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Measurement method for energy efficiency of wireless access network equipment

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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™.

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.

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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™	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:

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

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.