



**Environmental Engineering (EE);  
Metrics and measurement method for energy efficiency  
of wireless access network equipment;  
Part 1: Power consumption - static measurement method**

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**Reference**RES/EE-EEPS79

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**Keywords**energy efficiency, GSM, LTE, NR, power  
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# Foreword

This final draft ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the ETSI Membership Approval Procedure (MAP).

The present document is part 1 of a multi-part deliverable covering the metrics and measurement method for energy efficiency of wireless access network equipment, as identified below:

**ETSI ES 202 706-1: "Power consumption - static measurement method";**

ETSI TS 102 706-2: "Energy Efficiency - dynamic measurement method".

# Modal verbs terminology

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# Introduction

Energy efficiency is one of the critical factors of the modern telecommunication systems. The energy consumption of the access network is the dominating part of the wireless telecom network energy consumption. Therefore the core network and the service network are not considered in the present document. In the radio access network, the energy consumption of the Base Station is dominating (depending on technology often also referred to as BTS, NodeB, eNodeB, gNodeB, etc. and in the present document denoted as BS).

The present document defines the measurement method for the evaluation of base station power consumption and energy consumption with static load:

- Average power consumption of BS equipment under static test conditions: the BS average power consumption is based on measured BS power consumption data under static condition when the BS is loaded artificially in a lab for three different loads, low, medium and busy hour under given reference configuration.
- Daily average energy consumption.

ETSI TS 102 706-2 [i.8] defines energy efficiency measurement of the LTE base station with dynamic load, and ETSI TS 103 786 [i.9] defines energy efficiency measurement of the NR base station with dynamic load.

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# 1 Scope

The present document version covers base stations with the following radio access technologies:

- GSM.
- WCDMA.
- LTE.
- NR.

The methodology described in the present document is to measure base station static power consumption and RF output power. Within the present document it is referred to as static measurements.

The results based on "static" measurements provide power and energy consumption figures for BS under static load.

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

The scope of the present document is not to set and define target values for the power consumption nor the energy efficiency of equipment and neither for regulatory nor type approval purpose.

The results should only be used to assess and compare the power and energy consumption of complete base stations.

Wide Area Base Stations and Medium Range Base Stations (as defined in ETSI TS 125 104 [2], ETSI TS 136 104 [12], and ETSI TS 138 104 [15]) are covered in the present document.

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## 2 References

### 2.1 Normative references

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- |     |                                                                                                                                                                                                           |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [1] | Void.                                                                                                                                                                                                     |
| [2] | <a href="#">ETSI TS 125 104</a> : "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".                                         |
| [3] | <a href="#">ETSI EN 300 132-1</a> : "Environmental Engineering (EE); Power supply interface at the input to Information and Communication Technology (ICT) equipment; Part 1: Alternating Current (AC)".  |
| [4] | <a href="#">ETSI EN 300 132-2</a> : "Environmental Engineering (EE); Power supply interface at the input of Information and Communication Technology (ICT) equipment; Part 2: -48 V Direct Current (DC)". |
| [5] | Void.                                                                                                                                                                                                     |
| [6] | Void.                                                                                                                                                                                                     |
| [7] | <a href="#">ETSI TS 125 141</a> : "Universal Mobile Telecommunications System (UMTS); Base Station (BS) conformance testing (FDD) (3GPP TS 25.141)".                                                      |

- [8] Void.
- [9] Void.
- [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](#): "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] Void.
- [14] [ETSI EN 300 132-3](#): "Environmental Engineering (EE); Power supply interface at the input of Information and Communication Technology (ICT) equipment; Part 3: Up to 400 V Direct Current (DC)".
- [15] [ETSI TS 138 104](#): "5G; NR; Base Station (BS) radio transmission and reception (3GPP TS 38.104)".
- [16] [ETSI TS 138 141-1](#): "5G; NR; Base Station (BS) conformance testing Part 1: Conducted conformance testing (3GPP TS 38.141-1)".
- [17] [ETSI TS 138 141-2](#): "5G; NR; Base Station (BS) conformance testing Part 2: Radiated conformance testing (3GPP TS 38.141-2)".
- [18] [ETSI TS 138 211](#): "5G; NR; Physical channels and modulation (3GPP TS 38.211)".
- [19] [ETSI TS 138 214](#): "5G; NR; Physical layer procedures for data (3GPP TS 38.214)".
- [20] [ETSI TS 138 331](#): "5G; NR; Radio Resource Control (RRC); Protocol specification (3GPP TS 38.331)".
- [21] [ETSI TS 138 213](#): "5G; NR; Physical layer procedures for control (3GPP TS 38.213)".

## 2.2 Informative references

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- [i.1] Void.
- [i.2] IEC/ISO Guide 98-3:2008: "Evaluation of measurement data - Guide to the expression of uncertainty in measurement", 2008 or equivalent GUM:2008/JCGM 100:2008.
- [i.3] ETSI TS 145 005: "Digital cellular telecommunications system (Phase 2+) (GSM); GSM/EDGE 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+) (GSM); Base Station System (BSS) equipment specification; Radio aspects (3GPP TS 51.021)".
- [i.6] IEC 62018: "Power consumption of information technology equipment - Measurement methods".

NOTE: Equivalent to EN 62018 (produced by CENELEC).

- [i.7] Void.
- [i.8] ETSI TS 102 706-2: "Environmental Engineering (EE); Metrics and Measurement Method for Energy Efficiency of Wireless Access Network Equipment; Part 2: Energy Efficiency - dynamic measurement method".
- [i.9] ETSI TS 103 786: "Environmental Engineering (EE); Measurement method for energy efficiency of wireless access network equipment; Dynamic energy efficiency measurement method of 5G Base Station (BS)".

## 3 Definition of terms, symbols and abbreviations

### 3.1 Terms

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

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

**BS test control unit:** unit which can be used to control and manage BS locally in a lab

**BS type 1-C:** NR BS operating at FR1, with a conducted interface (antenna connectors available)

**BS type 1-H:** NR BS operating at FR1, with both a conducted (TAB connectors) and a radiated interface

**BS type 1-O:** NR BS operating at FR1, with only a radiated interface (no antenna connectors available)

**BS type 2-O:** NR BS operating at FR2, with only a radiated interface (no antenna connectors available)

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

**busy hour load:** highest measurement level of radio resource configuration

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

**efficiency:** relation between the useful output (telecom service, etc.) and energy consumption

**energy consumption:** integral of power consumption over time

**full load:** operating mode including all radio resources and 100 % traffic conditions

**integrated BS:** BS architecture in which all BS elements are located close to each other, for example in one single cabinet

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

**low load:** lowest measurement level of radio resource configuration

**medium load:** medium measurement level of radio resource configuration

**medium range BS:** Base Station that is characterized by a rated output power (PRAT) above 24 dBm and less than or equal to 38 dBm

NOTE 1: According to ETSI TS 136 104 [12], ETSI TS 125 104 [2] and ETSI TS 138 104 [15].

NOTE 2: For BS type 1-O and BS type 2-O specific definitions apply according to ETSI TS 138 104 [15].

**multi-band base station:** configuration which allows the simultaneous operation on at least two different frequency bands

**power saving feature:** software/hardware feature in a BS which contributes to decrease power consumption

**radiated interface boundary:** reference where the radiated requirements apply for BS type 1-O and 2-O

NOTE: For requirements based on EIRP, the *radiated interface boundary* is associated to the far-field region.

**rated output power:** mean power level per carrier that the manufacturer has declared to be available at the antenna connector

NOTE: For FDD BS, rated output power is the mean power level per carrier that the manufacturer has declared to be available at the antenna connector. For TDD BS rated output power is the mean power level per carrier over an active timeslot that the manufacturer has declared to be available at the antenna connector.

**site correction factor:** scaling factor to scale the BS 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 with pre-defined and fixed load levels

**transceiver array boundary:** conducted interface between the transceiver unit array and the composite antenna for BS type 1-H

**wide area BS:** Base Station that is characterized by a Rated output Power (PRAT) greater than 38 dBm

NOTE 1: According to ETSI TS 136 104 [12], ETSI TS 125 104 [2], and ETSI TS 138 104 [15].

NOTE 2: For BS type 1-O and BS type 2-O specific definitions apply according to ETSI TS 138 104 [15].

## 3.2 Symbols

Void.

## 3.3 Abbreviations

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

|       |                                                         |
|-------|---------------------------------------------------------|
| AAS   | Active Antenna System                                   |
| AAU   | Active Antenna Unit                                     |
| AC    | Alternating Current                                     |
| BCCH  | Broadcast Control CHannel                               |
| BH    | Busy Hour                                               |
| BS    | Base Station                                            |
| BSC   | Base Station Controller                                 |
| BTS   | Base Transceiver Station                                |
| CA    | Carrier Aggregation                                     |
| CATR  | Compact Antenna Test Range                              |
| CCE   | Control Channel Element                                 |
| CCH   | Common CHannel                                          |
| CCPCH | Common Control Physical CHannel                         |
| CP    | Cyclic Prefix                                           |
| CPICH | Common Pilot CHannel                                    |
| CS    | Circuit Switched                                        |
| DC    | Direct Current                                          |
| DL    | DownLink                                                |
| DPCH  | Dedicated Physical CHannel                              |
| DUT   | Device Under Test                                       |
| EDGE  | Enhanced Data rate GSM Evolution                        |
| EIRP  | Equivalent Isotropically Radiated Power                 |
| EPRE  | Emitted Power per Resource Element                      |
| FDD   | Frequency Division Duplex                               |
| FL    | Full Load                                               |
| FR1   | Frequency Range 1 (450 - 6 000 MHz), defined for NR     |
| FR2   | Frequency Range 2 (24 250 - 52 600 MHz), defined for NR |
| GERAN | GSM/EDGE Radio Access Network                           |

|                   |                                                |
|-------------------|------------------------------------------------|
| GP                | Guard Period                                   |
| GSM               | Global System for Mobile communication         |
| HSPA              | High Speed Packet Access                       |
| HW                | HardWare                                       |
| LTE               | Long Term Evolution                            |
| LTE-A             | Long Term Evolution Advanced                   |
| MCPA              | Multi Carrier Power Amplifier                  |
| MIMO              | Multiple Input Multiple Output                 |
| MNO               | Mobile Network Operator                        |
| MU-MIMO           | Multi-User MIMO                                |
| NA                | Not Applicable                                 |
| NIST              | National Institute of Standards and Technology |
| NR                | New Radio                                      |
| OFDM              | Orthogonal Frequency Division Multiplex        |
| OTA               | Over The Air                                   |
| PBCH              | Physical Broadcast Control CHannel             |
| P <sub>cell</sub> | Primary cell                                   |
| PCFICH            | Physical Control Format Indicator CHannel      |
| PCH               | Paging CHannel                                 |
| PCM               | Pulse Code Modulation                          |
| PDCCH             | Physical Downlink Control CHannel              |
| PDF               | Probability Density Function                   |
| PDSCH             | Physical Downlink Shared CHannel               |
| PHICH             | Physical Hybrid ARQ Indicator CHannel          |
| PICH              | Paging Indicator CHannel                       |
| PRAT              | RATed output Power                             |
| PRB               | Physical Resource Block                        |
| PSS               | Primary Synchronization Signal                 |
| RE                | Resource Element                               |
| REG               | Resource Element Group                         |
| RF                | Radio Frequency                                |
| RIB               | Radiated Interface Boundary                    |
| RMSI              | Remaining Minimum System Information           |
| RNC               | Radio Network Controller                       |
| RRH               | Remote Radio Head                              |
| RX                | Receiver                                       |
| SA                | Subframe Assignment                            |
| S <sub>cell</sub> | Secondary cell                                 |
| SCH               | Synchronization CHannel                        |
| SCS               | Sub-Carrier Spacing                            |
| SDH               | Synchronous Digital Hierarchy                  |
| SF                | Spreading Factor                               |
| SIB1              | System Information Block 1                     |
| SIMO              | Single Input Multiple Output                   |
| SS                | Synchronization Signal                         |
| SSB               | Synchronization Signal Block                   |
| SSS               | Secondary Synchronization Signal               |
| SW                | SoftWare                                       |
| TAB               | Transceiver Array Boundary                     |
| TDD               | Time Division Duplex                           |
| TMA               | Tower Mount Amplifier                          |
| TRX               | Transceiver                                    |
| TS                | Time Slot                                      |
| TTI               | Transmission Time Interval                     |
| TX                | Transmitter                                    |
| UE                | User Equipment                                 |
| UL                | UpLink                                         |
| WCDMA             | Wideband Code Division Multiple Access         |

## 4 Assessment method

The assessment method is covering the BS equipment average power and energy consumption for which the present document defines reference BS equipment configurations and reference load levels to be used when measuring BS RF output power, power consumption and calculating daily average energy consumption.

The assessment procedure contains the following tasks:

- 1) Identification of equipment under test (clause A.1):
  - 1.1) Identify BS basic parameters.
  - 1.2) List BS configuration and load level(s) for measurements (Annexes B, C, D and E).
  - 1.3) List used power saving features.
- 2) Measure BS RF output power and corresponding equipment power consumption for required load levels (clauses 5 and 6).
- 3) Calculate average power consumption and daily energy consumption (clause 7).
- 4) Collect and report the measurement and calculation results (clause A.2).

## 5 Reference configurations and Measurement conditions

### 5.0 Introduction

The BS equipment is a network component which serves one or more cells and interfaces the mobile station (through air interface) and a wireless network infrastructure (such as BSC or RNC, [i.3] and [2]).

### 5.1 Reference configurations

Reference configurations are defined for the different technologies (GSM/EDGE, WCDMA/HSPA, LTE, NR) in the corresponding annexes (Annexes B to E).

These configurations include integrated BS (Figure 1) and distributed BS (Figure 2), mast head amplifiers, remote radio heads, RF feeder cables, number of carriers, number of sectors, power range per sector, frequency range, diversity, MIMO.

With Active Antenna Systems (AAS), used in NR, more BS types are defined in ETSI TS 138 104 [15]:

- BS type 1-C: NR BS operating at FR1, with a conducted interface (antenna connectors available). This corresponds to legacy integrated BS and distributed BS, illustrated in Figures 1 and 2, respectively.
- BS type 1-H: Distributed NR BS operating at FR1, with both a conducted (at TAB connectors) and a radiated interface at the RIB.
- BS type 1-O and 2-O: Distributed NR BS operating at FR1 or FR2, respectively, with only a radiated interface at the RIB.

The BS shall be tested with its intended commercially available configuration at temperatures defined in clause 5.2.3 "Environmental conditions". It shall be clearly reported in the measurement report if the BS cannot be operated without additional air-conditioning at the defined temperatures.

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

- 1) UL diversity (This is a standard feature in all BS. 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).
- 2) DL diversity (Not considered in WCDMA and HSPA. LTE: Transmission mode 3 "Open loop spatial multiplexing" shall be according to ETSI TS 136 211 [10] (2×2 DL MIMO). NR: Rank 1, single layer transmission, (MU-MIMO)).

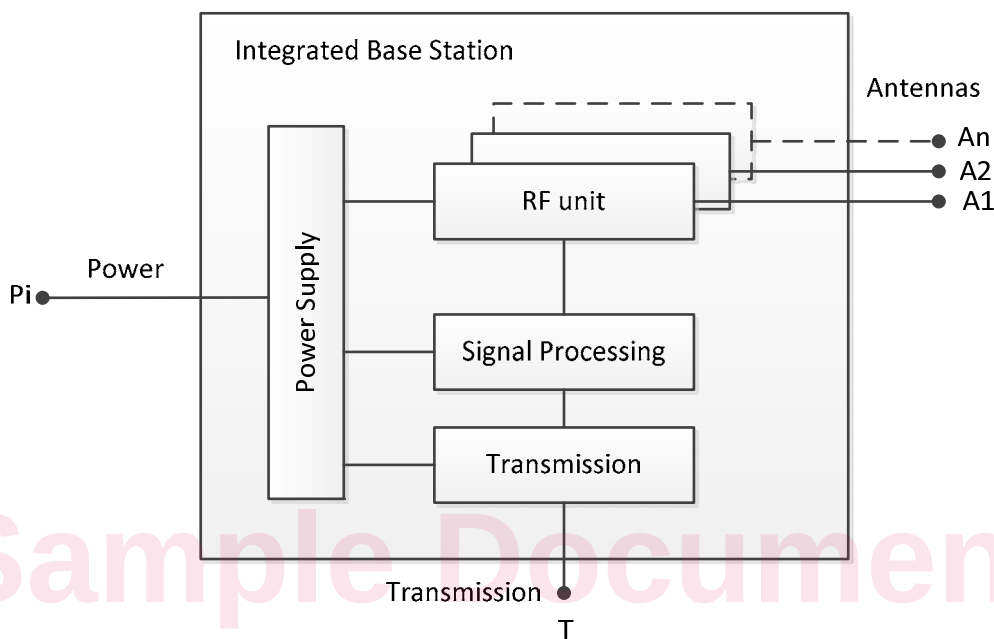
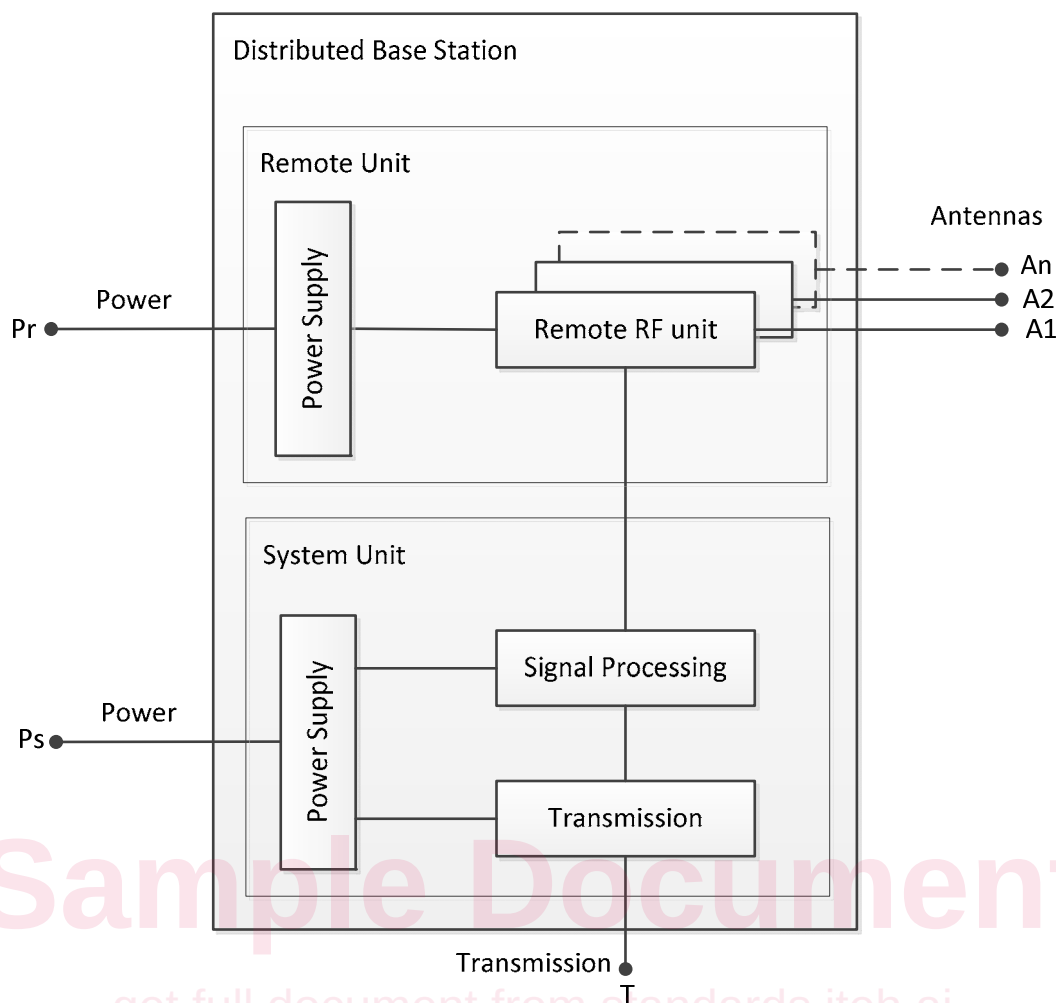


Figure 1: Integrated BS model (example)



**Figure 2: Distributed BS model (example)**

## 5.2 Measurement and test equipment requirements

### 5.2.0 Introduction

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 equipment 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:  $\leq 10 \text{ mA}$ ;  $\leq 100 \text{ mV}$ ;  $\leq 100 \text{ mW}$ .
  - DC current:  $\pm 1 \%$ .
  - DC voltage:  $\pm 1 \%$ .
  - AC power:  $\pm 1 \%$ :
    - An available current crest factor of 5 or more.

- The test instrument shall have a bandwidth of at least 1 kHz.

NOTE: Additional information on accuracy can be found in IEC 62018 [i.6].

- RF output power, conducted measurement:
  - $\pm 0,4$  dB.
- RF output power, radiated measurement:
  - $\pm 1,2$  dB (beam peak direction).

### 5.2.1 BS Configuration

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

The BS shall be tested with its typical configuration. In case of multiple configurations a configuration with 3 sectors shall be used.

EXAMPLE: A typical wide area BS configuration consists of three sectors and shall therefore be tested in a three sector configuration. If a BS is designed for dual or single sector applications, it shall be tested in its designed configuration.

The connection to the BS test control unit via the BS 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 BS configuration. Additional power consuming features like battery loading shall be switched off.

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

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

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

Due to the different nominal RF output power values of the various BS 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 BS (conducted measurement, clause 6.1.1), or Over The Air (OTA) for BS types where RF output connectors are not accessible (radiated measurement, clause 6.1.2).

During the test the BS shall be operated with the nominal RF output powers which would be applied in commercial operation regarding the reference networks and the traffic profiles listed in Annexes B, C, D and E.

The power amplifier(s) of the BS 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, LTE [12] and NR [15], shall be fulfilled.

### 5.2.3 Environmental conditions

The environmental conditions under which the BS has to be tested are defined in Table 1.

The measurements shall be performed when stable temperature conditions inside the equipment are reached. For this purpose the BS shall be placed in the environmental conditions for minimum two hours with a minimum operation time of one hour before conducting measurements. Also after change of load level, a minimum operation time of one hour shall be applied before conducting measurements again.