capacity of RBS. Thus the performance indicator (subscribers/W) for urban case is defined as:

$$EE_{capacity} = \frac{N_{busy\_hour}}{P_{site}} \qquad (5.8)$$

$N_{busy\_hour}$ is the number of subscribers based on average busy hour traffic demand by subscribers and average RBS busy hour traffic defined in table D.1 in annex D.

## 5.5.2 Energy efficiency for WCDMA/LTE/WiMAX$^{TM}$

To calculate the energy efficiency indicator in dynamic mode for the x$^{th}$ activity level, the power consumption of the RBS is sampled continuously (interval time $\Delta t_m$: 0,5 seconds or shorter) over the complete period $T_D$ of the test patterns (duty cycle period). For the integrated RBS $P_{i,k,equipment}^{ALx}$ is the measurement value for the i$^{th}$ measurement regarding the k$^{th}$ duty cycle period and the x$^{th}$ activity level. The test patterns are repeated *n* times where *n* is the total number of duty cycles during the test as defined in annex H. The average energy $E_{equipment}^{ALx}$ which is consumed by the RBS during one duty cycle period and for the x$^{th}$ activity level is evaluated as follows:

$$E_{equipment}^{ALx} = \frac{1}{n} \cdot \sum_{k=1}^{n} \left( \Delta t_m \cdot \sum_{i=1}^{T_D/\Delta t_m} P_{i,k,equipment}^{ALx} \right) \quad [J] \qquad (5.9)$$

$T_D/\Delta t_m$ shall be an integer.

For the distributed RBS case $E_{C,\ equipment}$ and $E_{RRH,\ equipment}$ [J] are the average energy consumption of the central and the remote parts in the dynamic method for the x$^{th}$ activity level defined as:

$$E_{RRH,equipment}^{ALx} = \frac{1}{n} \cdot \sum_{k=1}^{n} \left( \Delta t_m \cdot \sum_{i=1}^{T_D/\Delta t_m} P_{RRH,i,k,equipment}^{ALx} \right) \quad [J] \qquad (5.10)$$

$$E_{C,equipment}^{ALx} = \frac{1}{n} \cdot \sum_{k=1}^{n} \left( \Delta t_m \cdot \sum_{i=1}^{T_D/\Delta t_m} P_{C,i,k,equipment}^{ALx} \right) \quad [J] \qquad (5.11)$$

To calculate the site energy efficiency put $P_{c,site}$ and $P_{RHH,site}$ into above equations.

The average net data volume $DV^{ALx}$ during one duty cycle period and x$^{th}$ activity level is determined as given in (4b):

$$DV^{ALx} = \frac{1}{n} \cdot \sum_{k=1}^{n} \left( \sum_{j=1}^{m} DV_{j,k}^{ALx} \right) \quad [kbit] \qquad (5.12)$$

where *m* is the total number of UEs which are connected to the RBS and $DV_{j,k}^{ALx}$ the net data volume for the j$^{th}$ UE regarding the k$^{th}$ duty cycle period and x$^{th}$ activity level. Net data volume is the amount of data, successfully received at the UE.

The efficiency indicator $EE_{equipment}^{ALx}$ for x[th] activity level is then calculated as follows:

$$EE_{equipment}^{ALx} = \frac{DV^{ALx}}{E_{equipment}^{ALx}} \qquad \text{[kbit/J]} \qquad (5.13)$$

The measurements are carried out for all defined activity levels which are given in annex H.

In order to obtain the global efficiency indicator $EE_{equipment}$, the net date volume and energy consumption for the different activity levels have to be added taking the corresponding weighting factors $c_{ALx}$. The weighting factor considers the daily distribution of the traffic during the day, see annex H for the standard distribution proposed. *l* is the total number of activity levels. The global efficiency indicator $EE_{equipment}$ is then calculated as follows:

$$EE_{equipment} = \frac{\sum_{ALx=1}^{l} c_{ALx} \cdot DV^{ALx}}{\sum_{ALx=1}^{l} c_{ALx} \cdot E_{equipment}^{ALx}} \qquad \text{[kbit/J]} \qquad (5.14)$$

In which, $\sum_{ALx=1}^{l} c_{ALx} \cdot DV^{ALx}$ are total average date volume considering the daily distribution of traffic levels, $\sum_{ALx=1}^{l} c_{ALx} \cdot E_{equipment}^{ALx}$ are total average energy consumption considering the daily distribution of traffic levels.

**Indicator for coverage measurement**

In order to obtain the energy efficiency indicator for $EE_{Coverage}$ the cell areas covered by the RBS is divided by the total power consumption consumed for covering the area.

$$EE_{Coverage} = \frac{A}{P_{equipement}} \qquad [\text{km}^2/\text{W}] \qquad (5.15)$$

Where *A* is the coverage area and $P_{equipment}$ is the power consumption as explained in annex C.

# 6 Measurement methods for RBS power consumption

This clause describes the methods to measure the equipment performance taking into account the existing standards as listed in clause 2. It also gives the conditions under which these measurements should be performed. The aim is to have reproducible results.

## 6.1 Measurement basics

1) UL diversity:

   - Is a standard feature in all RBS. Therefore it is considered sufficient that the test is performed on the main RX antenna only. The diversity RX shall be active during the measurement without connection to the test signal.

DL diversity:

- Not considered in R99 and HSPA. LTE: Transmission mode 3 "Open loop spatial multiplexing" shall be according to TS 136 211 [10] (2×2 DL MIMO).

Smart antennas:

- Setup for smart antenna system will be defined in a later release.

### 6.1.1 General

The measurement method and the test setup for power consumption consist of two parts, static measurement and dynamic measurement. For both static and dynamic measurement the RBS shall be operated in a test and measuring environment as illustrated in figures 4 and 5.

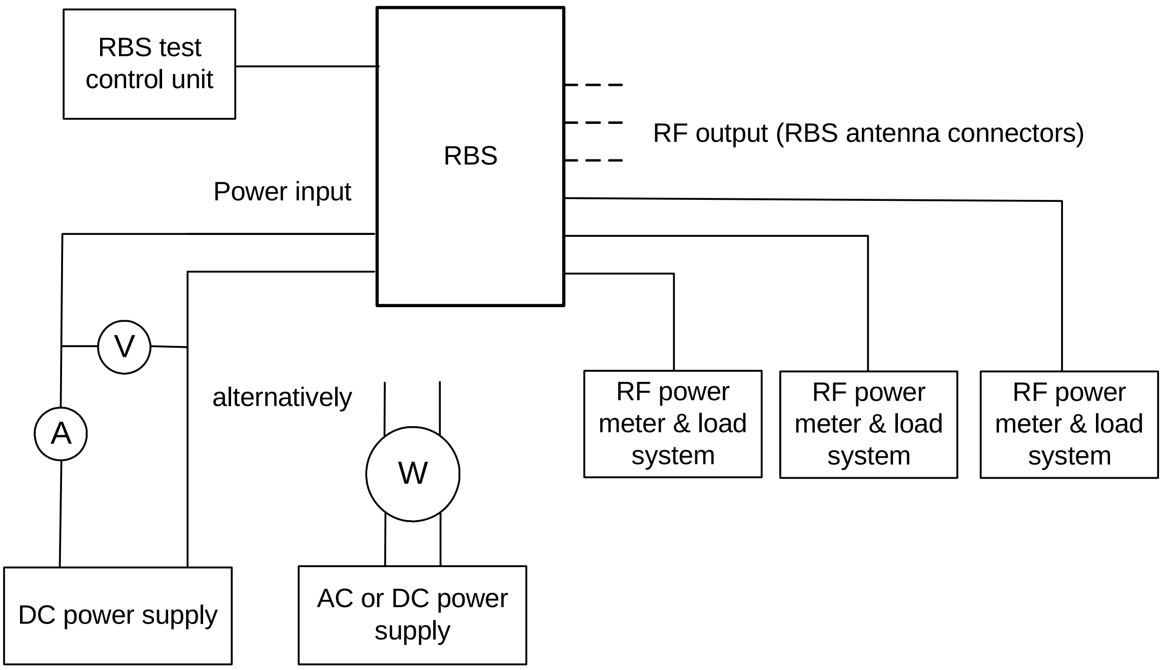


**Figure 4: Test set-up for static measurements (example for three sectors)**

In the static the RBS is powered either by a DC or AC power supply and operated by the RBS test control unit. This control unit provides the RBS with control signals and traffic data which are required to perform the static measurements. Each RF output (antenna) connector is terminated with a load with the capability to measure the RF output power.

In the dynamic mode the RBS is powered by a DC or AC power supply. The control unit itself is connected to the core network. The core network can be either a real network element or a core network simulator. On the antenna interface the RBS is connected to all sectors via coaxial cables, see figure 5.

Figure 5 shows the test setup with a three sectors RBS. At each sector four UE groups are used. These are connected to variable attenuators to generate different path loss.

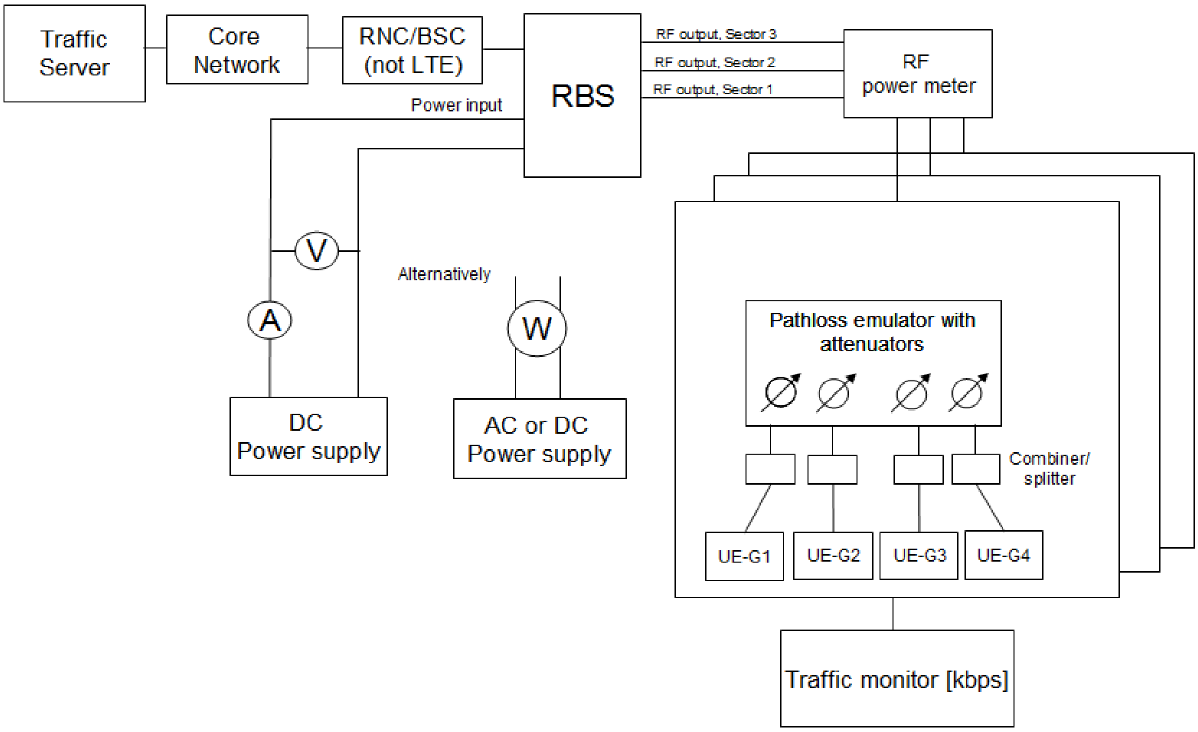


**Figure 5: Test setup for dynamic measurement with UEs (example for three sectors)**

## 6.1.2 Measurement and test equipment requirements

The measurement of the power consumption shall be performed by either measuring the power supply voltage and true effective current in parallel and calculate the resulting power consumption (applicable only for DC) or with a wattmeter (applicable for both AC and DC). The measurements can be performed by a variety of measurement equipment, including power clamps, or power supplies with in-built power measurement capability.

All measurement equipments shall be calibrated and shall have data output interface in order to allow long term data recording and calculation of the complete power consumption over a dedicated time.

The measurement equipment shall comply with following attributes:

- Input power:
  - Resolution: ≤ 10 mA; ≤ 100 mV; ≤ 100 mW.
  - DC current: ±1,5 %.
  - DC voltage: ±1 %.
  - Wattmeter: ±1 %.
  - An available current crest factor of 5 or more.
  - The test instrument shall have a bandwidth of at least 1 kHz.
  - RF output power: ±0,4 dB.

In the static mode the RBS shall be stimulated via the RBS controller interface by the emulation of the test-models in conjunction with the traffic profiles and reference parameters given in annexes D to G.

In the dynamic mode the RBS shall be operated via the controller units as illustrated in figure 5 in conjunction with the traffic profiles and reference parameters given in annexes D to G.

The UEs are distributed in the cell according to clause 6.4.2.1 and may be represented either by UE emulators or test mobiles. In either case the performance requirements apply as described in related clause 6.1.3 for each technology.

### 6.1.3 UE performance requirements

The dynamic RBS energy efficiency testing allows the usage of either user equipment (UE) emulator or a test setup with conventional UEs.

The RBS energy efficiency depends to a significant part on the performance of the UE. To achieve comparable results, the UE performance shall be according to the nominal minimum performance as specified in relevant 3GPP standard (for example TS 125 101 [8] for WCDMA).

Standard off-the-shelf UEs have typically a better performance than the minimum requirements to cope with production tolerances. To minimize the impact of the UEs on the test results, the performance variations have to be compensated. This clause describes a basic set of UE specifications and corrective actions to compensate for UE performance variations for the RBS EE test setup.

The downlink capacity test results described in the present document depend on the receiver sensitivity of the UE. UE emulators include usually means to calibrate key parameters like transmit power, receiver sensitivity, etc. The following procedure shall guarantee that all UEs used for the test setup match the required minimum performance as specified in the relevant UE standard.

UE Requirements:

1) UEs which have an external antenna connector as default shall be used as test device.

UEs used for testing shall achieve the minimum RF performance according to the relevant standard with an accuracy of ±0,5 dB.

Only UEs of power classes 3 and 3bis shall be applied since power classes 1and 2 are only specified for band 1.

Only UEs with a significant market penetration (for example models of the actual top ten sales lists, etc.) shall be used.

The used UE equipment has to be recorded in detail for the test protocol. This shall include origin, H/W and S/W versions of the UEs as well as any modifications or corrective measures made.

The RX sensitivity of the UEs applied shall be measured and corrected before the RBS capacity test. The UE sensitivity shall be measured with an UE test setup comprising of a signal generator and BER counter as described in figure 6. The UE sensitivity shall be reduced with an attenuator at the UE antenna port to the reference sensitivity as specified in table 7.2A in [8] and [9]. The measurements shall be done for all UEs used during the test at all frequencies and bandwidths used for efficiency testing.

The correction factors applied shall be documented in the test protocol.

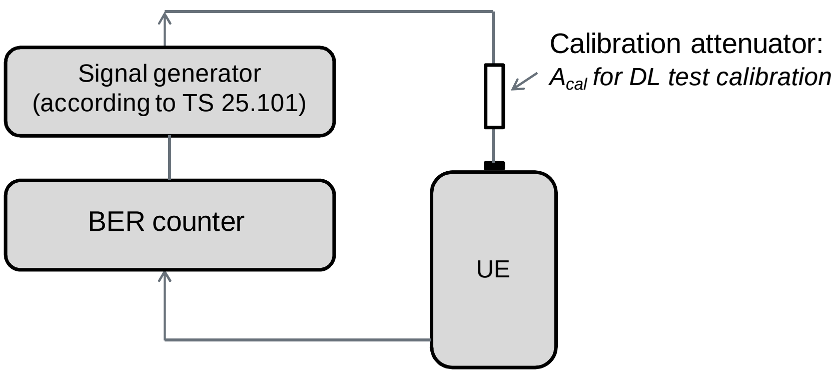


**Figure 6: UE calibration setup for UE sensitivity correction**

The calibration attenuator shall remain connected to the UE during all capacity tests like shown in figure 6. In the case that only one UE is used per UE group, the required attenuation can be added to the path loss attenuation instead.

## 6.2 Measurement conditions

### 6.2.1 RBS Configuration

The RBS shall be tested under normal test conditions according to the information accompanying the equipment. The RBS, test configuration and mode of operation (baseband, control and RF part of the RBS as well as the software and firmware) shall represent the normal intended use and shall be recorded in the test report.

In case of multiple configuration of RBS a configuration with 3 sectors shall be used.

For WCDMA/HSPA a configuration with one carrier per sector shall be used.

The connection to the simulator via the RBS controller interface shall be an electrical or optical cable-based interface (e.g. PCM, SDH, and Ethernet) which is commercially offered along with the applied RBS configuration. Additional power consuming features like battery loading shall be switched off.

Downlink ciphering on the air-interface shall be used.

The Power saving features and used SW version have to be listed in the measurement report.

The measurement report shall mention the configuration of the RBS including the type of RF signal combining (antenna network combining, air combining or multi-carrier).

### 6.2.2 RF output (transmit) power/signal

Due to the different nominal RF output power values of the various RBS models and additionally their RF output power tolerances within the tolerance ranges defined by the corresponding mobile radio standards, it is necessary to measure the real RF output power at each RF output connector of the RBS.

During the test the RBS shall be operated with the RF output powers which would be applied in commercial operation regarding the reference networks and the traffic profiles listed in annexes D to G.

The power amplifier(s) of the RBS shall support the same crest factor (peak to average ratio) and back-off as applied in the commercial product.

All relevant requirements from the corresponding 3GPP and GERAN specifications for the air-interface, e.g. [2] for WCDMA/HSPA and LTE, shall be fulfilled.

### 6.2.3 Environmental conditions

For the power consumption measurements the environmental conditions under which the RBS has to be tested are defined as follows.

**Table 1: RBS environmental conditions**

| Condition | Minimum | Maximum |
|---|---|---|
| Barometric pressure | 86 kPa (860 mbar) | 106 kPa (1 050 mbar) |
| Relative Humidity | 20 % | 85 % |
| Vibration | Negligible | |
| Temperature | Static: +25 °C and +40 °C<br>Dynamic: +25 °C | |
| Temperature accuracy | ±2 °C | |

### 6.2.4 Power supply

For measurements of the RBS power consumption the following operating voltage value shall be used (for non standard power supply voltages one should use operating voltage with ±2,5 % tolerances).

For nominal value and operating value shall be according for AC testing to [3] and DC testing to [4].

The frequency of the power supply corresponding to the AC mains shall be according to [3].

## 6.3 Static measurement procedure

The power consumption measurements shall be performed when stable temperature conditions inside the equipment are reached. For this purpose the RBS shall be placed in the environmental conditions for minimum two hours with a minimum operation time of one hour before doing measurements.

Measurement results shall be captured earliest when the equipment including the selected load is in stable operating conditions.

The RF output powers as well as the corresponding power consumptions of the RBS shall be measured with respect to the RF output power levels which are needed to fulfil the requirements from the reference networks as well as the traffic profiles described in annexes D to G.

The RF output power signal and levels shall be generated according to the test models described in annexes D to G.

Stimulation shall be realized via the RBS controller interface.

The test models as well as the system depended load levels are defined in annexes D to G.

The reference point for the RF output measurements is the antenna connector of the RBS.

The RF output power and corresponding input power consumption shall be measured at the lower, mid and upper edge of the relevant radio band for low load case (in order to have values over frequency band for calculation of coverage area) and at middle frequency channel for busy hour and middle load. For the evaluation the single values as well as the arithmetic average of these three measurements (only for low load) shall be stated in the measurement report (table A.3). The arithmetic average shall be taken for RBS reference power consumption evaluation as well as the network energy level efficiency calculations.

The measurements shall be performed for every antenna which is carrying downlink antenna carrier(s). The measured RF output power values shall be listed in the measurement report for every antenna.

The power consumption of the RBS as well as the RF output power shall be given in watts. in accordance with the accuracies and the resolutions given in clause 6.1.2.

### 6.3.1 Coverage measurement method

The coverage of a RBS in rural areas is typically limited by the UL connection. The coverage area (sensitivity of the RBS) is an important performance indicator especially for green field operators or when a new system is introduced. The initial RBS deployment is often determined by the contractual requirements to achieve an initial minimum area or population coverage.

The energy efficiency for coverage ($EE_{coverage}$) is measured and calculated under the following conditions:

- Apply RBS test generator (UE emulator).
- Measure the sensitivity of the RBS (with one RX path, other RX path for UL diversity shall be active but antenna connector terminated) as well as the power consumption P of the RBS with all sectors active and commissioned identically. A test generator shall be connected to one sector only.

The sensitivity shall be measured for the uplink throughput as specified below:

- WCDMA/Rel.99: Speech call with 12,2 kbps AMR.
  The Bit Error Rate (BER) shall be $\leq$ 0,001 as defined in TS 125 141 [7] and annex C.
- WCDMA/HSDPA: upload via UDP with a net data throughput not less than 256 kbps.
- LTE: upload via UDP with a net data throughput not less than 500 kbps.

After the UL requirements have been fulfilled the downlink throughput shall be configured to the following requirements:

- WCDMA/Rel.99: Speech call with 12,2 kbps AMR.
  The Bit Error Rate (BER) shall be $\leq$ 0,001 as defined in TS 125 141 [7] and annex C.

- WCDMA/HSDPA: download via UDP with a net data throughput not less than 1 280 kbps.
- LTE: download via UDP with a net data throughput not less than 2 500 kbps.

Ciphering shall be activated on the air-interface.

**Measurement setup:**

1) (e)NodeB: 1+1+1 configuration; 40W rated output power per transmitter or the maximum of RBS output power if 40 W is not reached; no TX-diversity in WCDMA / MIMO configuration in LTE activated but one antenna connector terminated.
2) Frequency bands as defined in annex E for WCDMA and annex F for LTE.
3) Common channels (all 3 sectors) as defined in annex E for WCDMA and annex F for LTE.
4) (e)NodeB from commercial production, commercial SW, default adjustments for RNC/SAE and (e)NodeB.

The coverage area is calculated from the measured path loss as specified in annex C.

## 6.4 Dynamic measurement procedure

The power consumption measurements shall be performed in the middle of RF band when stable temperature conditions inside the equipment are reached. For this purpose the RBS shall be placed in the environmental conditions for minimum two hours with a minimum operation time of one hour before doing measurements.

This clause describes the measurement method for capacity dynamic measurement including the distribution of UEs during measurement and throughput setup.

### 6.4.1 UE distribution for dynamic test method

In the dynamic test method 4 UE groups are distributed in each sector. The number of UEs in each group is dependent on which radio access technology is used during the test, see annex H. The distribution of UE groups is in a way that UE group1 has the lowest path loss and UE group 4 has the highest path loss, see figure 7.

Each UE group is connected to an attenuator with a specific attenuation representing the UE's position in the cell to give predefined received signal strength as stated in annex H.

Values for received signal strength at each UE with respect to different radio access technology are presented in annex H.

Multi-path or other propagation impairments are not considered.

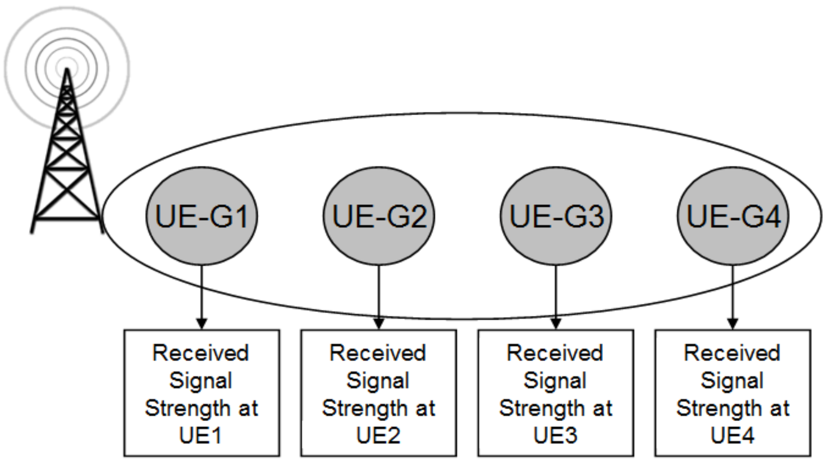


**Figure 7: UEs distribution in a sector**

## 6.4.2 Throughput setup

The following procedure is applied for one carrier.

Due to the different link budget conditions UEs at different positions in a sector get different net data transmissions per bit.

In order to equally weight the contribution of different UEs to the global energy efficiency metric, the active UEs shall evenly share the channel resources over their simultaneous active time.

As the test scenario of each duty cycle ($T_D$) (see annex H) shall be divided in 4 active phases ($T_p$) (depending if 4, 3, 2 or 1 UE are receiving DL traffic), the even distribution of resources shall be provided in the average during each phase (see clause 6.4.3).

For each of the different attenuations, the bit rate setting for the UDP traffic generators can be experimentally determined as follows (see figures 8 to 11):

1) Start with one connected UE. This UE (e.g. UE4) has the worst link budget conditions. Tune the UDP bit rate to the max value for which the net sends (data rate sent by UDP traffic generator) and receive throughput (maximum net throughput received by UE without data loss) are the same. This value is called $TPmax_{UE4}$.

2) Connect the next UE. This UE (e.g. UE3) has the second worst link budget. The previous UE(s) remain connected and get its/their data with unchanged UDP traffic generator data rate. Perform the same tuning operation for the new UE (e.g. UE3) as described for previous UE in step (1), but now in contention with all previous UEs. This value is called $TPmax_{UE3}$.

3) Sequentially perform the tuning operation of step (2) for each UE (in order of decreasing attenuation). The bit rate is thus achieved in contention with all UEs that have been tuned so far. This value is called $TPmax_{UE2}$ and $TPmax_{UE1}$ for UE2 and UE1 respectively.

The UDP data throughputs are now determined and will be used for the energy efficiency test. During test execution, the UDP data generator of each UE will be started and terminated several times according to the activity levels defined in annex H. The implied precondition of the Throughput setup is that UE1 is always in contention with the other UEs; UE2 always in contention with UE3 + UE4; UE3 always in contention with UE4. In any case, the configured bit rate stays fixed to the obtained values.

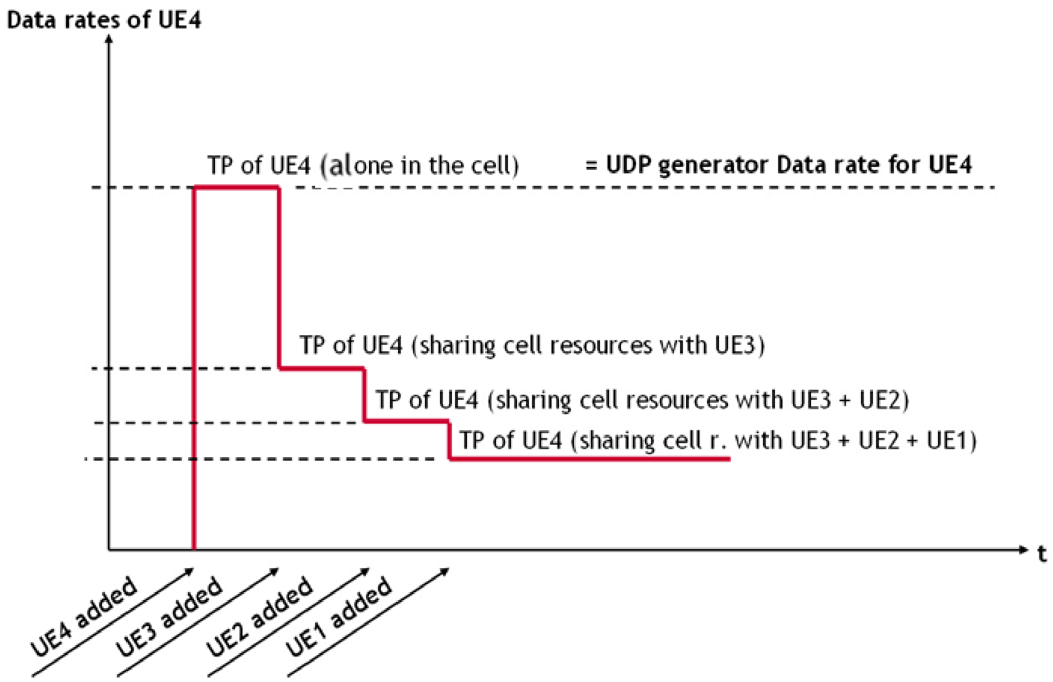


**Figure 8: UDP data rate for UE4**

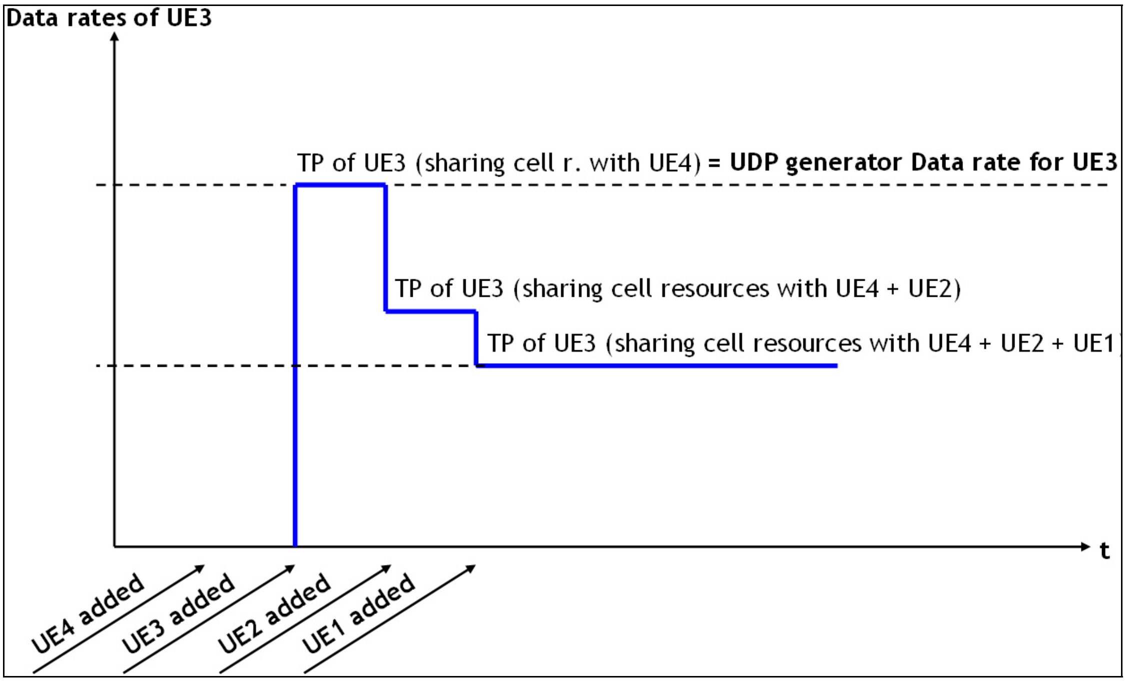


**Figure 9: UDP data rate for UE3**

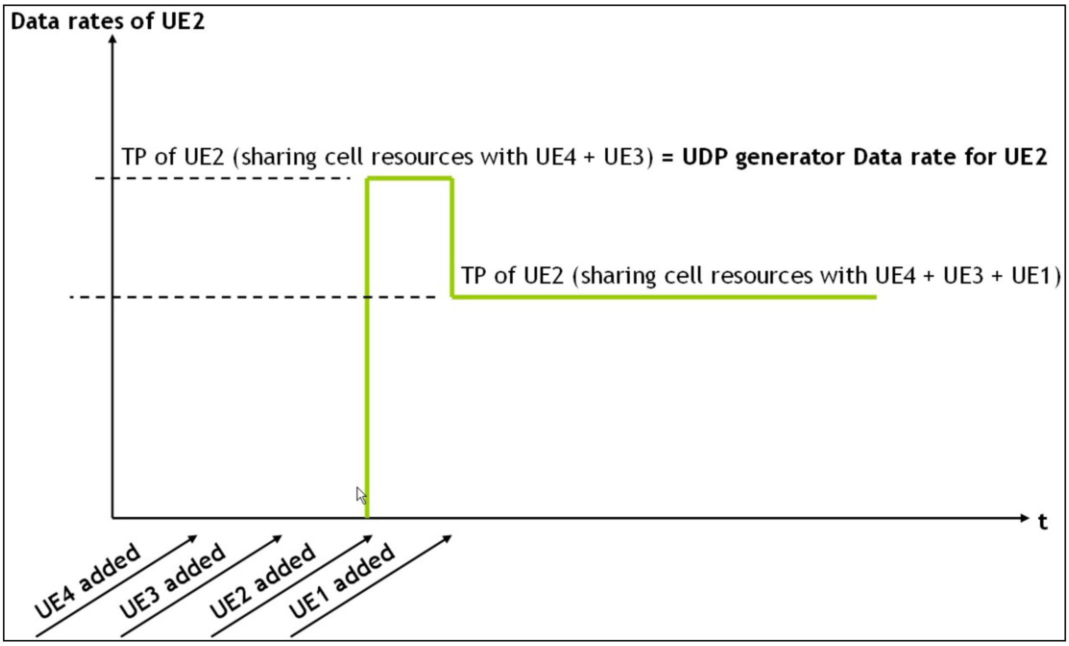


**Figure 10: UDP data rate for UE2**

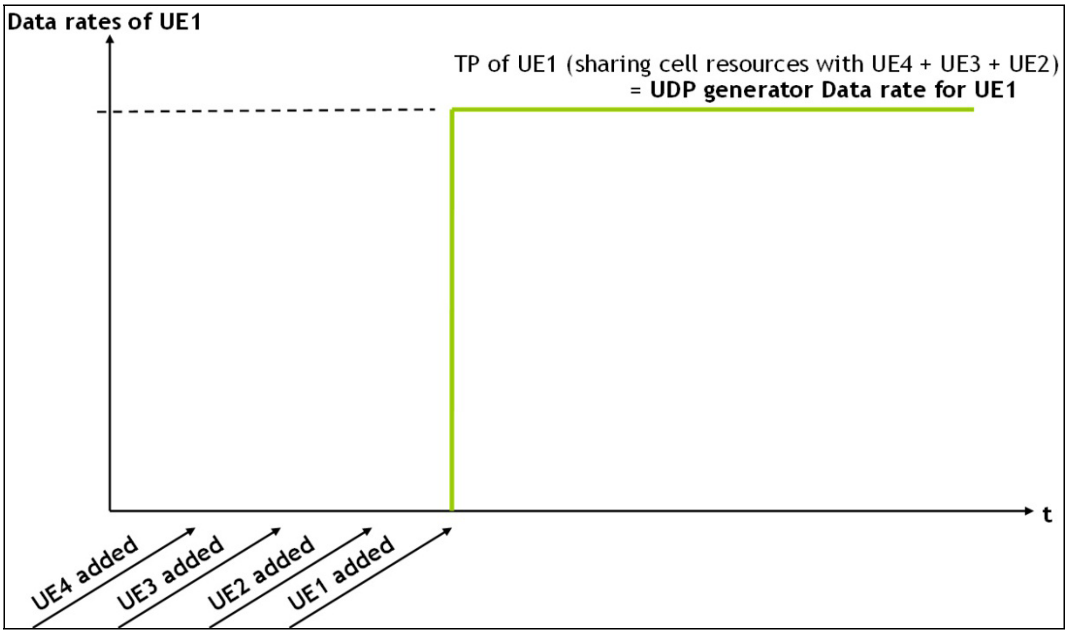


**Figure 11: UDP data rate for UE1**

### 6.4.3 Error tolerance for equal distributed resources

The amount of **accumulated data per Activity Level** (#Data$_{x,UEi}$) can be easily compared with the expected minimum data, based on the UDP-levelled Throughput (= measured TPmax) multiplied by the summarized recording time.

The minimum data per Activity Level (per UE-Group) is the evaluated volume of data, reduced by a tolerance factor TF. Via formula 6.b (see annex K) and with current values (e.g. $SF_{UE4}$ = 25/12; $SF_{UE3}$ = 26/12; $SF_{UE2}$ = 15/12; $SF_{UE1}$ = 12/12; n = 10; $T_D$ = 40 s; M = 4; TF = 0,25, see annex K):

**Evaluated data volume:**

- $\#Data_{x,UE1} \geq Pmax_{UE1} \times 75\ s \times AFx$
- $\#Data_{x,UE2} \geq TPmax_{UE2} \times 131{,}25\ s \times AFx$
- $\#Data_{x,UE3} \geq TPmax_{UE3} \times 162{,}5\ s \times AFx$
- $\#Data_{x,UE4} \geq TPmax_{UE4} \times 156{,}25\ s \times AFx$

The measured $TPmax_{UEi}$ as well as the volume of accumulated data $\#Dataaccu_{UEi,x}$ as well as the number of evaluated data $\#Data_{x,UEi}$ have to be mentioned in the Measurement Report (see annex A, table A.7).

# 7 Measurement report

The results of the assessments shall be reported accurately, clearly, unambiguously and objectively, and in accordance with any specific instructions in the required method(s).

A list of reference parameters, measurement conditions, test results and derived calculation results which are to be reported is given in annex A.

Further guidelines on the test report can be found in clause 5.10 of ISO/IEC 17025 [i.4].

# Annex A (normative): Measurement Reports

**Table A.1: Test general information**

| Items | Remarks |
|---|---|
| 1) Document reference and version | |
| 2) Date of the test | |
| 3) Version of TS 102 706 used | |
| 4) Location of the test | |
| 5) Name of test organization and responsible person | |
| 6) Tested equipment | |
| 6.1) Tested HW unit names and serial numbers | |
| 6.2) Software version of tested equipment | |
| 7) List of used measurements equipments including type, serial number and calibration information | |

**Table A.2: RBS reference parameters to be reported**

| Parameter | Value | Unit |
|---|---|---|
| 1) RBS configuration | | |
| 1.1) Number of sectors | | |
| 1.2) Number of Carriers per sector | | |
| 1.2.1) Number of carriers the RBS is able to support | | |
| 1.2.2) Number of carriers, for which the HW was enabled (independent whether or not the carriers were used for the test) | | |
| 1.2.3) Number of carriers used during the test | | |
| 1.3) TX diversity | | |
| 1.4) RX diversity | | |
| 1.5) Type of RF signal combining | | |
| 1.6) Remote Radio Head (Yes/No) | | |
| 2) Frequency | | |
| 2.1) Downlink band | | MHz |
| 2.2) Uplink band | | MHz |
| 2.3) Chanel bandwidth | | MHz |
| 3) Environment | | |
| 3.1) Temperature range | | °C |
| 3.2) Type of air filter | | |
| 4) Features | | |
| 4.1) Power saving features | | |
| 4.2) Coverage and capacity features | | |

**Table A.3: Measurements conditions and results to be reported in static method**

| Parameter | Test case 25 °C | Test case 40 °C | Unit |
|---|---|---|---|
| 1) Test environment | | | |
| 1.1) Temperature during test (measured) | | | °C |
| 1.2) Pressure (measured) | | | kPa |
| 1.3) Relative humidity (measured) | | | |
| 2) Downlink frequency used at test | | | |
| 2.1) Centre frequency of low end channel | | | MHz |
| 2.2) Centre frequency of middle channel | | | MHz |
| 2.3) Centre frequency of high end channel | | | MHz |
| 3) Supply voltage | | | |
| 3.1) DC voltage (measured) | | | V |
| 3.2) AC voltage (measured, phase to neutral) | | | V |
| 3.3) AC Frequency (measured) | | | Hz |
| 4) Static power consumption (measured) | | | |
| 4.1) Busy hour load, Middle frequency channel | | | W |
| 4.2) Medium load, Middle frequency channel | | | W |
| 4.3) Low load | | | |
| 4.3.1) Low end frequency channel | | | W |
| 4.3.2) Middle frequency channel | | | W |
| 4.3.3) High end frequency channel | | | W |
| 4.3.4) Average consumption with low load | | | W |
| 5) TX output power (pilot signal only) | | | |
| 5.1) Output power at low end channel | | | W |
| 5.2) Output power at middle end channel | | | W |
| 5.3) Output power at high end channel | | | W |
| 5.4) Average output power per sector | | | W |
| 6) RX receiver sensitivity at middle channel | | | dBm |

**Table A.4: Calculation results to be reported in static method**

| Parameter | Value | Unit |
|---|---|---|
| 1) $P_{equipequipmentment}$ of integrated RBS power consumption at 25 °C | | W |
| 2) $P_{equipement}$ of integrated RBS power consumption at 40 °C | | W |
| 3) $P_{equipement}$ of distributed RBS power consumption at 25 °C | | W |
| 3.1) $P_{equipement}$ of distributed RBS power consumption at 25 °C for central part | | W |
| 3.2) $P_{equipement}$ of distributed RBS power consumption at 25 °C for remote part | | W |
| 4) $P_{equipement}$ of distributed RBS power consumption at 40 °C | | W |
| 4.1) $P_{equipement}$ of distributed RBS power consumption at 40 °C for central part | | W |
| 4.2) $P_{equipement}$ of distributed RBS power consumption at 40 °C for remote part | | W |
| 5) Site average power consumption at 25 °C | | W |
| 5.1) Used power supply factor | | |
| 5.2) Used cooling factor | | |
| 5.3) Used power feeding factor for RRH | | |
| 6) Site average power consumption at 40 °C | | W |
| 6.1) Used power supply factor (PSF) | | |
| 6.1.1) PSF for integrated RBS | | |
| 6.1.2) $PSF_c$ for central part of distributed RBS | | |
| 6.1.3) $PSF_{RRH}$ for RRH part of distributed RBS | | |
| 6.2) Used cooling factor (CF) | | |
| 6.2.1) CF for integrated RBS | | |
| 6.2.2) $CF_c$ for central part of distributed RBS | | |
| 6.2.3) $CF_{RRH}$ for RRH part of distributed RBS | | |
| 6.3) Used power feeding factor for RRH | | |
| 7) Site efficiency | | |
| 7.1) [(Output power at antenna connector at 25 °C) / (Site average power consumption at 25 °C )] × 100 | | % |
| 7.2) [(Output power at antenna connector at 40 °C) / (Site average power consumption at 40 °C )] × 100 | | % |
| 8) Coverage efficiency (only for GSM system) | | |
| 8.1) Calculated uplink coverage area | | $km^2$ |
| 8.2) Calculated downlink coverage area | | $km^2$ |
| 8.3) Performance indicator for rural area | | $km^2/W$ |

| Parameter | Value | Unit |
|---|---|---|
| 9) Capacity efficiency (only for GSM system) | | |
| 9.1) Busy hour capacity | | Subscribers |
| 9.2) Performance indicators for urban area | | Subscribers/W |

**Table A.5: Measurements conditions and results to be reported in dynamic method**

| Parameter | Test case 25 °C | Test case 40 °C | Unit |
|---|---|---|---|
| 1) Test environment | | | |
| 1.1) Temperature during test (measured) | | | °C |
| 1.2) Pressure (measured) | | | kPa |
| 1.3) Relative humidity (measured) | | | |
| 2) Downlink frequency used at test | | | |
| 2.1) Centre frequency of low end channel | | | MHz |
| 2.2) Centre frequency of middle channel | | | MHz |
| 2.3) Centre frequency of high end channel | | | MHz |
| 3) Supply voltage | | | |
| 3.1) DC voltage (measured) | | | V |
| 3.2) AC voltage (measured, phase to neutral) | | | V |
| 3.3) AC Frequency (measured) | | | Hz |
| 4) Dynamic energy consumption (measured) | | | |
| 4.1) 70 % activity level | | | J |
| 4.2) 40 % activity level | | | J |
| 4.3) 10 % activity level | | | J |
| 5) Average measured data volume | | | |
| 5.1) 70 % activity level | | | kbit |
| 5.2) 40 % activity level | | | kbit |
| 5.3) 10 % activity level | | | kbit |
| 6) Measure path loss coverage test | | | dB |

**Table A.6: Calculation results to be reported in dynamic method**

| Parameter | Value | Unit |
|---|---|---|
| 1) Average power consumption at 25 °C | | W |
| 2) Site average power consumption at 25 °C | | W |
| 2.1) Used power supply factor | | |
| 2.2) Used cooling factor | | |
| 2.3) Used power feeding factor for RRH | | |
| 3) Site efficiency | | |
| 3.1) [(Output power at antenna connector at 25 °C) / (Site average power consumption at 25 °C )] × 100 | | % |
| 4) Coverage calculation | | |
| 4.1) Energy Efficiency for coverage | | $km^2/W$ |
| 5) Capacity calculation | | |
| 5.1) Total downlink throughput during the test | | kbit |
| 5.2) Energy Efficiency for capacity | | kbit/J |

**Table A.7: UE reporting table for UE at position *i***

| Item | Value | Remarks | Unit |
|---|---|---|---|
| UE Position | | | |
| Antenna attenuator for DL test | | *value of sensitivity and power correction attenuators as specified in section UE requirements* | dB |
| Antenna attenuator for UL test | | *value of sensitivity and power correction attenuators as specified in section UE requirements* | dB |
| Standard antenna connector for UE(i) (Yes/NO) | | | |
| The UE type at position *i* | | | |
| The maximum throughput $TP_{max,UEi}$ | | | kbit |
| The estimated volume of data, $\#data_{AL1,UEi}$ | | | kbit |
| The estimated volume of data, $\#data_{AL2,UEi}$ | | | kbit |
| The estimated volume of data, $\#data_{AL3,UEi}$ | | | kbit |
| The measured volume of data, $\#dataacumulated_{AL1,UEi}$ | | | kbit |
| The measured volume of data, $\#dataacumulated_{AL2,UEi}$ | | | kbit |
| The measured volume of data, $\#dataacumulated_{AL3,UEi}$ | | | kbit |
| Category | | smart phone, data card, etc. | |
| HW version | | | |
| Location ID | | Identify sector and group in the test setup | |
| Manufacturer | | | |
| Maximum specified DL data rate | | according to manufacturer data sheet | kbps |
| Maximum specified UL data rate | | according to manufacturer data sheet | kbps |
| Model name | | | |
| Modifications | | modifications of UE should be avoided | |
| Origin | | source and date of purchase | |
| Serial number | | | |
| SW version | | | |

# Annex B (normative): RBS site parameters

This annex defines RBS site reference parameters to be used for the network level energy efficiency assessment.

For site equipment that is not part of the product configuration, following reference parameter values apply:

- Power Supply Factor (PSF) depending on power supply:
  - Equipment with AC power interface: PSF = 1,0.
  - Equipment with DC power interface: PSF = 1,1.
- Cooling Factor (CF) to compensate for consumption and losses depending on type of cooling solution in order to scale different RBS equipments for outdoor conditions:
  - Indoor RBS equipment with fresh air fan based cooling solution: CF = 1,05.
  - Indoor RBS equipment with air condition controlled to 25 °C: CF = 1,5.
  - Outdoor RBS equipment: CF = 1,0.
- Power Feeding Factor (PFF) for remote units, to compensate for power supply losses for remote units:
  - Remote radio heads: PFF = 1,05.
- Feeder losses (including feeder, jumpers and connectors):
  - Standard macro RBS site configuration: 3,0 dB.
  - For TMA configurations, the UL (Uplink) feeder loss between antenna and TMA is 0,5 dB.
  - For RBS with remote radio head, UL/DL feeder loss is 0,5 dB (jumper loss).

# Annex C (normative): Coverage area definition

This annex presents a method to define RBS coverage area.

The maximum path loss for downlink $L_{Pd}$ and uplink $L_{Pu}$ can be calculated based on the downlink and uplink service requirement of voice and data:

For downlink:

$$L_{Pd} = P_{Btx} - L_{Bcom} - L_{Bf} + G_{Ba} + G_{Ma} - L_{In} - L_{Ph} - P_{Msen} - P_{margin} \quad \text{(C.1)}$$

For uplink:

$$L_{Pu} = P_{Mtx} - L_{Ph} + G_{Ma} + G_{Ba} - L_{Bf} - P_{Bsen} - P_{margin} - L_{In} \quad \text{(C.2)}$$

Okumura-Hata model is the most widely used model in radio frequency propagation for macro RBS (rural area model). The path loss is described by:

$$L_P = 69{,}55 + 26{,}16 \lg f - 13{,}82 \lg h_b - a(h_m) + (44{,}9 - 6{,}55 \lg h_b) * \lg d + C \quad \text{(C.3)}$$

$$a(h_m) = (1{,}1 \lg f - 0{,}7) h_m - (1{,}56 \lg f - 0{,}8)$$

*C = 0 dB for medium sized cities and suburban centres with moderate tree density;*

Formula (C.3) can be written as (C.4) where *A* is the fixed attenuation in Okumura-Hata model. This model can be used for rough estimation of the size of macrocells, without respect to specific terrain features in the area. The validity of the formula C.4 is the same as for the Hata model, except that the frequency range has been stretched up to 2,6 GHz in table C.1. Depending on value for *A* the formula (C.4) gives different pathloss for different frequencies stated in table C.1.

The values of *A* for different frequency band can be found in table C.1.

$$L_p = A - 13{,}82 \lg h_b - a(h_m) + (44{,}9 - 6{,}55 \lg h_b) * \lg d \quad \text{(C.4)}$$

**Table C.1: Fixed attenuation *A* in Okumura-Hata propagation model**

| Frequency (MHz) | 700 | 850 | 900 | 1700 | 1800 | 1900 | 2100 | 2600 |
|---|---|---|---|---|---|---|---|---|
| Attenuation A (dB) | *144,0* | *146,2* | *146,8* | *154,1* | *154,7* | *155,3* | *156,5* | *158,9* |

Resolving (C4) according *d* gives the radius of the coverage area:

$$d = 10^{\frac{L_P - A + 13{,}82 \lg h_b + a(h_m)}{44{,}9 - 6{,}55 \lg h_b}} \quad \text{(C.5)}$$

The coverage area can be calculated as following:

$$Coverage\_Area = \frac{9 \cdot \sqrt{3} \cdot d^2}{8} \quad \text{(C.6)}$$

**Table C.2: Propagation and path loss parameters**

| Parameters | Definition | Value |
|---|---|---|
| A | Fixed attenuation factor | According to table C.1 |
| d | The cell radius | According to formula C3 |
| f | The used frequency | According to annexes D to G |
| GBa | RBS antenna gain [dBi] | 17,5 |
| GMa | UE antenna gain [dB] | According to annexes D to F |
| Hb | RBS antenna height [m] | 40 |
| Hm | UE antenna height [m] | According to annexes D to F |
| LBcom | RBS combiner loss [dB] | Measured according to annexes D to F |
| LBf | RBS feeder and connector loss [dB] | According to annex B |
| $L_p$ | Path loss in Okumara-Hata model | Measured value in dB |
| LPh | Body loss | 3 dB for voice services / 0dB for data services |
| PBsen | RBS sensitivity [dBm] | Measured according to annexes D to F<br>3 dB RX-Div. gain shall be included here as well |
| PBtx | RBS transmit power [dBm] | Measured according to annexes D to F |
| Pmargin | Shadow fading margin [dB] | 6 |
| Lin | Indoor loss (dB) | 12 |
| PMsen | UE sensitivity [dBm] | According to annexes D to F |
| PMtx | UE transmit power [dBm] | According to annexes D to F |

# Annex D (normative): Reference parameters for GSM/EDGE system

Reference configurations for GSM/EDGE:

- Number of sectors and carriers: 222 (2 carriers per sector, 3 sectors), 444, 888.
- Power Input: -48 V DC, +24 V DC, 230 V AC.
- Nominal TX power to be used for TS with user traffic.
- RF output power level: Applicable range from 3 W to 100 W.

**GSM load model:**

The test model is derived from measurements used in clause 6.5.2 of TS 151 021 [i.5] and defines the RF output composition as shown in table D.1 and figure D.1.

For Multi Carrier Power Amplifier (MCPA) the carrier spacing shall be equidistant over the specified bandwidth. The used carrier spacing and total bandwidth shall be stated in measurement report.

Load allocation rules for:

- Busy hour load: the active time slots are equally distributed over all TRX required for the relevant test case (222, 444, 888).
- Medium and low load: the number of active TRX can be optimized with the help of energy saving features available in the BTS.

**Table D.1: Load model for GSM**

| | Low load | Medium load | Busy hour load |
|---|---|---|---|
| **Load for 222** | BCCH: Figure D.1<br>Other TRX: Idle | BCCH: Figure D.1<br>Other TRX: idle. | BCCH: Figure D.1 (TRX 1)<br>Other TRX: 2 active TS per each sector at static power level. Other TS idle. |
| **Load for 444** | BCCH: Figure D.1<br>Other TRX: Idle | BCCH: Figure D.1<br>Other TRX 6 active TS per each sector at static power level. Other TS idle. | BCCH: Figure D.1 (TRX 1)<br>Other TRX 12 active TS per each sector at static power level. Other TS idle. |
| **Load for 888** | BCCH: Figure D.1<br>Other TRX: Idle | BCCH: Figure D.1<br>Other TRX 18 active TS per each sector at static power level. Other TS idle. | BCCH: Figure D.1 (TRX 1)<br>Other TRX 36 active TS per each sector at static power level. Other TS idle. |
| **Load level duration** | 6 hours | 10 hours | 8 hours |

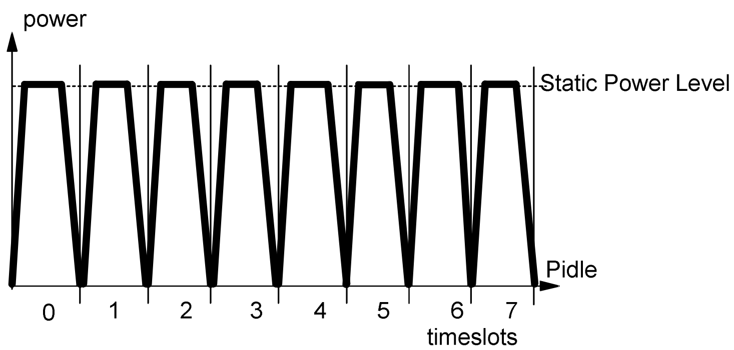


**Figure D.1: Power levels for BCCH TRX (all TS active)**

**Model for GSM subscriber and busy hour traffic:**

- CS voice traffic: 0,020 Erlangs/subscriber during Busy Hour.

**Table D.2: Busy hour traffic for GSM site**

| Model for busy hour average traffic load according to table D.1 | Busy hour traffic |
|---|---|
| S222 | 18 Erlangs (3×6) |
| S444 | 51 Erlangs (3×17) |
| S888 | 123 Erlangs (3×41) |

**Frequency bands for GSM/EDGE:**

The frequency band should be according to equipment specifications. For measurement centre frequency of the specified band is used as a reference.

Table D.3 gives examples of frequencies for bands defined in TS 145 005 [i.3].

**Table D.3: GSM/EDGE frequency bands**

| Band | Uplink [MHz] | Downlink [MHz] |
|---|---|---|
| 900 | 880 to 915 | 925 to 960 |
| 1 800 | 1 710 to 1 785 | 1 805 to 1 880 |

**Reference parameter for GSM cell size calculation:**

| Parameter | |
|---|---|
| **RBS combiner loss [dB]** | 3 dB for single carrier PA ,0 dB for MCPA |
| **UE antenna height** | 1,5 m |
| **UE antenna gain** | 0 dB |
| **UE sensitivity** | -104 dBm (static) |
| **UE RF output power** | 31 dBm (900 MHz)<br>28 dBm (1 800 MHz) (minimum 3GPP requirements) |
| **RBS transmit power for downlink** | BCCH TRX power level |
| **Downlink traffic type** | Voice |
| **Uplink traffic type** | Voice |

# Annex E (normative): Reference parameters for WCDMA/HSDPA system

**Reference configurations for WCDMA/HSDPA shall be:**

- Number of sectors and carriers: 111.
- Channel capacity: Able to handle busy hour traffic + extra 50 %.
- RF output power level:
  - Power Range applicable to the "Wide Area BS" class as defined in TS 125 104 [2].
  - Suggested maximum RF output power at antenna connector according to TS 125 141 [7]: 40 W per cell.
- Power Input: -48 V DC, 230 V AC.

**WCDMA/HSDPA static load model:**

The test model shall be according TS 125 141 [7] (V8.3.0), clause 6.1.1.1, Test Model 1. For RF output powers below 100 %, only a dedicated number of codes out of 64 (counted from top of the table) shall be used to generate the desired RF-load as stated in table E.1.

For a RF load of 50 %, only the first 15 codes listed in Test Model 1 shall be applied (DPCH power: 27,8 %).
For a RF load of 30 % only the first 3 codes shall be applied (DPCH power: 7,53 %).
Regarding a RF load of 10 % only the "Primary CPICH" shall be activated.

The DPCH power given above is relative to the maximum output power on the TX antenna interface under test. CCH contains P-CCPCH+SCH, Primary CPICH, PICH and S-CCPCH (including PCH (SF=256)).

**Table E.1: Load model for WCDMA/HSDPA**

| | Low load (10 %) | Medium load (30 %) | Busy hour load (50 %) |
|---|---|---|---|
| RF load for 111 per cell | Only Primary CPICH | CCH + first 3 codes | CCH + first 15 codes |
| Load level duration | 6 hours | 10 hours | 8 hours |

**Coverage measurement setup configuration:**

- WCDMA/HSDPA according to TS 125 141 [7], clause 6.1.1.4A Test model "5" (P-CCPCH+SCH, Primary.
- CPICH, PICH, S-CCPCH (containing PCH (SF=256)).
- **Frequency bands for WCDMA/HSDPA:**

The frequency band should be according to equipment specifications. For measurement centre frequency of the specified band is used.

Table E.2 gives examples of frequencies for bands applied in Europe and defined in [2].

**Table E.2: WCDMA/HSPA frequency bands**

| Band | Uplink [MHz] | Downlink [MHz] |
|---|---|---|
| I | 1 920 to 1 980 | 2 110 to 2 170 |
| VIII | 880 to 915 | 925 to 960 |

**Reference parameter for WCDMA/HSDPA cell size calculation:**

| Parameter | |
|---|---|
| **RBS combiner loss[dB]** | 0 dB |
| **UE antenna height** | 1,5 m |
| **UE antenna gain** | 0 dB |
| **Downlink traffic type** | Data |
| **Uplink traffic type** | Data |

# Annex F (normative): Reference parameters for LTE system

**Reference configurations for LTE shall be:**

- Only normal cyclic prefix is used.
- Number of sectors and transmitters:
  - 111 (1 TX, 2 RX-paths per sector, SIMO);
  - 111 (1 carrier, 2 TX, 2 RX-paths per sector, 2x2 MIMO);
  - at both 10 MHz and 20 MHz.

RF output power level:

- Power Range applicable to the "Wide Area BS" class as defined in TS 136 104 [12].
- For 111 configurations, the suggested RF output power at antenna connector according to reference to TS 136 141 [11] (V8.6.0): 40 W per TX path.

Power Input:

- -48 V DC, 230 V AC.

**LTE dynamic load model:**

The channels have to be configured as following:

- The Reference Signals (RS) have to be configured with the corresponding nominal power. All other channels should be configured and processed as typically done in the field.

The control format indicator CFI1 has to be used.

**LTE static load model:**

The test model shall be according TS 136 141 [11] (V8.6.0), clause 6.1.1.1, Test Model E-TM1.1, with following adaptations:

- **For low load:**
  All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted (as TM1.1).
  REs dedicated to PDCCH, PHICH and PDSCH shall not be transmitted.
- **For medium load:**
  All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted (as TM1.1).
  REs dedicated to PDCCH, PHICH and PDSCH shall be limited as following:
  - Only a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be calculated as such, for 10 MHz bandwidth 15 PRBs and 20 MHz bandwidth 30 PRBs.
  - As for the PDSCH, the amount of transmitted control channel resources shall be such that the power of the first OFDM symbol within each sub-frame accounts approximately for an average value of 30 % of the maximum rated power of the cell. This corresponds to a fixed PDCCH pattern of 72 transmitted REs at 10 MHz and 144 REs at 20 MHz.
  - REs dedicated to PHICH shall not be transmitted.

- **For busy hour load:**
  All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted (as TM1.1).
  REs dedicated to PDCCH, PHICH and PDSCH shall be limited as following:
  - Only a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be calculated as such, for 10 MHz bandwidth 25 PRBs and for 20 MHz bandwidth 50 PRBs.
  - As for the PDSCH, the amount of transmitted control channel resources shall be such that the power of the first OFDM symbol within each sub-frame accounts approximately for an average value of 50 % of the maximum rated power of the cell. This corresponds to a fixed PDCCH pattern of 144 transmitted REs at 10 MHz and 288 REs at 20 MHz.
  - REs dedicated to PHICH shall not be transmitted.

**Table F.1: Load model for LTE**

| | Low load | Medium load | Busy hour load |
|---|---|---|---|
| RF load for 111 (1 TX, 2 RX-paths per sector, SIMO),at 10 MHz | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PDCCH, PHICH and PDSCH shall not be transmitted. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 72 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be 15 PRBs. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 144 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be trans-mitted. The number of trans-mitted PRBs dedicated to PDSCH shall be 25 PRBs. |
| RF load for 111 (1 TX, 2 RX-paths per sector, SIMO), at 20 MHz | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PDCCH, PHICH and PDSCH shall not be transmitted. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 144 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be 30 PRBs. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 288 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be trans-mitted. The number of trans-mitted PRBs dedicated to PDSCH shall be 50 PRBs. |
| RF load for 111 (1 carrier, 2 TX, 2 RX-paths per sector, 2x2 MIMO), at 10 MHz | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PDCCH, PHICH and PDSCH shall not be transmitted. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 72 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be 15 PRBs. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 144 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be 25 PRBs. |

| | Low load | Medium load | Busy hour load |
|---|---|---|---|
| RF load for 111 (1 carrier, 2 TX, 2 RX-paths per sector, 2x2 MIMO), at 20 MHz | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PDCCH, PHICH and PDSCH shall not be transmitted. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 144 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be transmitted. The number of transmitted PRBs dedicated to PDSCH shall be 30 PRBs. | All REs dedicated to PCFICH, reference- and synchronization signals shall be transmitted. REs dedicated to PHICH shall not be transmitted. For the PDCCH, 288 further REs shall be transmitted within the first OFDM symbol of each sub-frame. In addition a certain number of PRBs dedicated to PDSCH shall be trans-mitted. The number of transmitted PRBs dedicated to PDSCH shall be 50 PRBs. |
| Load level duration | 6 hours | 10 hours | 8 hours |

**Coverage measurement setup configuration:**

- Bandwidth: 20 MHz or less.
- The reference signals (RS), Synchronization signals (SCH), control channels (PBCH, PCFICH, PHICH, PDCCH) and shared channel (PDSCH), have to be configured and processed the same way as done for the capacity measurements of the dynamic load model.

**Frequency bands for LTE:**

The frequency band should be according to equipment specifications. For measurement centre frequency of the specified band is used.

Table F.2 gives examples of frequencies for bands applied in Europe and defined in Reference to TS 136 104 [12].

**Table F.2: LTE frequency bands**

| Band | Uplink [MHz] | Downlink [MHz] |
|---|---|---|
| I | 1 920 to 1 980 | 2 110 to 2 170 |
| VII | 2 620 to 2 690 | 2 620 to 2 690 |
| VIII | 880 to 915 | 925 to 960 |

**Reference parameter for LTE cell size calculation:**

| Parameter | |
|---|---|
| **RBS combiner loss** | 0 dB |
| **UE antenna height** | 1,5 m |
| **UE antenna gain** | 0 dB |
| **Downlink traffic type** | Data |
| **Uplink traffic type** | Data |

# Annex G (normative): Reference parameters for WiMAX™ system

**Reference configurations for WiMAX™ system:**

- Number of sectors and carriers: 3S3C (one different carrier per sector).
- Channel BW: 5,7 MHz or 10 MHz.
- RF output power level: 2x 35 dBm (MIMO configuration) or 4x 35 dBm (Beam forming configuration) per sector.
- Power Input: -48 V DC, 230 V AC.

**WiMAX™ traffic model:**

The sub-frame ratio has impact on the RBS power consumption. For measurement the subframe ratio is 29:18 shall be according to the specification IEEE 802.16e [13].

**Table G.1: Traffic model for WiMAX™**

| | Low load | Medium load | Busy hour load |
|---|---|---|---|
| **Load for S111 at 5 MHz** | Three symbols dedicated to preamble, FCH, MAP shall be transmitted at static power level. | Three symbols dedicated to preamble, FCH, MAP and 50 % DL date symbols shall be transmitted at static power level. | Three symbols dedicated to preamble, FCH, MAP are active and 100 % DL date symbols shall be transmitted at static power level. |
| **Load for S111 at 7 MHz** | Three symbols dedicated to preamble, FCH, MAP shall be transmitted at static power level. | Three symbols dedicated to preamble, FCH, MAP and 50 % DL date symbols shall be transmitted at static power level. | Three symbols dedicated to preamble, FCH, MAP are active and 100 % DL date symbols shall be transmitted at static power level. |
| **Load for S111 at 10 MHz** | Three symbols dedicated to preamble, FCH, MAP shall be transmitted at static power level. | Three symbols dedicated to preamble, FCH, MAP and 50 % DL date symbols shall be transmitted at static power level. | Three symbols dedicated to preamble, FCH, MAP are active and 100 % DL date symbols shall be transmitted at static power level. |
| **Load level duration** | 6 hours | 10 hours | 8 hours |

**Frequency bands for WiMAX™:**

The frequency band should be according to equipment specifications. For measurement centre frequency of the specified band is used.

Table F.2 gives examples of frequencies for bands defined in WiMAX™ Forum Mobile system profile:

- Table F.2 defines the RF channels to be calculated using the following formula:

$$RFChannel_n = F_{start} + n \cdot \Delta F_c, \forall n \in N_{range}$$

Where:

$F_{start}$ is the start frequency for the specific band;

$\Delta F_c$ is the centre frequency step;

$N_{range}$ is the range values for the n parameter.

**Table G.2: Example of centre frequency definition for WiMAX™**

| RF Profile Name | Channel BW (MHz) | Centre Frequency Step (KHz) | $F_{start}$ (MHz) | $N_{range}$ | Comment |
|---|---|---|---|---|---|
| Prof1.B_2.3-5 | 5 | 250 | 2 302,5 | {0 to 380} | |
| Prof1.B_2.3-10 | 10 | | 2 305 | {0 to 360} | |
| Prof2.B_2.305 | 5 | 250 | 2 307,5 and 2 347,5 | {0 to 40} | |
| Prof2.C_2.305 | 10 | 250 | 2 310 and 2 350 | {0 to 20} | |
| Prof3.A_2.496-5 | 5 | 250 | 2 498,5 | {0 to 756} | 200 KHz Frequency step is considered for Europe 2,5 GHz extension. |
| Prof3.A_2.496-10 | 10 | | 2 501 | {0 to 736} | 200 KHz Frequency step is considered for Europe 2,5 GHz extension. |
| Prof5.A_3.4 | 5 | 250 | 3 402,5 | {0 to 1 580} | |
| Prof5L.A_3.4 | | | | {0 to 780} | |
| Prof5H.A_3.4 | | | | {800 to 1 580} | |
| Prof5.B_3.4 | 7 | 250 | 3 403,5 | {0 to 1 572} | |
| Prof5L.B_3.4 | | | | {0 to 772} | |
| Prof5H.B_3.4 | | | | {800 to 1 572} | |
| Prof5.C_3.4 | 10 | 250 | 3 405 | {0 to 1 560} | |
| Prof5L.C_3.4 | | | | {0 to 760} | |
| Prof5H.C_3.4 | | | | {800 to 1 560} | |

# Annex H (normative): Definition of load level

The UEs shall be connected to each sector of the RBS via power splitters and attenuators according to the method described in clause 6.4.2.1 and with the total path loss for the different UEs as defined in table H.1. The power levels for the pilot channels (CPICH for HSPA and RS for LTE) at the respective UE groups shall be as stated in table H.2.

Based on the path loss L defined in table H.1 the required pilot channel power can be calculated with formula H.1.

$$L_{UE,i} = P_{pilot\ channel,BS} - P_{pilot\ channel,UE,i} \qquad \text{(H.1)}$$

Where:

$L_{UE,i}$ the required total attenuation between the antenna connector of the RBS and the UE group i;

$P_{pilot\ channel,BS}$ the power levels of the pilot channel transmitted at RBS;

$P_{pilot\ channel,UE,i}$ the power levels of the pilot channel received at the UE group i.

**Table H.1: Total attenuation for different UE groups for different RAT**

| | Path loss for UE group 1 [dB] | Path loss for UE group 2 [dB] | Path loss for UE group 3 [dB] | Path loss for UE group 4 [dB] |
|---|---|---|---|---|
| WCDMA/HSPA | 85 | 100 | 115 | 130 |
| LTE | 85 | 100 | 115 | 130 |

The pilot channel power allocation shall be made to achieve the following signal levels at each UE defined in table H.2.

**Table H.2: Received pilot signal strength at different UE groups for different RAT**

| Technology | Control channel power | Received signal strength at UE group 1 [dBm] | Received signal strength at UE group 2 [dBm] | Received signal strength at UE group 3 [dBm] | Received signal strength at UE group 4 [dBm] |
|---|---|---|---|---|---|
| WCDMA/HSPA | CPICH = 33dBm | -52 | -67 | -82 | -97 |
| LTE | RS = 15,2dBm | -69,8 | -84,8 | -99,8 | -114,8 |

The same path loss settings and received pilot signal strength shall be used for the test, independent of the total RF power of the base station in the wide area BS category defined in [2] and [12]. This will ensure that all capacity tests are carried out for the same cell size.

During the test, the UEs will receive data generated by IPERF or similar tool. The amount of data sent to each UE is defined according to clause 6.4.3 and is sent to each UE based on the equation (H2) for transmission timer $T_{t,UEi}$ and table H.4.

In LTE there is 1 UE in each UE group.

In WCDMA/HSPA there is 1 UE per carrier in each UE group.

A duty cycle includes the time for both activity level and the silence period. The total number of duty cycles during each test is $n = 10$.

There are three activity levels defined, 10 %, 40 % and 70 % corresponding to low, medium and busy hour traffic, see table H.3.

The activity levels are distributed over the time in a way that 10 % activity level is related to 6 hours a day, 40 % to 10 hours and 70 % to 8 hours. This distribution is weighted by factor *c* according to table H.3.

UDP (User Data Protocol) is used to generate data.

The tolerance factor TF is 0,25.

**Table H.3: Time duration and weighting factor for duty cycle and different activity levels**

| | Low traffic (10 %) | Medium traffic (40 %) | Busy hour traffic (70 %) |
|---|---|---|---|
| *T*, activity time [s] | 4 | 16 | 28 |
| $T_D$, Duty cycle time [s] | 40 | 40 | 40 |
| n, number of duty cycles | 10 | 10 | 10 |
| Hours during a day [hours] | 6 | 10 | 8 |
| Weighting factor, c | 0,25 | 0,42 | 0,33 |

*T* is activity time for generating data by IPERF or similar tool during each duty cycle. This time is in seconds.

$T_D$ is the time for each duty cycle including both transmission and silence period.

*M* is the number of UE groups in each sector.

$T_{t,UEi}$ is the transmission time for data generated by IPERF or similar tool to different UE groups, see equation (H.2).

$T_{s,UE1}$ is the silence time when no data is transferred by IPERF or similar tool for each UE group during each duty cycle, see equation (H.3).

$$T_{t,UEi} = \frac{T}{M} \times i, \text{ for } i = 1, 2, \ldots M \qquad \text{(H.2)}$$

$$T_{s,UEi} = T_D - T_{t,UEi} \text{ for } i = 1, 2, \ldots M \qquad \text{(H.3)}$$

**Table H.4: Transferring and silence time for each UE group for different activity levels**

| | Low traffic (10 %) | | Medium traffic (40 %) | | Busy hour traffic (70 %) | |
|---|---|---|---|---|---|---|
| | $T_t$ [s] | $T_s$ [s] | $T_t$ [s] | $T_s$ [s] | $T_t$ [s] | $T_s$ [s] |
| UE group 1 | 1 | 39 | 4 | 36 | 7 | 33 |
| UE group 2 | 2 | 38 | 8 | 32 | 14 | 26 |
| UE group 3 | 3 | 37 | 12 | 28 | 21 | 19 |
| UE group 4 | 4 | 36 | 16 | 24 | 28 | 12 |

Figure H.1 shows the data traffic pattern for different UE groups with different transmission and silence time.

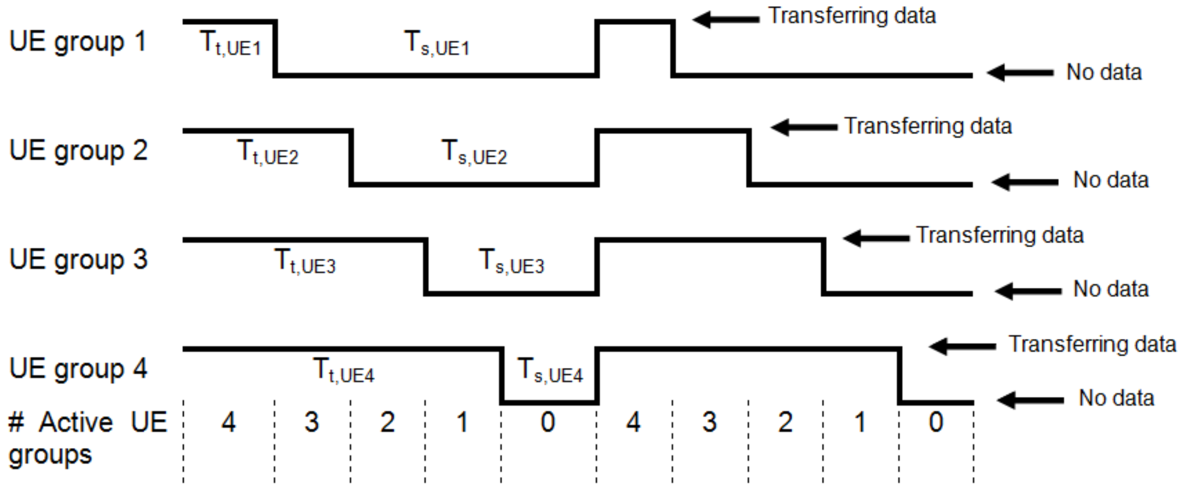


**Figure H.1: Data traffic model for each UE group**

# Annex I (informative): Uncertainty assessment

This annex suggests methods by which to carry out the global uncertainty assessment.

The wireless network efficiency data produced by the methods detailed in the present document will be subject to uncertainty due to the tolerance of measurement procedures or variance of real installations to the standard models suggested. The uncertainty of the measured parameters can be evaluated and will therefore provide comparable data, whilst that of the models used is subjective and should be assigned a sensitivity to assess significance.

Determination of an absolute value for wireless network efficiency uncertainty is beyond the scope of the present document, but guidelines for assessment are suggested.

Suitable parameters for the input quantities may be taken from the clauses of the present document.

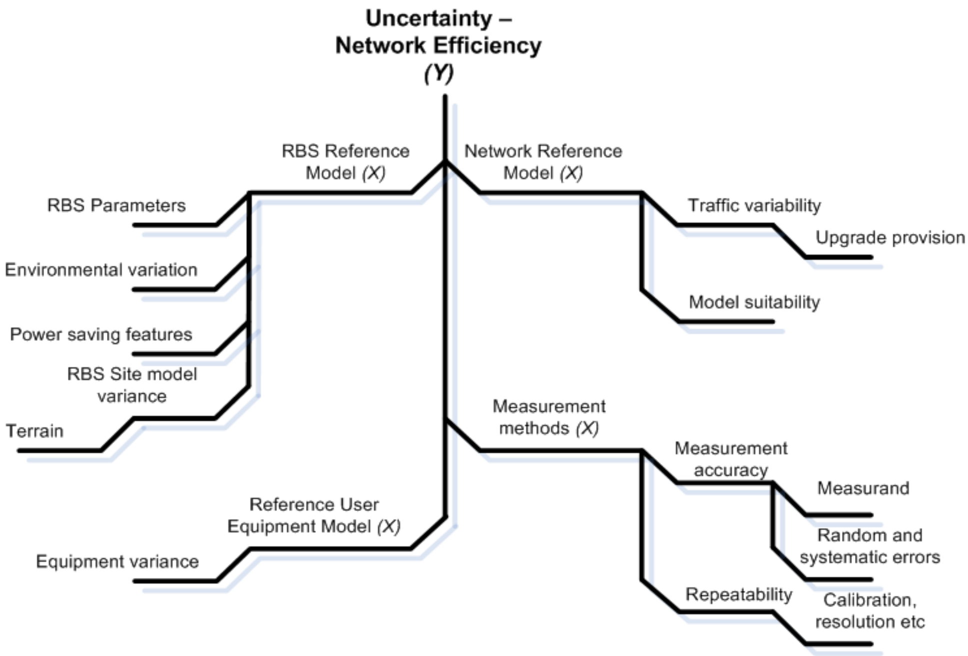


**Figure I.1**

Uncertainty factors may be grouped into two categories according to the method used to estimate their numerical value:

- Type A: Those which are evaluated by statistical means.
- Type B: Those which are evaluated by other means, usually by scientific judgment using information available.

***Measurement method uncertainty:*** This parameter may be considered a standard uncertainty of type A which is derived from known data and produces normal distribution to a quantifiable standard deviation. Subsections of this parameter include measurement accuracy and repeatability which may be evaluated by a measurement system analysis.

***Reference user equipment:*** The model can be considered a type B evaluation and subject to some variance with the actual equipment in use due to variation of performance of subscriber equipment.

***Network reference uncertainty:*** This parameter can be considered a type B evaluation being subject to some variation due to traffic model inaccuracies or model suitability.

***RRBS reference model uncertainty:*** This uncertainty is a combination of type A - RRBS parameters, and type B - environmental and site model variance.

**Data distribution**

Estimates for upper and lower uncertainty limits ($a_+$ to $a_-$) will be subject to a quantity distribution according to the data model. A normal distribution will be quantified by $Uj = (a_+ - a_-)/2$. If the data distribution used to model the quantity is triangular then $Uj = (a_+ - a_-)/\sqrt{6}$.

In the absence of any other information it is reasonable to assume that the quantity is equally probable to lie anywhere between upper and lower limits and therefore follows a rectangular distribution, and is therefore quantified by:

$$Uj = (a_+ - a_-)/\sqrt{3}.$$

**Combined uncertainty**

The combined system uncertainty in its simplified form can be defined by the following expression:

$$Y = a_1X_1, a_2X_2, a_3X_3, a_nX_n\ldots$$

Where:

$Y$ = Uncertainty.

$a_n$= Input sensitivity.

$Xn$= Input quantity.

Combination of uncertainty factors to evaluate total uncertainty ($Y$) uses the RSS (Root Sum of Squares) method. An example uncertainty budget is shown in table I.1.

**Table I.1**

| Source of Uncertainty | | Value ±% | Probability Distribution | Divisor | Sensitivity Coefficient $a_n$ | *Standard Uncertainty $U_i$ ±%* | |
|---|---|---|---|---|---|---|---|
| $X_1$ | Measurement Uncertainty | | | | | | 1,31 |
| | Calibration factor | *2,5* | normal | 2 | 1 | 1,25 | |
| | Drift since last calibration | *0,5* | rectangular | sqrt(3) | 1 | 0,29 | |
| | Instrumentation Uncertainty | *0,5* | normal | 2 | 1 | 0,25 | |
| $X_2$ | Network Reference Model | 5 | rectangular | sqrt(3) | | | 2,89 |
| $X_3$ | RRBS Reference Model | 5 | rectangular | sqrt(3) | 1 | | 2,89 |
| $X_4$ | Reference User Equipment Model | 5 | rectangular | sqrt(3) | 1 | | 2,89 |
| $U_C(Y)$ | ***Combined Standard Uncertainty*** | | **normal** | | | | **5,17** |
| $U(Y)$ | ***Expanded Uncertainty*** | | **normal** | **2** | | | **10,34** |

If a more detailed uncertainty assessment is required the following publications are suggested:

- NIST Technical Note 1297 [i.1].
- ISO/IEC Guide 98: 1995 [i.2].

# Annex J (informative): Example assessment

This annex presents results of a fictive assessment for 900 MHz GSM system. The system reference parameters are listed in table J.1 and results in tables J.2 and J.3.

**Table J.1: Reference parameters of fictive 900 MHz GSM RBS**

| Parameter | Value | Unit |
|---|---|---|
| 1) RBS configuration | | |
| 1.1) Number of sectors | 3 | |
| 1.2) Number of Carriers or TRXs per sector | 2 | |
| 1.3) TX diversity | Cross polar antenna | |
| 1.4) RX diversity | Two way diversity | |
| 1.5) Type of RF signal combining | Air combining with cross polar antenna | |
| 2) Frequency | | |
| 2.1) Downlink band | 925 to 960 | MHz |
| 2.2) Uplink band | 880 to 915 | MHz |
| 2.3) Channel bandwidth | 0,20 | MHz |
| 3) Environment | | |
| 3.1) Temperature range | -33 to +40 | °C |
| 3.2) Type of air filter | NA | |
| 4) Features | | |
| 4.1) Power saving features | None | |
| 4.2) Coverage and capacity features | None | |

**Table J.2: Measurements conditions and results of fictive 900 MHZ GSM RBS**

| Parameter | Test case 25 °C | Test case 40 °C | Unit |
|---|---|---|---|
| 1) Tested equipment | | | |
| 1.1) Tested HW unit names & serial numbers | Baseband TT99, SN 1234567-A<br>RF TT88, SN 1234567-B | | |
| 1.2) Software version of tested equipment | SW release 3.14 | | |
| 2) Test environment | | | |
| 2.1) Temperature during test (measured) | 25,3 | 40,2 | °C |
| 2.2) Pressure (measured) | 102,5 | 102,6 | kPa |
| 2.3) Relative humidity (measured) | 41 % | 46 % | |
| 3) Downlink frequency used at test | | | |
| 3.1) Centre frequency of low end channel | 925,1 | 925,1 | MHz |
| 3.2) Centre frequency of middle channel | 942,5 | 942,5 | MHz |
| 3.3) Centre frequency of high end channel | 959,9 | 959,9 | MHz |
| 4) Supply voltage | | | |
| 4.1) DC voltage (measured) | 54,0 | 54,0 | V |
| 4.2) AC voltage (measured, phase to neutral) | NA | NA | V |
| 4.3) AC Frequency (measured) | NA | NA | Hz |
| 5) Power consumption (measured) | | | |
| 5.1) Busy hour load, Middle frequency channel | 819 | 840 | W |
| 5.2) Medium load, Middle frequency channel | 681 | 698 | W |
| 5.3) Low load | | | |
| 5.3.1) Low end frequency channel | 642 | 663 | W |
| 5.3.2) Middle frequency channel | 640 | 661 | W |
| 5.3.3) High end frequency channel | 644 | 665 | W |
| 5.3.4) Average consumption with low load | 642 | 663 | W |
| 6) TX output power (pilot signal only) | | | |
| 6.1) Output power at low end channel | 41,7 | 41,7 | W |
| 6.2) Output power at middle end channel | 41,8 | 41,8 | W |
| 6.3) Output power at high end channel | 41,6 | 41,6 | W |
| 6.4) Average output power per sector | 41,7 | 41,7 | W |
| 7) RX receiver sensitivity at middle channel | -113,0 | -113,0 | dBm |

**Table J.3: Assessment results for fictive 900 MHz GSM RBS**

| Parameter | Value | Unit |
|---|---|---|
| 1) Average power consumption at 25 °C | 717 | W |
| 2) Average power consumption at 40 °C | 737 | W |
| 3) Site average power consumption at 25 °C | 789 | W |
| 3.1) Used power supply factor | 1,1 (DC feed) | |
| 3.2) Used cooling factor | 1,0 (outdoor RBS) | |
| 3.3) Used power feeding factor for RRH | NA | |
| 4) Site average power consumption at 40 °C | 868 | |
| 4.1) Used power supply factor | 1,1 (DC feed) | |
| 4.2) Used cooling factor | 1,0 (outdoor RBS) | |
| 4.3) Used power feeding factor for RRH | NA | |
| 5) Rural area (only for GSM system) | | |
| 5.1) Calculated uplink coverage area | 106 | $km^2$ |
| 5.2) Calculated downlink coverage area | 173 | $km^2$ |
| 5.3) Performance indicator for rural area | 0,12 (=106/868) | $km^2$/W |
| 6) Urban area (only for GSM system) | | |
| 6.1) Busy hour capacity | 900 (=18 erlangs / 0,020 erlangs) | Subscribers |
| 6.2) Performance indicators for rural area | 1,0 (=900/868) | Subscribers/W |

# Annex K (informative): Derivation of formula in clause 6.4.3

This annex shows the derivation of formula mentioned in clause 6.4.3.

For better understanding the contents of this clause it is assumed that any group of UE is composed just by only one UE.

To not prioritize the cell centre UE with the best throughput compared with the cell border UE, it is required to have an equal distribution of the resources over the time for all active UE having available input data and this is to be checked by the following method.

The UE maximum throughput depends on the individual UE position in the cell (attenuation), as well on the number of UEs with active data to be scheduled.

Note that the measured UE maximum Throughput is not depending on the activation-level.

**The measured maximum Throughput per UE:**

The individual UE Throughput-maximum ($TPmax_{UE1}$, … $TPmax_{UE4}$) is measured with different number of UEs with active data to be scheduled:

- $TPmax_{UE4}$ is measured with UE4 alone in the cell.
- $TPmax_{UE3}$ is measured when sharing the resources together with UE4.
- $TPmax_{UE2}$ is measured when sharing the resources together with UE4 and UE3.
- $TPmax_{UE1}$ is measured when sharing the resources together with UE4 and UE3 and UE2.

Annex H defines the scenarios of the appearance of the activity level per UE. Due to the fixed scenario there are 5 different phases, defined by the UEs, which receive their data during their activity levels:

The 5 phases, with active data of the UEs:

- Ph1: UE1, UE2, UE3, UE4
- Ph2: UE2, UE3, UE4
- Ph3: UE3, UE4
- Ph4: UE4
- Ph5: idle (no UE)

NOTE: The phases Ph1 to Ph4 are of the same duration (see clauses annex H for definition of activity level).

**The evaluated averaged Throughput per UE per transmission time:**

Example for UE4:

$TPmax_{UE4}$ is measured during Phase4, when UE4 is alone in the cell and gets all physical resources (LTE: PRB of PDSCH).

During Phase3, the UE4 has to share its resources with another UE, so there are 2 UEs in the cell:

$$TP_{Ph3,UE4} = 1/2 \times TP_{Ph4,UE4} = 1/2 \times TPmax_{UE4} \quad \textbf{(}K.0)$$

Analogue for the other phases the throughput is estimated as following:

1) TP estimation of UE4 for its transmission time, $T_{t,UE4}$:

$TP_{Ph4,UE4} = TPmax_{UE4} \times 1/1 = TPmax_{UE4} \times 12/12$

$TP_{Ph3,UE4} = TPmax_{UE4} \times 1/2 = TPmax_{UE4} \times 6/12$

$TP_{Ph2,UE4} = TPmax_{UE4} \times 1/3 = TPmax_{UE4} \times 4/12$

$TP_{Ph1,UE4} = TPmax_{UE4} \times 1/4 = TPmax_{UE4} \times 3/12$

**$TP_{t,UE4}$ = average of all phases = $TPmax_{UE4} \times 25/12 / p_{UE4}$**

2) TP estimation of UE3 for its transmission time, $TP_{t,UE3}$:

$TP_{Ph3,UE3} = TPmax_{UE3} \times 1/1 = TPmax_{UE3} \times 12/12$

$TP_{Ph2,UE3} = TPmax_{UE3} \times 2/3 = TPmax_{UE3} \times 8/12$

$TP_{Ph1,UE3} = TPmax_{UE3} \times 2/4 = TPmax_{UE3} \times 6/12$

**$TP_{t,UE3}$ = average of all phases = $TPmax_{UE3} \times 26/12 / p_{UE3}$**

3) TP estimation of UE2 for its transmission time, $TP_{t,UE2}$:

$TP_{Ph2,UE2} = TPmax_{UE2} \times 1/1 = TPmax_{UE2} \times 12/12$

$TP_{Ph1,UE2} = TPmax_{UE2} \times 3/4 = TPmax_{UE2} \times 9/12$

**$TP_{t,UE2}$ = average of all phases = $TPmax_{UE2} \times 21/12 / p_{UE2}$**

4) TP estimation of UE1 for its transmission time, $TP_{t,UE1}$:

$TP_{Ph1,UE1} = TPmax_{UE1}$

**$TP_{t,UE1}$ = average of all phases = $TPmax_{UE1} / p_{UE1}$**

**General:**

$$TP_{t,UEi} = TPmax_{UEi} \times SF_{UEi} / p_{UEi} \quad (K.1)$$

Where:

- $TP_{t,UEi}$ is the averaged throughput during the active window of UE Group i;
- $TPmax_{UEi}$ is the measured maximum Throughput per UE-Group i;
- $SF_{UEi}$ is the Scenario dependent Factor per UE Group i, elaborated before (e.g. $SF_{UE4} = 25/12$);
- $p_{UEi}$ is the number of different phases during the UE transmission time, equal to the UE group index:
  - $p_{UE1} = 1$; $p_{UE2} = 2$; $p_{UE3} = 3$; $p_{UE4} = 4$.

Finally, the sum of the received data per UE can be evaluated and compared with real received data:

- The real received data are those of the different Activation levels, but not yet weighted with the correction factor of the traffic model.
- The number of (correctly) received data per UE and per Activity Level, $\#Data_{x,UE1}$, … $\#Data_{x,UE4}$:
  - This is the sum of (correctly) received data per UE of all duty cycles per activity-level.
- The phase duration is given by duty cycle time $T_D$, activity Factor $AF_x$ and number of UE Groups M:
  - Phase duration = $T_D \times AF_x / M$.
- The number of phases per UE group = $p_{UEi}$. It is given by the UE group index.

- The #data have to be calculated on a Phase basis, multiplied with the number of phases.

A **tolerance factor TF** is introduced (see annex H), so the number of data (#Data) is allowed to be less than evaluated in the margin of example TF = 25 %.

**Derivation of formula 6.b:**

- #Datax,UEi ≥ TP × t × (1-TF)
- #Datax,UEi ≥ TPt,UEi × n × TD × AFx / M × pUEi × (1-TF)
- #Datax,UEi ≥ TPmaxUEi × SFUEi / pUEi × n × TD × AFx / M × pUEi × (1-TF)
- #Datax,UEi ≥ TPmaxUEi × SFUEi × n × TD × AFx / M × (1-TF)
- $\#Data_{x,UEi} \geq TPmax_{UEi} \times SF_{UEi} \times n \times T_D \times AF_x / M \times (1\text{-}TF)$ (K.2)

Where:

- $\#Data_{x,UEi}$ is the tolerated, evaluated amount of data per UE-Group per Activation Level x;
- n is the number of duty cycles per activity level;
- $T_D$ is the duty cycle duration;
- x is the Activity level;
- $AF_x$ is the activityFactor per Activity level x;
- M is the number of UE Groups;
- $TPmax_{UEi}$ is the measured maximum Throughput per UE-Group i;
- $SF_{UEi}$ is the Scenario dependent Factor per UE-Group i, elaborated before (e.g. $SF_{UE4}$ = 25/12);
- TF is the tolerance factor.

With current values (e.g. $SF_{UE4}$ = 25/12; $SF_{UE3}$ = 26/12; $SF_{UE2}$ = 21/12; $SF_{UE1}$ = 12/12; n = 10; TD = 40 s; M = 4; TF = 0,25), the number of data per UE per Activity Level is evaluated as:

- $\#Data_{x,UEi} \geq$ **$TPmax_{UEi}$** × **$SF_{UEi}$** × 10 × 40 s × AFx / 4 × 75 %
- $\#Data_{x,UE1} \geq TPmax_{UE1}$ × 75 s × AFx
- $\#Data_{x,UE2} \geq TPmax_{UE2}$ × 131,25 s × AFx
- $\#Data_{x,UE3} \geq TPmax_{UE3}$ × 162,5 s × AFx
- $\#Data_{x,UE4} \geq TPmax_{UE4}$ × 156,25 s × AFx

Note that here an example is computed and that the formula has to be used with actual parameter settings.

# History

| Document history | | |
|---|---|---|
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| V1.3.1 | July 2013 | Publication |
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