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Technical Specification

Environmental Engineering (EE)
Energy Efficiency of Wireless Access Network Equipment

Reference
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Contents

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Foreword

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

Introduction

Energy efficiency is one critical factor of modern telecommunication systems. The power consumption of the access network is the dominating part of the wireless telecom network. Hence the Core Network and Service Networks are not considered in the first version of 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 GSM system 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 following radio access technologies:

- GSM/EDGE.
- WCDMA.
- WiMAX^{TM}.

As the RBS energy consumption is the dominant part of total energy consumption of wireless access network, the present document version covers methods which takes into account only the RBS site energy consumption when defining the total power consumption of wireless access networks. Functionality located in RNC or BSC nodes may however have significant impact on power consumption of base station nodes. These are however not included in the present document.

The present document describes the network efficiency based on "static" measurements of the RBS power consumption. In a later version of the present docuement, the efficiency based on dynamic measurements (including the functionality located in the radio network controller e.g. BSC/RNC and dynamic traffic load) will be defined.

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

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

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

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
  - for informative references.

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 indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

[1] ETSI TS 145 005: "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception (3GPP TS 45.005 Release 8)".

[2] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104 Release 8)".

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

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

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

[6] ETSI TS 151 021: "Digital cellular telecommunications system (Phase 2+); Base Station System (BSS) equipment specification; Radio aspects (3GPP TS 51.021 Release 8)".

[7] ETSI TS 125 141: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) conformance testing (FDD) (3GPP TS 25.141 Release 8)".

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

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

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Not applicable.

3 Definitions and abbreviations

3.1 Definitions

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

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

busy hour load: average RBS load during busy hour

concentrated RBS: RBS architecture in which all RBS element are located close to each other for example in one or two cabinet

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

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

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

low load: average RBS load during time when there is only very low traffic in network

medium term load: defined RBS load level between busy hour and low load levels

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

power saving feature: feature which decreases power consumption comparing to the case if the feature is not implemented

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

RBS text 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 without variations in the load during single test case test, e.g. no fading or traffic variations are applied during the measurement

telecommunication network: network operated under a license granted by a national telecommunications authority, which provides telecommunications between Network Termination Points (NTPs)

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:

BCCH	Broadcast Control CHannel
BH	Busy Hour
BSC	Base Station Controller
CCH	Common CHannel
CDF	Cumulative Distribution Function
CE	Channel Element
CF	Cooling Factor
CPICH	Common PIlot CHannel
CS	Circuit Switched
DL	DownLink
DPCH	Dedicated Physical CHannel
EDGE	Enhanced Datarate GSM Evolution
GSM	Global System for Mobile communication
GUM	Guide to the expression of Uncertainty in Measurement
HSPA	High Speed Packet Access
HW	HardWare
MCPA	Multi Carrier Power Amplifier
NA	Not Applicable
NIST	National Institute of Standards and Technology
NTP	Network Termination Point
PCM	Pulse Code Modulation
PDF	Proportional Distribution Function
PSF	Power Supply Factor
QPSK	Quadrature Phase Shift Keying
RBS	Radio Base Station
RF	Radio Frequency
RNC	Radio Network Controller
RRH	Remote Radio Head
RX	Receiver
SDH	Synchronous Digital Hierarchy
SW	SoftWare
TMA	Tower Mount Amplifier
TRX	Transceiver
TS	Time Slot
TX	Transmitter
UE	User Equipment
UL	UpLink
WCDMA	Wideband Code Division Multiple Access
WiMAX™	Worldwide interoperability for Microwave Access

4 Assessment method

4.1 Assessment principle

The present document defines three level assessment methods 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 for GSM system which is based on RBS site energy consumption as well as site coverage area and capacity. These indicators provides 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:

1) Identify RBS basic parameters (table A.1 in annex A).
2) List RBS configuration and traffic load(s) for measurements (annexes D to F).
3) Measure RBS equipment power consumption for required load levels.
4) Calculate RBS equipment average power consumption according to equation 1 (a to d).
5) List required RBS site level correction factors (annex B).
6) Calculate RBS site average power consumption according to equation 2 (a and b).
7) Calculate site coverage area (annex C).
8) Define site busy hour capacity (annex D).
9) Calculate network level performance indicators.
10) Document results.

Steps 1 to 4 and 10 are mandatory and steps 5 to 6 optional. Steps 7 to 9 are valid only for GSM system (optional steps for GSM system like steps 5 to 6).

5 Energy efficiency model for wireless access networks

5.1 RBS equipment power 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 [1] and [2]. The RBS may in each cell serve one or multiple carriers.

The appropriate wireline based transmission (a transport function for E1/T1 or similar providing capacity corresponding to the RBS capacity) must be included in the RBS configuration during testing.

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

- 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.

5.1.1 Concentrated RBS

The power consumption of concentrated RBS equipment is defined for three different load level 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 detailed for a given system. The model covers voice and/or data hour per hour. The models are provided in annexes D to F.

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

$$P_{equipment} = \frac{P_{BH} \cdot t_{BH} + P_{med} \cdot t_{med} + P_{low} \cdot t_{low}}{t_{BH} + t_{med} + t_{low}}, \tag{1a}$$

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).

5.1.2 Distributed RBS

The power consumption of distributed RBS equipment is defined for three different load level as following (for details of load levels see annexes D to F):

- $P_{BH,C}$ 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:

$$P_{equipment} = P_C + P_{RRH}, \tag{1b}$$

in which P_C and P_{RRH} [W] are average power consumption of central and remote parts defined as:

$$P_C = \frac{P_{BH,C} \cdot t_{BH} + P_{med,C} \cdot t_{med} + P_{low,C} \cdot t_{low}}{t_{BH} + t_{med} + t_{low}}, \tag{1c}$$

$$P_{RRH} = \frac{P_{BH,RRH} \cdot t_{BH} + P_{med,RRH} \cdot t_{med} + P_{low,RRH} \cdot t_{low}}{t_{BH} + t_{med} + t_{low}}, \quad (1d)$$

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 5.2.

5.2 RBS site energy 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.

Parts to 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's. 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 AC 230V.
- Different cooling solutions. For the reference RBS site ambient air temperature is +25 °C and +40 °C (optionally at +5 °C for outdoor BTS).
- Power supply losses. For distributed BTS a reference loss for RRH power supply is included.

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

$$P_{site} = PSF \cdot CF \cdot P_{equipment} \quad (2a)$$

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:

$$P_{site} = PSF_C \cdot CF_C \cdot P_C + PSF_{RRH} \cdot CF_{RRH} \cdot PFF \cdot P_{RRH}, \quad (2b)$$

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.

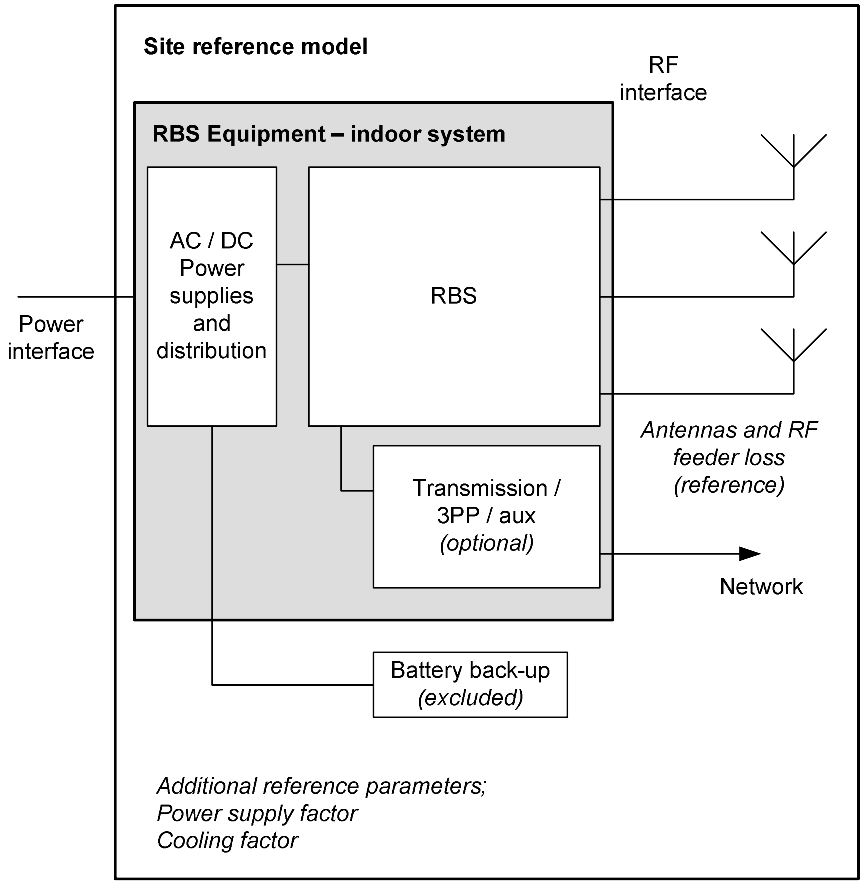

Figure 1: Indoor RBS site model showing RBS equipment and support system infrastructure

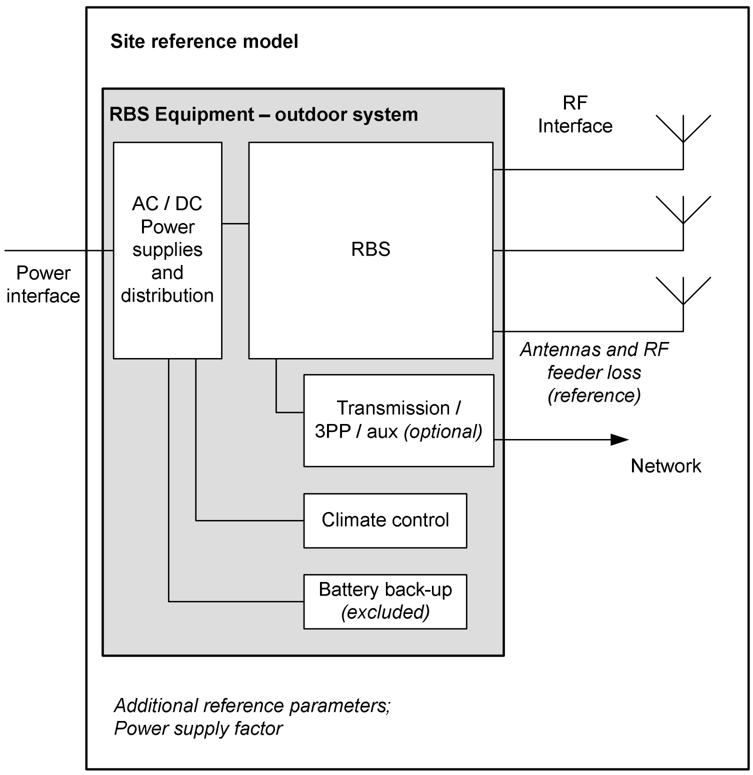

Figure 2: Outdoor RBS site model showing RBS equipment and support system infrastructure

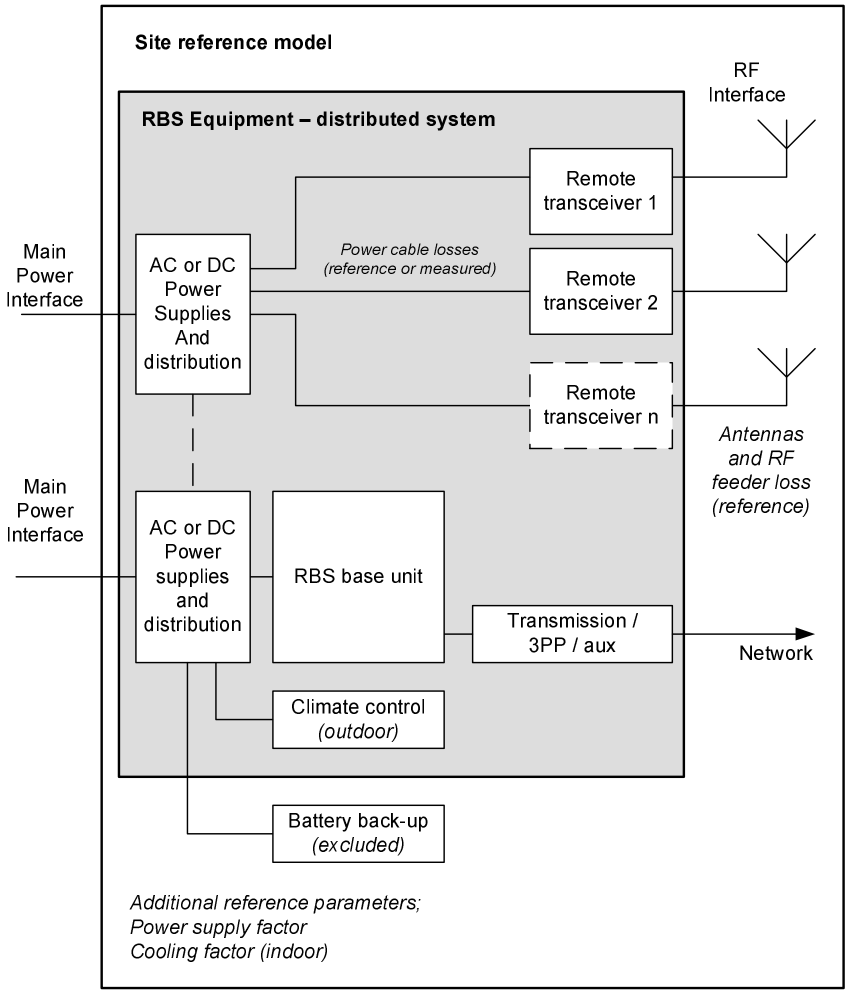

Figure 3: Distributed RBS site model showing RBS equipment and support system infrastructure

5.3 Network level energy efficiency for GSM

The network level energy efficiency provides a mean to evaluate the energy efficiency of wireless access network at network 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.

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 network level performance indicator [km^2/W] for rural area is defined as:

$$PI_{rural} = \frac{A_{coverage}}{P_{site}}, \tag{3}$$

in which $A_{coverage}$ 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 how to calculate system values and respectively cell radius see annex C). The limiting value of uplink and downlink coverage areas is used. Both coverage areas are calculated under low traffic load situation. For downlink calculation the RBS pilot signal power level and UE receiver sensitivity and traffic type defined in annexes D to F is used. For uplink calculation the measured RBS receiver sensitivity with UE transmission power and traffic type defined in annexes D to F are used.

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

$$PI_{urban} = \frac{N_{busy\_hour}}{P_{site}}, \quad (4)$$

in which 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 D1.

6 Measurement methods

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

6.1.1 General

Depending on the type of test the RBS shall be operated in a test and measuring environment for static measurements as illustrated in figure 4.

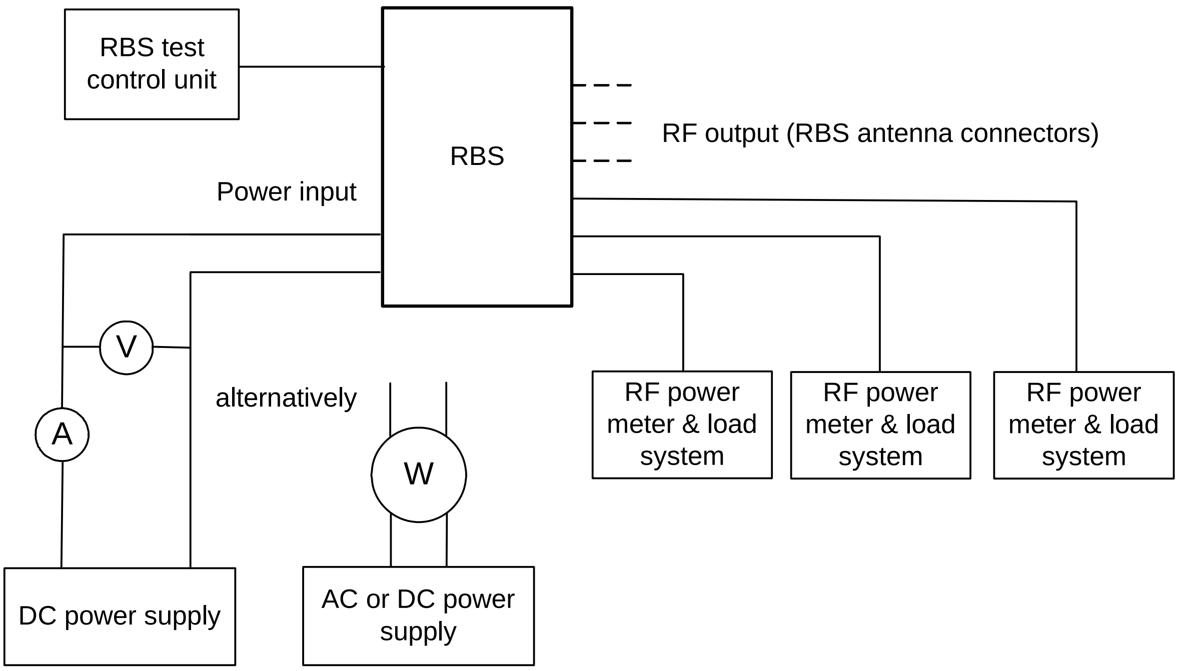

Figure 4: Test set-up for static measurements

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.

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.

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 F.

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.

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.

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

If the RBS has a distributed architecture, e.g. Radio Server - Remote Radio Head concept, the power consumption of both subunits have to measured and added for the evaluation. This is also true, if the radio unit is fed by the baseband unit. The appropriate correction factor to consider DC feeder losses which occur in field between radio unit and baseband unit is described in annex B.

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

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 F.

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, shall be fulfilled.

6.2.4 Environmental conditions

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

Condition	Minimum	Maximum
Barometric pressure	86 kPa (860 mbar)	106 kPa (1 050 mbar)
Relative Humidity	20 %	85 %
Vibration	Negligible	
Temperature	+25 °C and +40 °C. Optionally test at +5 °C can be done.	
Temperature accuracy	±2 °C	

6.2.5 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):

Type	Standard	Nominal value	Operating value for testing
AC	BS EN 50160 [3]	230 V	230 V ± 15 V (each phase to neutral)
DC	EN 300 132-2 [4]	-48 V	-54,5 V ± 1,5 V

The frequency of the power supply corresponding to the AC mains shall be according to BS EN 50160 [3].

6.3 Measurement procedure

6.3.1 Tests to be performed

The power consumption measurements shall be performed when stable temperature conditions inside of the equipment are reached. For this purpose the RBS shall be placed in the environmental conditions for two hours minimum 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 in 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 F.

The RF output power signal and levels shall be generated according to the 3GPP test models described in annexes D to F.

Stimulation shall be realized via the RBS controller interface.

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

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

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

6.3.2 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.

In addition the measurement report shall include the following information:

- Date and location of the test.
- Name(s) of the responsible(s).
- Model(s) and serial number(s) of the RBS and terminals.
- Data of the used measurement equipment (type, serial number, calibration information).

Further guidelines on the test report can be found in clause 5.10 of ISO/IEC 17025 [5].

Annex A (normative): RBS parameters

Table A.1: RBS reference parameters to be reported

Parameter	Value	Unit
1. RBS configuration		
1.1 Number of sectors		
1.2 Number of Carriers or TRXs per sector		
1.3 TX diversity		
1.4 RX diversity		
1.5 Type of RF signal combining		
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.2: Measurements conditions and results to be reported

Parameter	Test case 25 °C	Test case 40 °C	Unit
1. Tested equipment			
1.1 Tested HW unit names & serial numbers			
1.2 Software version of tested equipment			
2. Test environment			
2.1 Temperature during test (measured)			°C
2.2 Pressure (measured)			kPa
2.3 Relative humidity (measured)			
3. Downlink frequency used at test			
3.1 Centre frequency of low end channel			MHz
3.2 Centre frequency of middle channel			MHz
3.2 Centre frequency of high end channel			MHz
4. Supply voltage			
4.1 DC voltage (measured)			V
4.2 AC voltage (measured, phase to neutral)			V
4.3 AC Frequency (measured)			Hz
5. Power consumption (measured)			
5.1 Busy hour load, Middle frequency channel			W
5.2 Medium load, Middle frequency channel			W
5.3 Low load			
5.3.1 Low end frequency channel			W
5.3.2 Middle frequency channel			W
5.3.3 High end frequency channel			W
5.3.4 Average consumption with low load			W
6. TX output power (pilot signal only)			
6.1 Output power at low end channel			W
6.2 Output power at middle end channel			W
6.3 Output power at high end channel			W
6.4 Average output power per sector			W
7. RX receiver sensitivity at middle channel			dBm

Table A.3: Calculation results to be reported

Parameter		Unit
1. Average power consumption at 25 °C		W
2. Average power consumption at 40 °C		W
3. Site average power consumption at 25 °C		W
3.1 Used power supply factor		
3.2 Used cooling factor		
3.3 Used power feeding factor for RRH		
4. Site average power consumption at 40 °C		W
4.1 Used power supply factor		
4.2 Used cooling factor		
4.3 Used power feeding factor for RRH		
5. Rural area (only for GSM system)		
5.1 Calculated uplink coverage area		km^2
5.2 Calculated downlink coverage area		km^2
5.3 Performance indicator for rural area		km^2 /W
6. Urban area (only for GSM system)		
6.1 Busy hour capacity		Subscribers
6.2 Performance indicators for urban area		Subscribers/W

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:

- PSF, Power Supply Factor depending on power supply:
  - Equipment with AC power interface: PSF = 1,0.
  - Equipment with DC power interface: PSF = 1,1.
- CF, Cooling factor, 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.
- PFF, power feeding factor 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: $$L_{Pd} = P_{Btx} - L_{Bcom} - L_{Bf} + G_{Ba} + G_{Ma} - L_{in} - L_{Ph} - P_{Msen} - P_{margin} \quad (C1)$$

For uplink: $$L_{Pu} = P_{Mtx} - L_{Ph} + G_{Ma} + G_{Ba} - L_{Bf} - P_{Bsen} - P_{margin} \quad (C2)$$

Okumura-Hata model is the most widely used model in radio frequency propagation for GSM 900 MHz macro RBS (rural area model). The path loss is described by:

$$L_P = 69.55 + 26.16\lg f - 13.82\lg h_b - A(h_m) + (44.9 - 6.55\lg h_b) * \lg d - C \quad (C3)$$

$$A(h_m) = (1.1\lg f - 0.7)h_m - (1.56\lg f - 0.8)$$

$$C = 4.78(\lg f)^2 - 18.33\lg f + 40.94 - L_{rural}$$

in which, f: is carrier frequency [MHz], A(hm): correction factor for mobile station antenna height (dB), d: radius of RBS coverage areas [km].

Resolving (C3) according d gives the radius of the coverage area:

$$d = 10^{\frac{L_P - 69.55 - 26.16\lg f + 13.82\lg h_b + A(h_m) + C}{44.9 - 6.55\lg h_b}} \quad (C4)$$

Cost231-Hata model is used for GSM 1 800 MHz macro RBS. The path loss for rural area is described by:

$$L_p = 46.3 + 33.9\lg f - 13.82\lg h_b - A(h_m) + (44.9 - 6.55\log h_b)\lg d - C \quad (C5)$$

$$A(h_m) = (1.1\lg f - 0.7)h_m - 1.56\lg f - 0.8$$

$$C = 4.78(\lg f)^2 - 18.33\lg f + 40.94 - L_{rural}$$

$$d = 10^{\frac{L_P - 46.3 - 33.9\lg f + 13.82\lg h_b + A(h_m) + C}{44.9 - 6.55\lg h_b}} \quad (C6)$$

The coverage area can be calculated as following:

$$CoverageAreas = 9\sqrt{3}d^2/8 \quad (C7)$$

Parameters	Definition	Value
P_{Btx}	RBS transmit power [dBm]	Measured according to annexes D to F
L_{Bcom}	RBS combiner loss [dB]	Measured according to annexes D to F
P_{Bsen}	RBS sensitivity [dBm]	Measured according to annexes D to F RX-Div. gains shall be included here as well
L_{Bf}	RBS feeder and connector loss [dB]	according to annex B
G_{Ba}	RBS antenna gain [dBi]	17,5
P_{Mtx}	UE transmit power [dBm]	according to annexes D to F
G_{Ma}	UE antenna gain [dB]	according to annexes D to F
P_{Msen}	UE sensitivity [dBm]	according to annexes D to F
L_{Ph}	Body loss [dB]	3
P_{margin}	Shadow fading margin [dB]	6
L_{in}	Indoor penetration loss [dB]	17
L_{rural}	Correction factor for rural area [dB]	9
h_b	RBS antenna height [m]	40
h_m	UE antenna height [m]	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 of 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 [6] and defines the RF output composition as shown in table D.1 and figures D.1 and D.2.

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

Table D.1: Load model for GSM

	Low load	Medium load	Busy hour load
Load for 222	BCCH: figure D.1 Other TRX: Idle	BCCH: figure D.1 Other TRX: idle.	BCCH: figure D.1 Other TRX: 2 active TS per each sector at static power level. Other TS idle.
Load for 444	BCCH: figure D.1 Other TRX: Idle	BCCH: figure D.1 Other TRX 6 active TS per each sector at static power level. Other TS idle.	BCCH: figure D.1 Other TRX 12 active TS per each sector at static power level. Other TS idle.
Load for 888	BCCH: figure D.1 Other TRX: Idle	BCCH: figure D.1 Other TRX 18 active TS per each sector at static power level. Other TS idle.	BCCH: figure D.1 Other TRX 36 active TS per each sector at static power level. Other TS idle.
Load level duration	6 hours	10 hours	8 hours

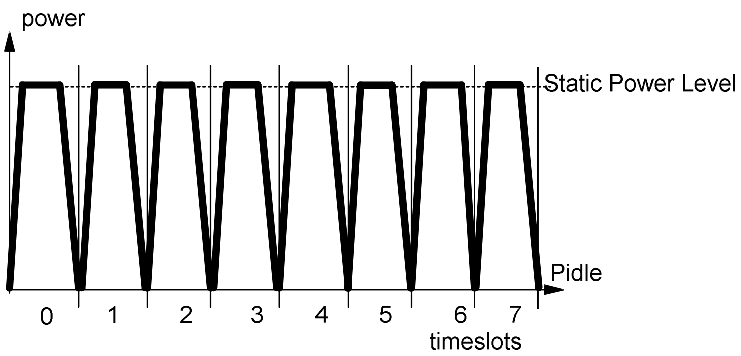

Figure D.1: Power levels for BCCH TRX (all TS active)

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.2	Busy hour traffic
S222	18 Erlangs (3×6)
S444	51 Erlangs (3×17)
S888	118 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 [1]:

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	
UE antenna height	1,5 m
UE antenna gain	0 dB
UE sensitivity	-104 dBm (static)
UE RF output power	31 dBm (900 MHz) 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:

- Number of sectors and carriers: 111, 222, 333.
- Channel capacity: Able to handle busy hour traffic + extra 50 %.
- RF output power level:
  - Applicable range of 3 W to 100 W.
  - 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 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
RF load for 222 per cell	Only Primary CPICH	CCH + first 3 codes	CCH + first 15 codes
RF load for 333 per cell	Only Primary CPICH	CCH + first 3 codes	CCH + first 15 codes
Load level duration	6 hours	10 hours	8 hours

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

Annex F (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 35dBm (MIMO configuration) or 4x 35dBm (Beam forming configuration) per sector.
- Power Input: -48 V DC, 230 V AC.

WiMAX™ traffic model:

Table F.1: Traffic model for WiMAX™

	Low load	Medium load	Busy hour load
Traffic per cell	20 % of the cell capacity	50 % of the cell capacity	80 % of the cell capacity
Load level duration	5 hours	12 hours	7 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;

ΔF_c is the centre frequency step;

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

Table F.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 G (normative): 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 must 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.

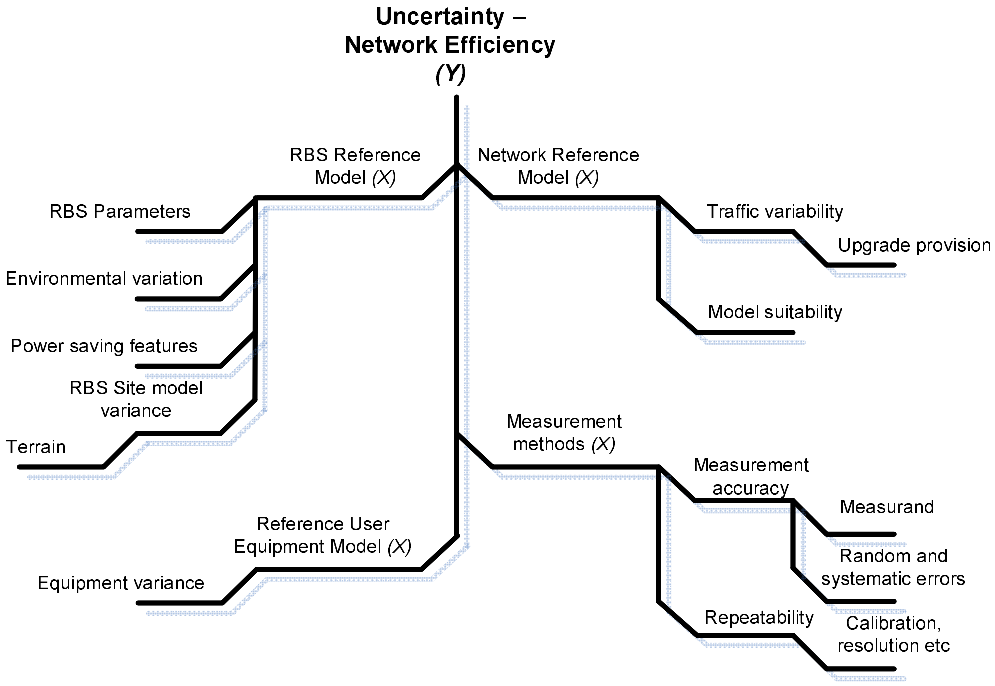

Figure G.1

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 G.1.

Table G.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 [8].
- ISO/IEC Guide 98: 1995 [9].

Annex H (normative): Example assessment

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

Table H.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 H.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 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
3.2 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 H.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

History

Document history		
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