INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

Base stations RF-EMF exposure assessment methods standardization

Driving principles & implementation case studies

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Base stations RF-EMF exposure assessment methods
International standardization panorama – IEC

- IEC 62232:2022, Determination of RF field strength, power density and SAR in the vicinity of base stations for the purpose of evaluating human exposure

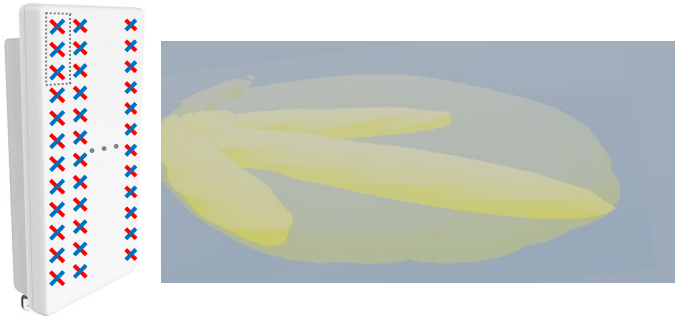
  Referenced in multiple regulations

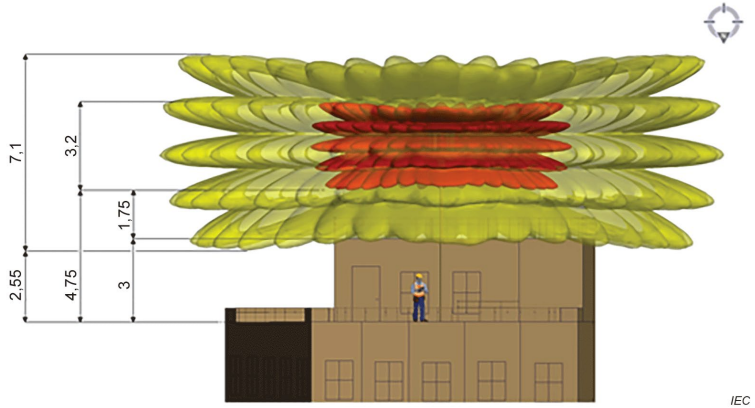
  - IEC 62232:2024 publication is expected by the end of 2024
    (Same technical content, includes only minor error corrections and editorial updates to improve readability and align with TR 62669:2025)

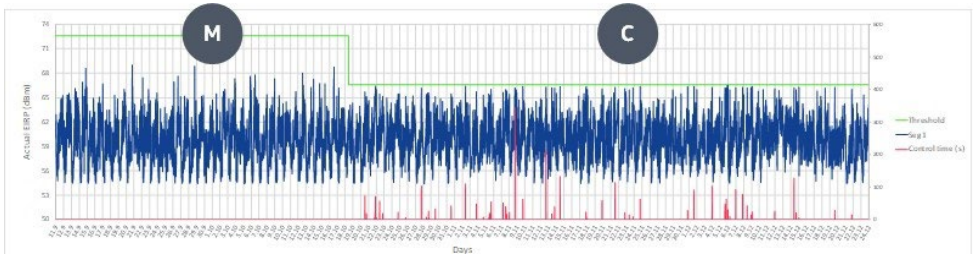
- IEC TR 62669:2019, Case studies supporting IEC 62232 - Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure

  30+ case studies
  from 12 national committees

  - IEC TR 62669:2025 publication is expected during 1st half 2025







IEC

Base stations RF-EMF exposure assessment methods
International standardization panorama – CENELEC & ITU

CENELEC TC106X WG1

Ongoing updates to align with IEC/EN 62232:2024
Referenced in the Official Journal of the European Union

- EN 50385:2017, Product standard to demonstrate the compliance of base station equipment with radiofrequency electromagnetic field exposure limits (110 MHz - 100 GHz), when placed on the market
- EN 50401:2017, Product standard to demonstrate the compliance of base station equipment with radiofrequency electromagnetic field exposure limits (110 MHz - 100 GHz), when put into service

ITU-T SG5 Q3/5

Referenced in some regulations

- ITU-T K.52 (08/2024), Guidance on complying with limits for human exposure to electromagnetic fields
- ITU-T K.100 (08/2024), Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into operation

Base stations RF-EMF exposure assessment methods
International standardization panorama – Teamwork

Standardization involved teamwork & cross-fertilization

Paris 2024-09-25 HYM attendees

IEC TC106 MT3 has 80+ registered members from 21 national committees
including operators, mobile network vendors, regulators, academics, laboratories, measurement equipment vendors

IEC 62232 scope (extract Clause 2)

a) considers **intentionally radiating BS** which transmit on one or more antennas using one or more **frequencies in the range 110 MHz to 300 GHz**;

b) considers the impact of **ambient sources** on RF exposure at least in the 100 kHz to 300 GHz frequency range;

c) specifies the methods to be used for RF exposure **evaluation for compliance assessment applications**, namely:

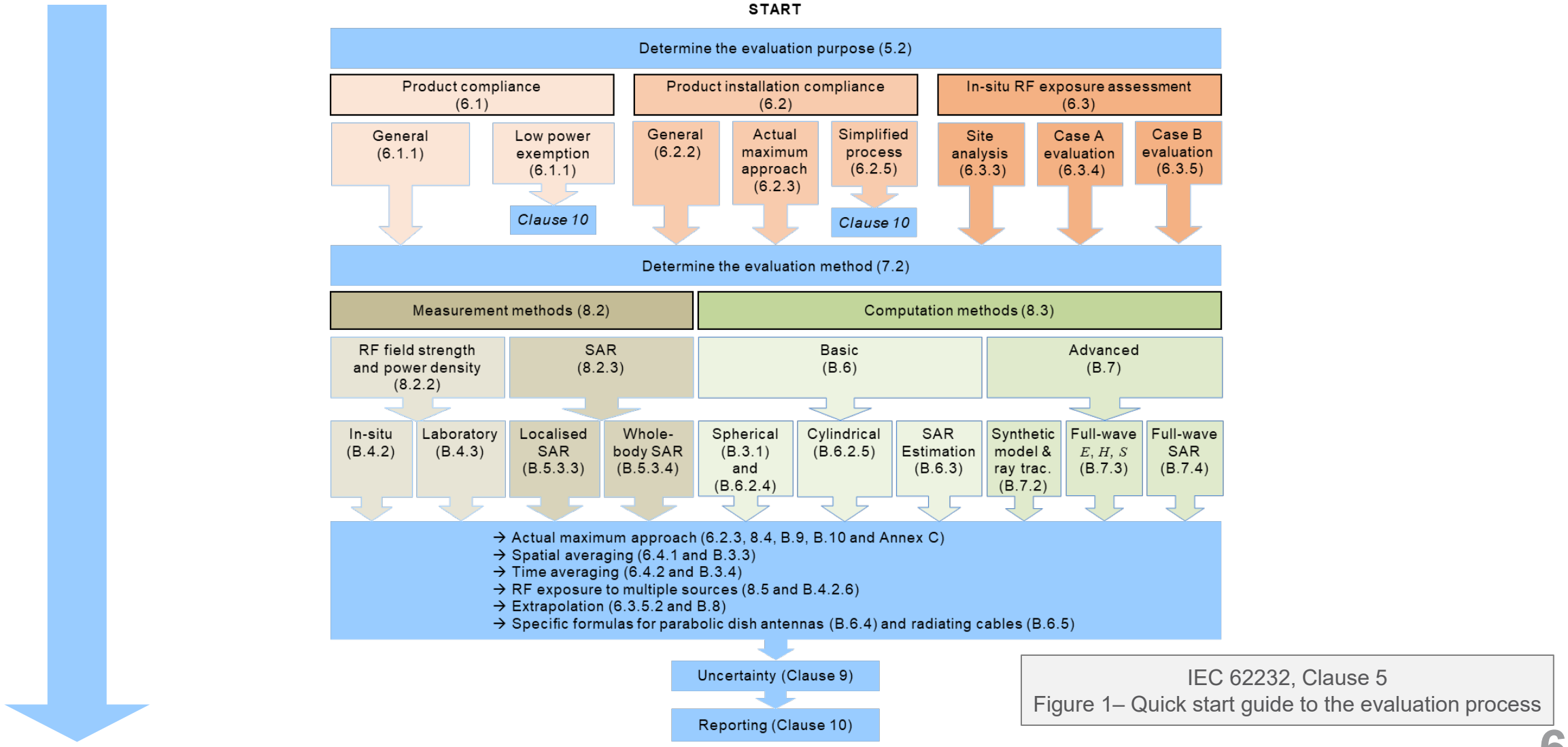
   1) **product compliance** – determination of compliance boundary information for a BS product before it is placed on the market;

   2) **product installation compliance** – determination of the total RF exposure levels in accessible areas from a BS product and other relevant sources before the product is put into operation;

   3) **in-situ RF exposure assessment** – measurement of in-situ RF exposure levels in the vicinity of a BS installation after the product has been taken into operation; (…)

e) describes several RF field strength, power density, and SAR **measurement and computation methodologies** with guidance on their applicability to address both the in-situ evaluation of installed BS and laboratory-based evaluations

IEC 62232 structure follows the global implementation flow



IEC 62232, Clause 5
Figure 1– Quick start guide to the evaluation process

IEC TR 62669 case studies have been regrouped per evaluation type, BS type and evaluation method

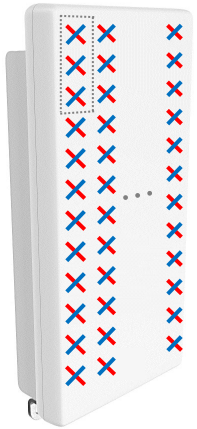
Clause	Annex	BS type	Evaluation type with IEC 62232:2024 reference	Evaluation method with IEC 62232:2024 reference
6	none	Small cells	Product compliance (6.1)	SAR measurements (B.5)
7	none	Street cell with omnidirectional antenna	Product compliance (6.1)	SAR (B.5) and field strength (B.4) measurements
8	none	Macro BS with mMIMO	Product compliance (6.1)	Field strength computations (B.6.2)
9	none	Wireless link	Product compliance (6.1)	Field strength computations (B.6.4)
10	Annex A	Small cell	Product installation compliance (6.2)	Simplified installation criteria; Field strength computations (B.4)
11	Annex B and Annex C	Macro BS and millimetre wave (FR2) small cell with mMIMO	Product installation compliance (6.2)	Computations (6.2.8) ; synthetic method modelling (B.7.2) ; multiple segments (8.4)
12	Annex C	General	Product installation compliance (6.2)	Actual maximum approach implementation; actual power or EIRP counters monitoring (6.2.3, 8.4 and B.9)
13	none	General	Product installation compliance (6.2)	Validation of power or EIRP control features and monitoring counter(s) (Annex C)
14	Annex D	Small cells	In-situ RF exposure assessment (6.3)	Field strength measurements (B.4.2)
15	none	Small cell at millimetre wave frequencies (FR2, see NOTE 3)	In-situ RF exposure assessment (6.3)	Field strength measurements (B.4.2)
16	none	Macro BS	In-situ RF exposure assessment (6.3)	Field strength measurements (B.4.2)
17	none	Macro BS NR FR1 (see NOTE 3)	In-situ RF exposure assessment (6.3)	Field strength measurements (B.4.2) ; Extrapolation (B.8)
18	Annex E	Macro BS	In-situ RF exposure assessment (6.3)	Field strength measurements (B.4.2); Inspection with a drone (8.2.2)
19	none	Emerging laboratory measurement methods for product compliance assessments	Product compliance (6.1)	Laboratory based RF field strength and power density measurements (B.4.3)

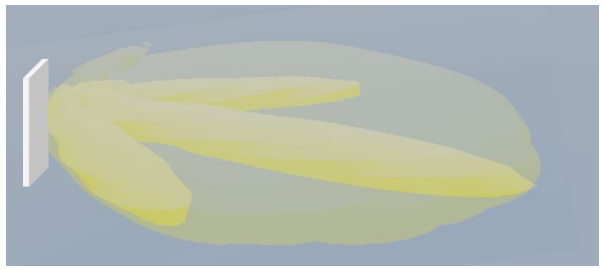
IEC 62232 – Product compliance (6.1)

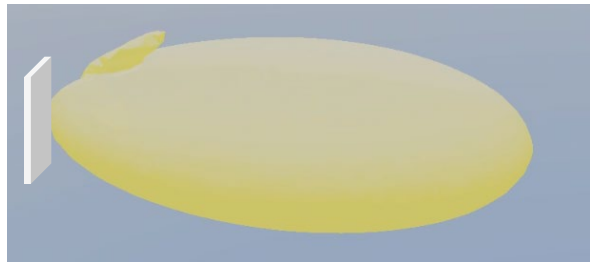
- Extract from (6.1.5.1)
- The compliance boundary shall be established in accordance with 6.1.5.2 to 6.1.5.8 using evaluation methods specified in Clause 8 and Annex B.
- The compliance boundary shall be evaluated for:

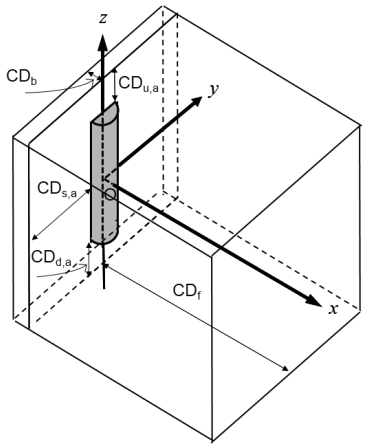
  a) the **rated maximum power or EIRP**, see 8.6; and

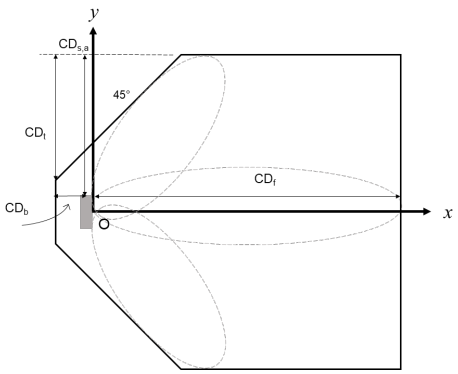
  b) one or more actual maximum transmitted power or EIRP value(s) using a power reduction factor if the equipment that is put on the market is able to implement the actual maximum approach specified in 6.2.3, 8.4 and Clause B.9.











IEC TR 62669 – Product compliance case studies

Clause 6 (small cells)
Case study A

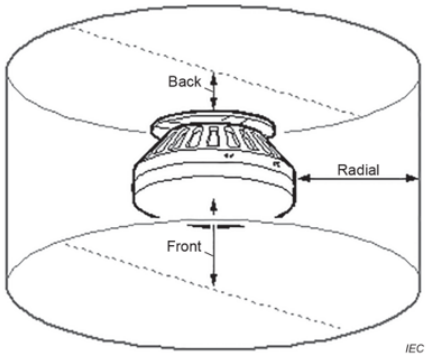
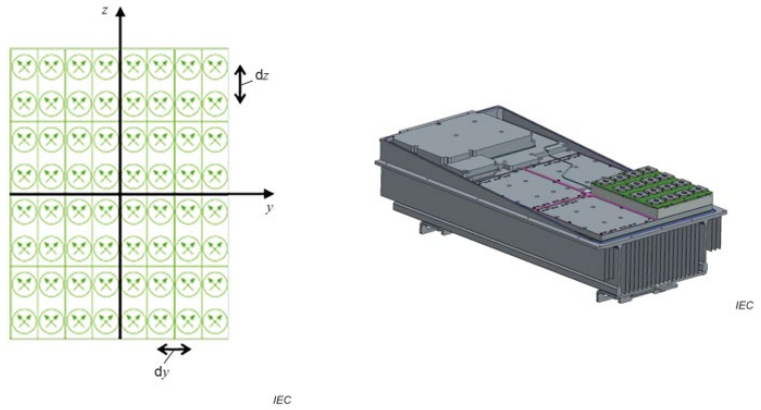


Figure 2 – Definition of cylindrical RF compliance boundary

Table 6 – Dimensions of the cylindrical-shaped RF compliance boundary for general public (GP) and occupational (O) exposure

Mode and transmitted power for the EUT		Dimensions of the cylindrical-shaped RF compliance boundary (m)					
		Distance in front of EUT		Distance in radial direction		Distance behind EUT	
3GPP bands	IEC 62232 installation class	GP	O	GP	O	GP	O
B1 + B3 + B78U	E10	0,02	0	0,02	0,01	0	0

Clause 8
Macro BS with massive MIMO



a) Schematic view of the four antenna modules with cross-polarized antenna elements

b) One antenna module mounted in the BS product

Figure 8 – 5G BS product

Table 15 – Dimensions of the box-shaped RF compliance boundary for general public (GP) and occupational (O) exposure for an actual maximum transmitted power configuration

Mode and RF transmitted power for EUT			Dimensions of the box-shaped RF compliance boundary (m)									
			Distance in front of EUT (CD_f)		Distance to the side of EUT ($CD_{s,s}$)		Distance above EUT ($CD_{u,a}$)		Distance below EUT ($CD_{d,a}$)		Distance behind EUT (CD_b)	
Band	Rated maximum transmitted power from the EUT	Actual maximum transmitted power	GP	O	GP	O	GP	O	GP	O	GP	O
B42 (3 500 MHz)	200 W	62,9 W	11,6	5,2	7,1	3,1	4,0	1,5	4,3	1,8	0	0

IEC 62232 – Product installation compliance (6.2)
Simplified assessment – EIRP installation classes

Table 2 – Example of product installation classes where a simplified evaluation process is applicable (based on ICNIRP general public limits [1] and [2])

Instal. class	EIRP[a] (W)	EIRP (dBm)	Product installation criteria
E0	n/a	n/a	The product complies with IEC 62479 or the product compliance distance(s) are zero. No specific requirement for product installation.
E2	≤ 2	≤ 33	The product is installed in accordance with instructions from the manufacturer and/or entity putting into operation. Compliance with the exposure limits is generally obtained at zero distance or within a few centimetres.
E10	≤ 10	≤ 40	The product is installed in accordance with instructions from the manufacturer and/or entity putting into operation and the lowest radiating part of the antenna(s) is at a minimum height of 2,2 m above the walking or standing surface accessible by the general public.
E100	≤ 100	≤ 50	The product is installed in accordance with instructions from the manufacturer and/or entity putting into operation and: a) the lowest radiating part of the antenna(s) is at a minimum height of 2,5 m above the walking or standing surface accessible by the general public, b) the minimum distance to areas accessible to the general public in the main lobe direction is CD_m [b], and c) there is no pre-existing RF source with EIRP above 10 W installed within a distance of 5×CD_m metres in the main lobe direction (as determined by considering the half power beam width) and within CD_m metres in other directions. CD_m is the compliance distance in the main lobe assessed in accordance with 6.1. If CD_m is not available, a value of 2 m can be used or 1 m if all product transmit frequencies are greater than or equal to 1 500 MHz.[c]
E+	> 100	> 50	The product is installed in accordance with instructions from the manufacturer and/or entity putting into operation and: a) the lowest radiating part of the antenna(s) is at a minimum height of h_m metres above the walking or standing surface accessible by the general public, b) the minimum distance to areas accessible to the general public in the main lobe direction is CD_m [b] metres, and c) there is no pre-existing RF source with EIRP greater than 100 W installed within a distance of 5×CD_m metres in the main lobe direction and within CD_m metres in other directions. CD_m is the compliance distance in the main lobe assessed in accordance with 6.1 and h_m is given by Equation (1), Equation (2), Equation (3), and Equation (4).[d]

Equation (1) applies for frequencies between 100 MHz and 400 MHz:

$$h_m = \max\left\{\begin{matrix} 2+\sqrt{\frac{EIRP \cdot A_{sl}}{2\pi}} \\ 2+\sqrt{\frac{EIRP}{2\pi}}\sin(\alpha + 1{,}129 \times \Delta\theta_{3dB}) \end{matrix}\right. \quad \text{and} \quad CD_m = \sqrt{\frac{EIRP}{2\pi}} \qquad (1)$$

Equation (2) applies for frequencies between 400 MHz and 2 000 MHz:

$$h_m = \max\left\{\begin{matrix} 2+\sqrt{\frac{200 \times EIRP \cdot A_{sl}}{f \cdot \pi}} \\ 2+\sqrt{\frac{200 \times EIRP}{f \cdot \pi}}\sin(\alpha + 1{,}129 \times \Delta\theta_{3dB}) \end{matrix}\right. \quad \text{and} \quad CD_m = \sqrt{\frac{200 \times EIRP}{f \cdot \pi}} \qquad (2)$$

Equation (3) applies for frequencies between 2 000 MHz and 300 000 MHz (i.e. 300 GHz):

$$h_m = \max\left\{\begin{matrix} 2+\sqrt{\frac{EIRP \cdot A_{sl}}{10\pi}} \\ 2+\sqrt{\frac{EIRP}{10\pi}}\sin(\alpha + 1{,}129 \times \Delta\theta_{3dB}) \end{matrix}\right. \quad \text{and} \quad CD_m = \sqrt{\frac{EIRP}{10\pi}} \qquad (3)$$

where

f is the frequency of operation of the BS in MHz;

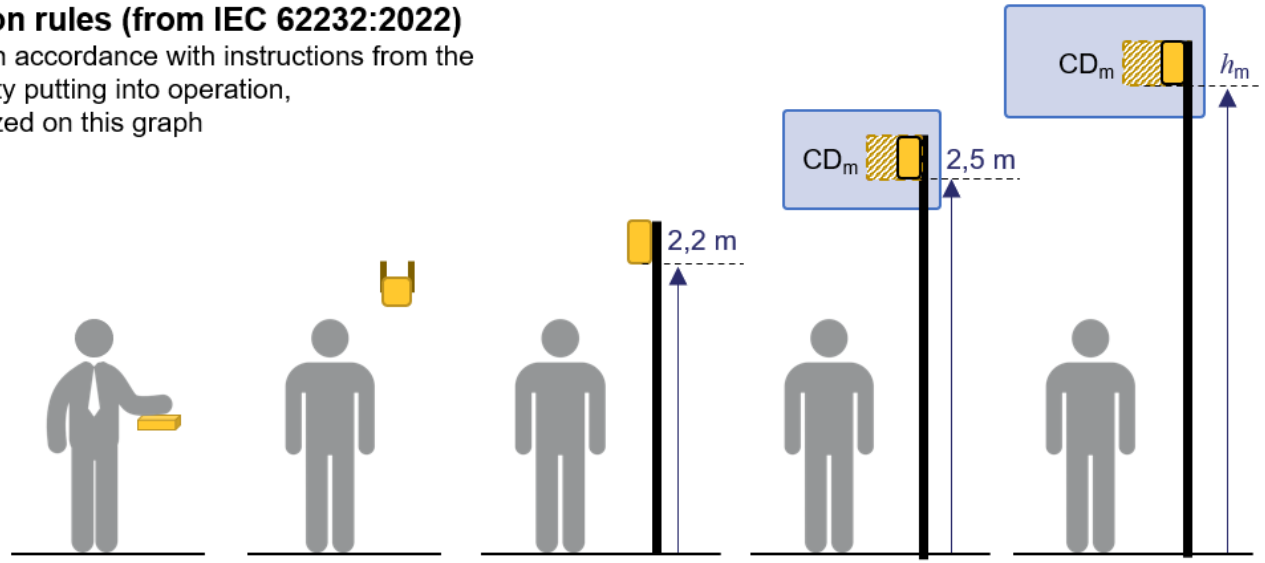
A_{sl} is the side lobe suppression value specified in a linear scale;

α is the downtilt in radians (both electrical and mechanical);

$\Delta\theta_{3dB}$ is the vertical half power beamwidth in radians.

IEC TR 62669 – Product installation compliance case studies
Simplified assessment – Implementation of installation classes (TR 62669 Clause 10)

Simplified installation rules (from IEC 62232:2022)
The product is installed in accordance with instructions from the manufacturer and/or entity putting into operation, and the criteria summarized on this graph

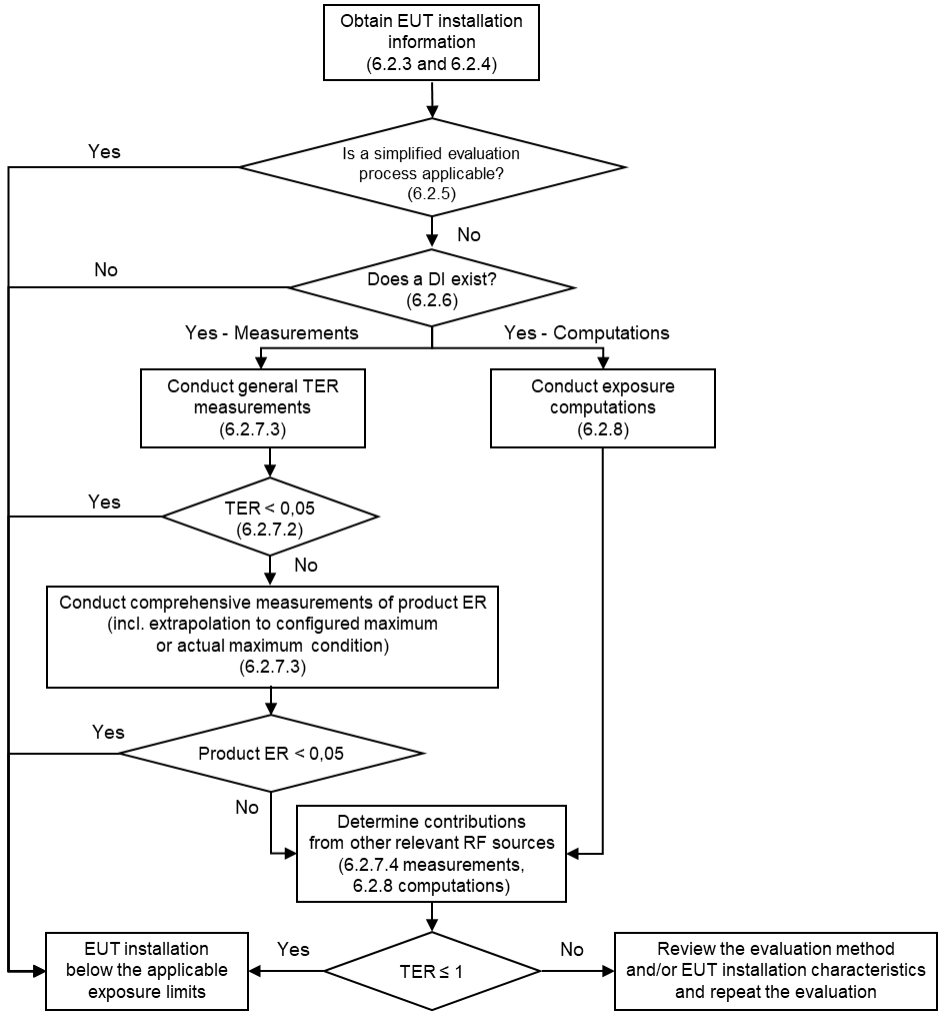


Installation class	E0	E2	E10	E100	E+
Total EIRP	None	≤ 2 W	≤ 10 W	≤ 100 W	No limit
Minimum height above walkway	None	None	2,2 m	2,5 m	h_m (calculation)
Exclusion zone	None, touch compliant	Provided in manufacturer's instructions Small CD_m (not shown on the picture)		Provided in manufacturer's instructions CD_m in main lobe direction	
Check pre-existing RF sources	Not applicable	Not applicable	Not applicable	$5 \times CD_m$ in main lobe direction CD_m in other directions	

IEC 62669, Clause 10
Figure 12 – Overview of BS installation classes for simplified RF exposure assessment of small cells

IEC 62232 – Product installation compliance (6.2)
General process

- Extract from (6.2.1)
- The RF exposure levels **from the BS product and other relevant sources**, and the resulting compliance distance(s), if any, shall be determined using:
  - a) either the configured maximum power; or
  - b) the actual maximum threshold power or EIRP as specified in 6.2.3 and 8.4.
- The assessment of RF exposure levels shall be performed using **measurements**, see B.4.2,
  or computations, see Clause B.6.
  Contributions from multiple sources shall be determined using summation formulas, see 8.5.



IEC 62232 – Product installation compliance (6.2)
IEC TR 62669 – Modelling case studies (Clause 11)

Case study A

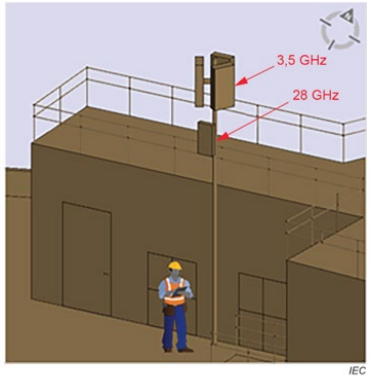


Figure 13 – Outline of the 5G site

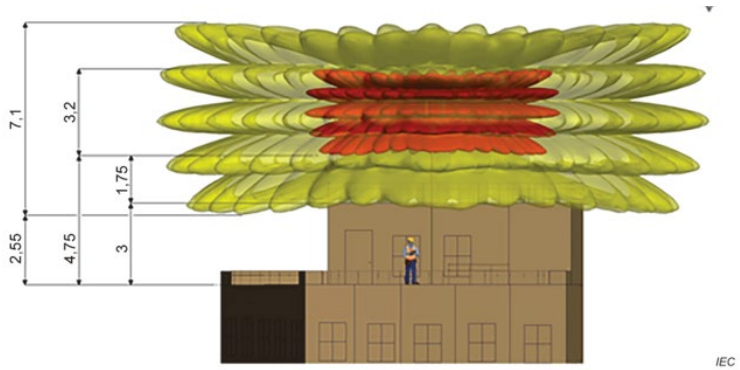


Figure 15 – Side view of the compliance boundaries (red: occupational, yellow: general public)

Case study B

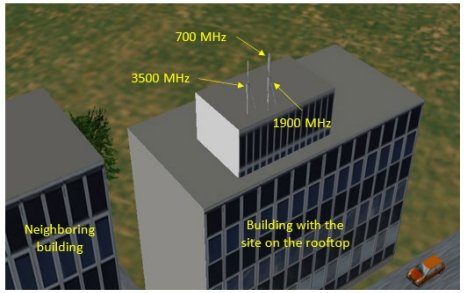
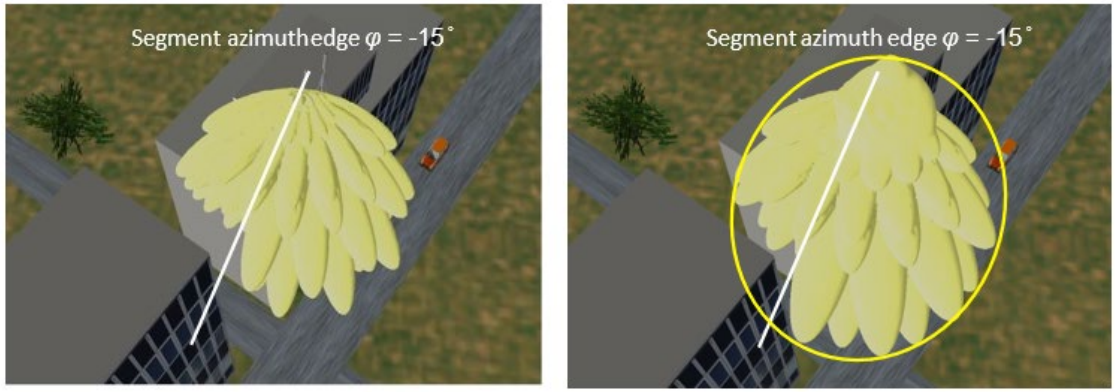


Figure 16 – Outline of the multiband site



a) NR BS only

b) All BSs

NOTE The yellow line indicates the initial compliance boundaries (scenario 0) without EMF mitigation

Figure 20 – Compliance boundaries for the new site using installation scenario 4 – EIRP control using two segments

IEC 62232 – Product installation compliance (6.2)
Actual maximum approach – Rationale (from IEC TR 62669 Annex C)

Modelling studies (9)

Study	BS product	Techno-logy	Traffic load	UE spatial distribution	Number of UE (or beam instances) within the averaging time	UE (or beam) scheduling time	F_{PR}
Thors et al. [24]	mMIMO (up to 15×15 antenna array) Codebook (one layer)	5G (mid-band)	0% to 100%	Uniform and cosine with and without scanning in elevation	360s / Ts * n Ts: scheduling time n: number of instantaneous users according to M/M/1 queue	36 s	≤0,32 (-4,9 dB) (8×8 antenna array)
Baracca et al. [32]	mMIMO (8×8 antenna array) Reciprocity-based beamforming (one layer)	5G (mid-band)	100%	Uniform with scanning in elevation (from 3GPP TR 38.901 [18])	360/Ts*K Ts: scheduling time K: number of instantaneous users ranging from 1 to 5	From 1 s to 60 s	≤0,26 (-5,9 dB)
Shikantsov et al. [44]	mMIMO (up to 10×10 antenna array) Codebook and reciprocity-based beamforming (one layer)	5G (mid-band)	100%	Uniform (azimuth and elevation)	360/Ts*k Ts: scheduling time k: number of instantaneous users ranging from 1 to 10	From 1 s to 60 s	≤0,47 (-3,3 dB) (8×8) antenna array
Pinchera et al. [45]	mMIMO (8×8, 12×12, 16×16 antenna array) Codebook and reciprocity-based beamforming (up to 8 layers with SU-MIMO)	5G (mid-band)	100%	Uniform (azimuth and elevation) and uniform with UE in a planar region	200 to 1000	0.36 s to 1.8 s	≤0,17 (- 7,7 dB) (8×8 antenna array)
Rybakowski et al [49]	mMIMO (8×8 antenna array, 32 and 128 Tx) Codebook and reciprocity-based beamforming (up to 8 layers)	5G (mid-band)	100%	Uniform with scanning in elevation (from 3GPP TR 38.901 [18])	360/Ts*K Ts: scheduling time K: number of instantaneous users ranging from 1 to 8	From 10 s to 60 s (Results for the extended range from 10 s to 360 s are available in [49])	≤0,29 (-5,4 dB) (8×8 antenna array with codebook-based beamforming) ≤0,25 (-6,0 dB) (8×8 antenna array with reciprocit

Extracts from Table C.1 in Annex C.4

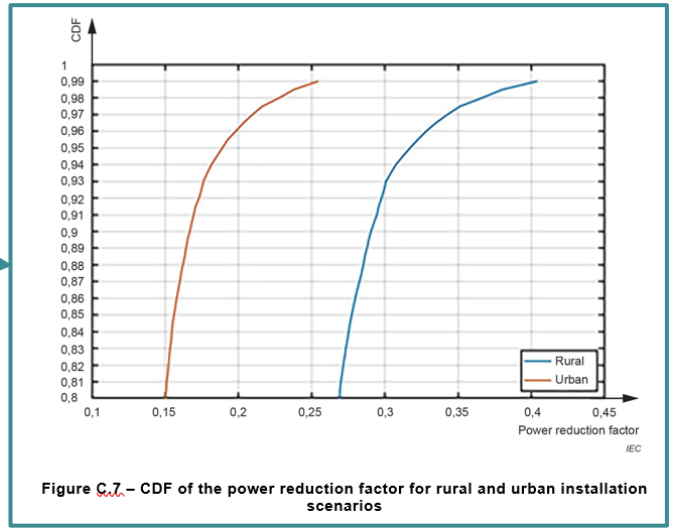
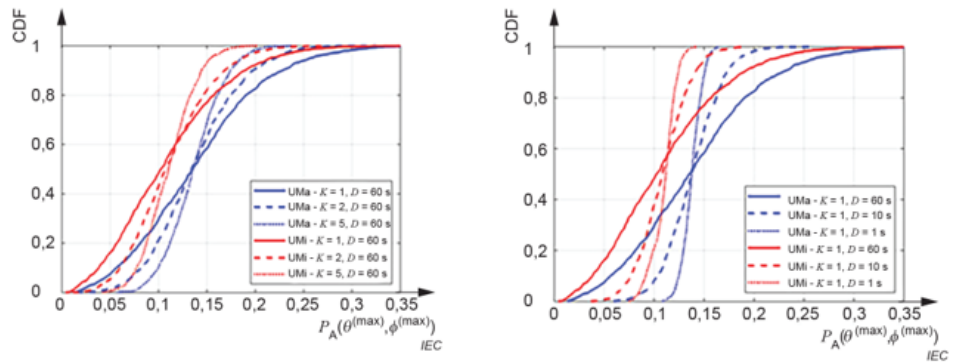


Figure C.7 – CDF of the power reduction factor for rural and urban installation scenarios



a) When the UE service duration D = 60 s and the number of simultaneously served UEs K = 1; 2; 5

b) When K = 1 and D = 1 s; 10 s; 60 s

Figure C.8 – CDF of the normalized transmitted power for both UMa and UMi

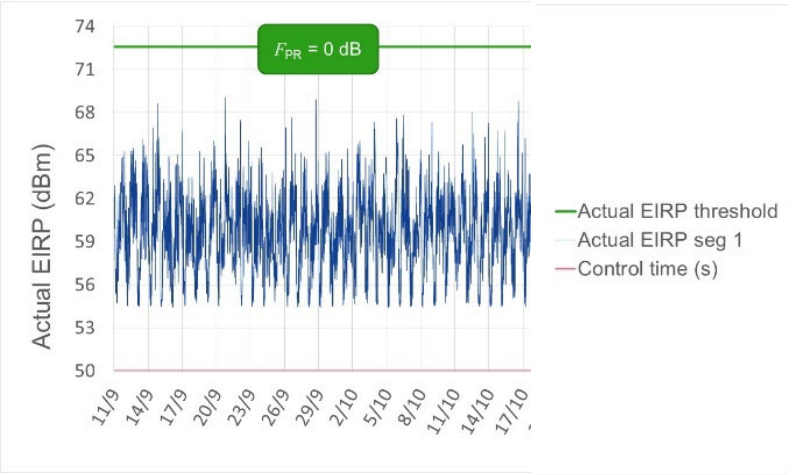
IEC 62232 – Product installation compliance (6.2)
Actual maximum approach – Rationale (from IEC TR 62669 Annex C)

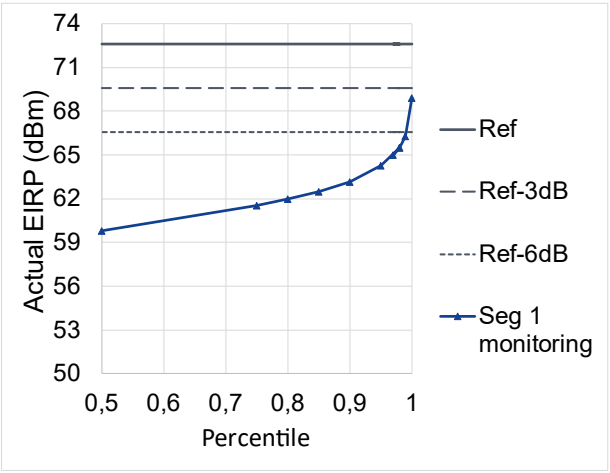
Experimental studies (5)

Table C.2 – Summary of experimental studies on F_{PR}

Study	Technology	Nb of BS	Monitoring time	Traffic load	Environment	Method.	F_{PR}
Werner et al. [88]	LTE (mid-band) mMIMO BS	1	4 week days (8 h per day)	Up to 67 % (hourly averaged)	Dense urban	In-situ measurements	≤0,09 (≤-10,5 dB) ≤0,21 (≤-6,8 dB) when scaling up F_{PR} for 100 % traffic load)
Colombi et al. [89]	LTE (mid-band) mMIMO BS	1	Network data: 3 days In-situ measurements: 15 or 30 minutes depending on the MEP	Up to 58 % (averaged over 15 minutes)	Urban/ office area	In-situ measurements and monitoring of network counters	≤0,07 (≤-11,5 dB) for in-situ measurements ≤0,18 (≤-7,4 dB) for network data
Colombi et al. [90]	NR (mid-band) mMIMO BS	25	24 hours	Up to 33 % (averaged over 6 minutes)	Dense urban	Monitoring of network counters	≤0,01 (≤-20 dB)

Extracts from Table C.2 in Annex C.5

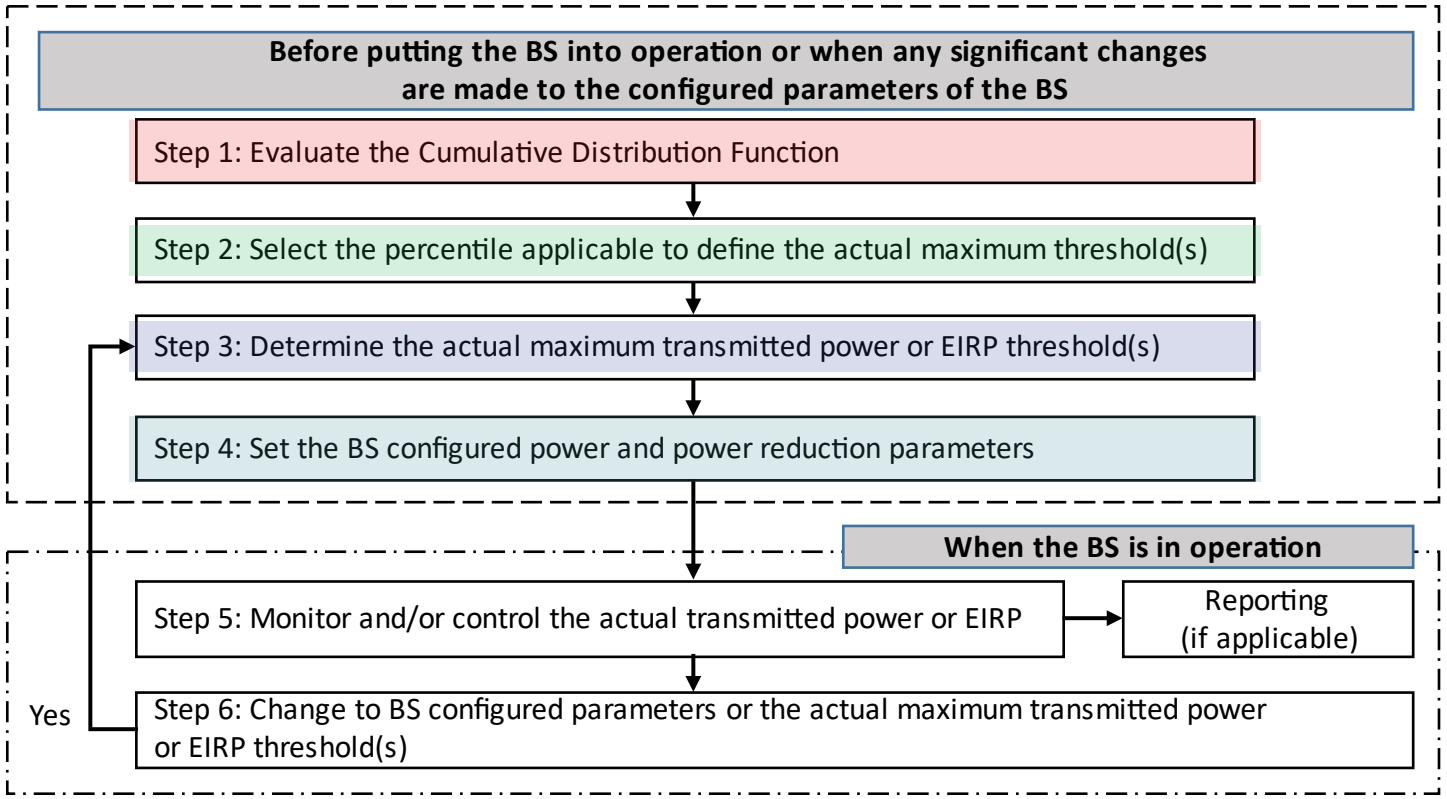


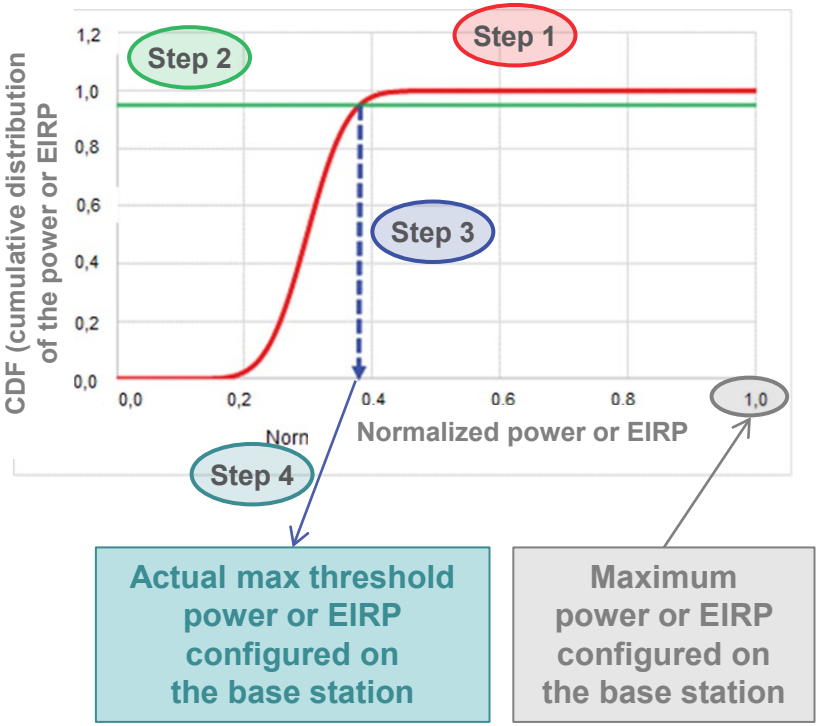


Extracts from Figure 22 in Clause 12 Case study A

IEC 62232 – Product installation compliance (6.2)
Actual maximum approach – Implementation principles

General process for putting a BS into operation



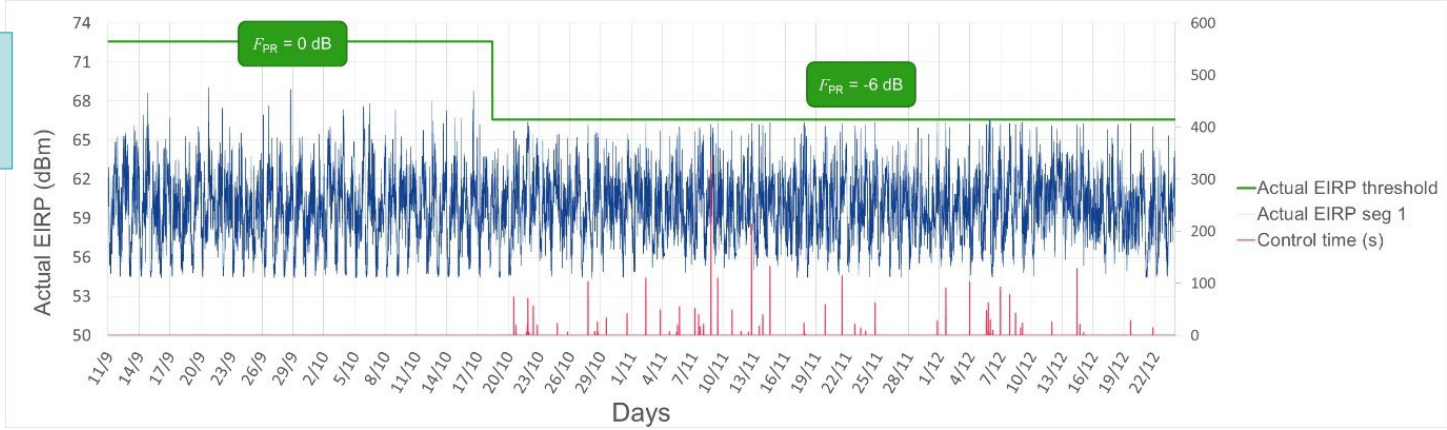


Extracts from Figure 12 and Figure 11

IEC 62232 – Product installation compliance (6.2)

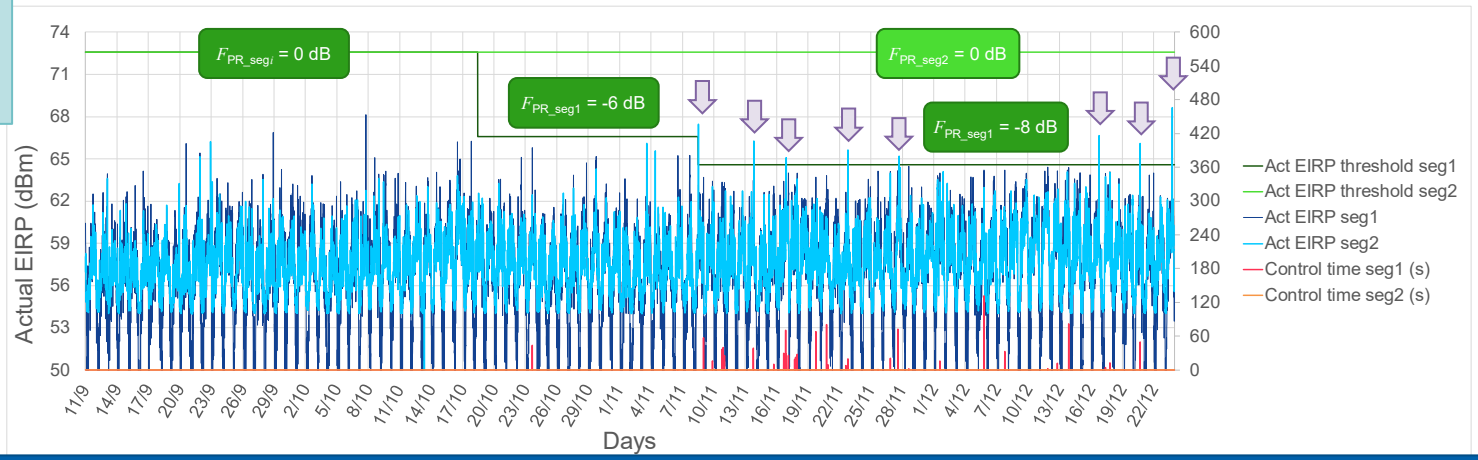
Actual maximum approach – Implementation case study A (IEC TR 62669 Clause 12)

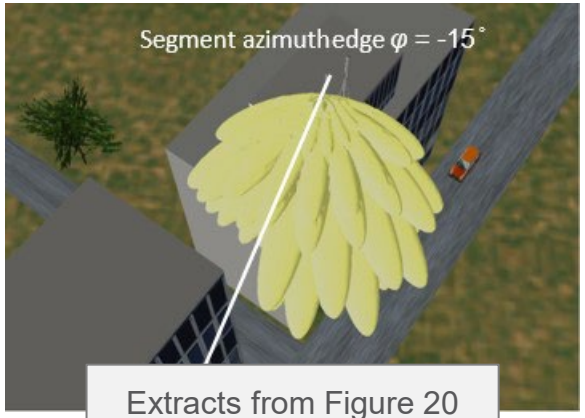
Single segment



Extracts from Figure 19

Two segments





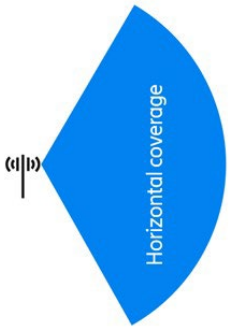
Extracts from Figure 20

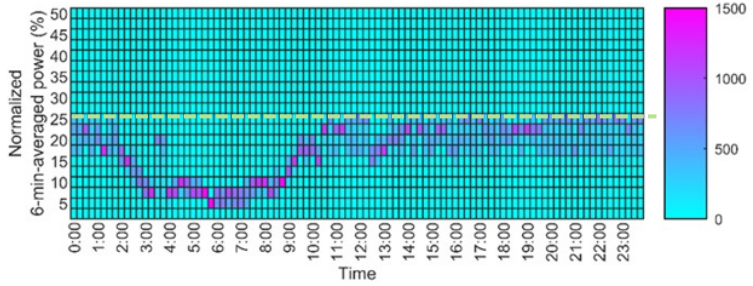
Counters collected in the network management system and methods described in IEC 62232:2022 can be used to verify that the configured actual power or EIRP is not exceeded during BS operation.

IEC 62232 – Product installation compliance (6.2)

Actual maximum approach – Implementation case study B (IEC TR 62669 Clause 12)

Single segment

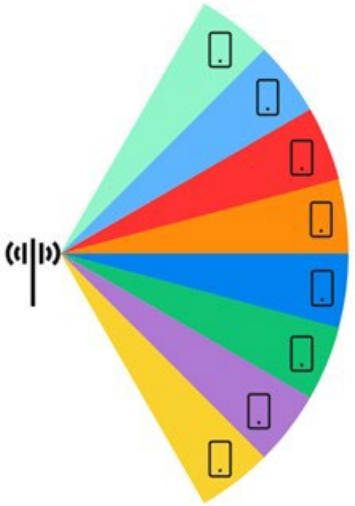


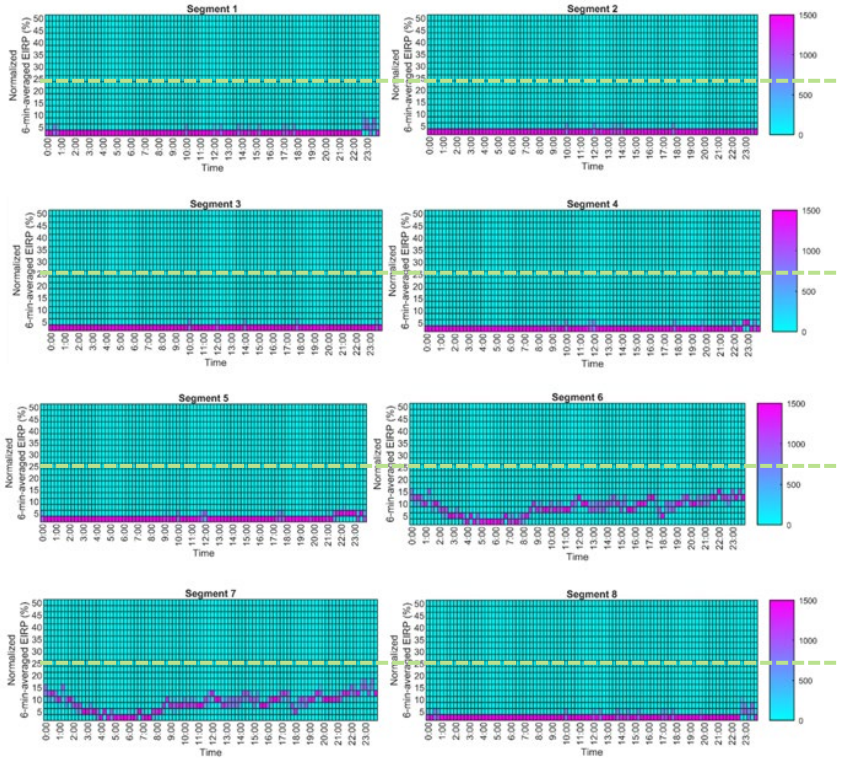


NOTE 1500 samples of P_{avg} are reported every 15 minutes; the heat map shows that the maximum actual power is never above 25% of the configured maximum

Figure 25 – 6-minute time-averaged transmitted power (cell-wide) distribution normalized to the configured maximum for a cell-wide monitoring and control feature

8 segments





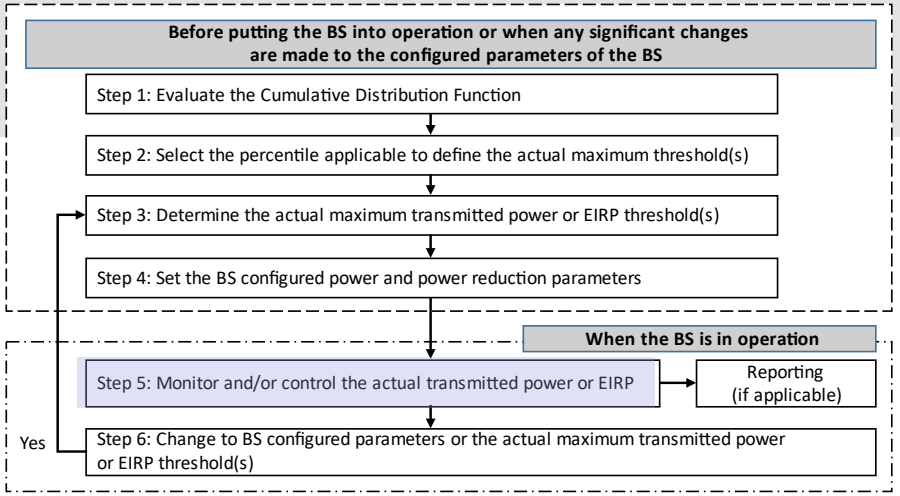
NOTE 1500 samples of P_{avg} are reported every 15 minutes for each of the eight segments; the heat map shows that the maximum actual EIRP is never above 25% of the configured maximum EIRP for each of the segment.

Figure 26 – Distribution of the 6-minute time-averaged maximum EIRP within each segment normalized to its maximum for a directional monitoring and control feature

Counters collected in the network management system and methods described in IEC 62232:2022 can be used to verify that the configured actual power or EIRP is not exceeded during BS operation.

IEC 62232 – Product installation compliance (6.2)

Actual maximum approach – Monitoring & control features (MCF) validation



- [Extract from 6.2.3.2.3, step 5]
- When implementing control features (e.g. actual transmitted power or EIRP threshold mechanisms), the network operator shall follow the requirements in 8.4 and Clause B.9.
- The network operator monitors the actual transmitted power or EIRP counters per BS sector, cell or segment, see B.9.5, made available by the BS management system to the network operator and records the CDF(s) periodically. The report of CDF records should be done depending on applicable regulation (e.g. every 7 days).
  - NOTE 1 It is possible that logging of the actual transmitted power, EIRP and other BS operational details necessary to demonstrate the implementation of the actual maximum approach is required by the applicable regulation.
- When power or EIRP monitoring counters or control functions are implemented by the network operator, the reporting of the CDF(s) and/or counters can be optional provided that they have been validated in accordance with Annex C.
- .[Extract from Annex C.1] When implementing the actual maximum approach as specified in 6.2.3, .8.4 and Clause B.9, the BS actual maximum power or EIRP should not exceed the actual maximum threshold value during its operation. This Annex C provides guidance for the validation of actual power or EIRP monitoring counters and control tools related to the actual maximum approach (…)

IEC 62232 – Product installation compliance (6.2)
Actual maximum approach – MCF validation case study A (IEC TR 62669 Clause 13)

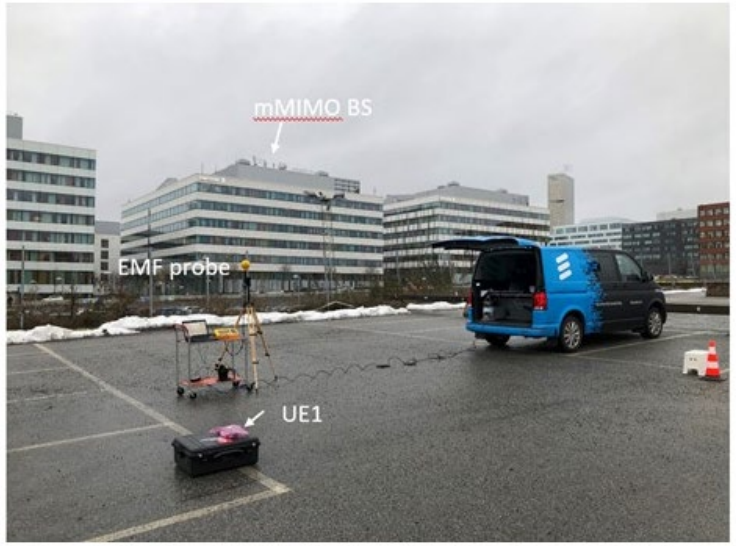


Figure 27 – Measurement setup for validation case study A

Table 25 – Overview of validation test results

Test case	Description	F_{TDC}	F_{PR}	$F_{TDC} \cdot F_{PR}$	$S_{baseline\_sample}$ (mW m^{-2})	$S_{baseline\_inst}$ (mW m^{-2})	$S_{measured}$ (mW m^{-2})	$S_{measured} / S_{baseline\ inst}$
TC1	Baseline measurement (feature OFF)	0,743	NA	NA	99,5	146,0	NA	NA
TC2	Feature ON; 1 UE with 100% traffic load; the actual maximum threshold is set equal to 25%	0,743	0,33 (all segments)	0,25	99,5	146,0	36,5	0,25
TC3	Feature ON; 3 UEs with 100% traffic load; the actual maximum threshold is set equal to 25%	0,743	0,33 (all segments)	0,25	99,5	146,0	32,2	0,22
TC4	Feature ON; the beam is steered in two directions sequentially (100% traffic load); in one of these directions no actual maximum threshold is set (configured maximum allowed)	0,743	1 for the segment corresponding to the MEP, and 0,33 elsewhere.	0,75 for the segment correspondin g to the MEP, and 0,25 elsewhere.	99,5	146,0	80,4	0,55 (see NOTE 1)
TC5	Feature ON; all beams are scanned sequentially in the azimuth plane; the actual maximum threshold is set equal to 25%	0,743	0,33 (all segments)	0,25	99,5	146,0	13,5	0,1 (see NOTE 2)

NOTE 1 The actual EIRP provided by the counter for the segment with F_{PR} = 0,33 and served by the 10 s beam is less than or equal to 17,5 % of the configured maximum.

NOTE 2 The actual EIRP provided by the counter was less than or equal to 17,5 % of the configured maximum for all segments

IEC 62232 – Product installation compliance (6.2)

Actual maximum approach – MCF validation case study B (IEC TR 62669 Clause 13)

Figure C.7 – Overview of the measurement site

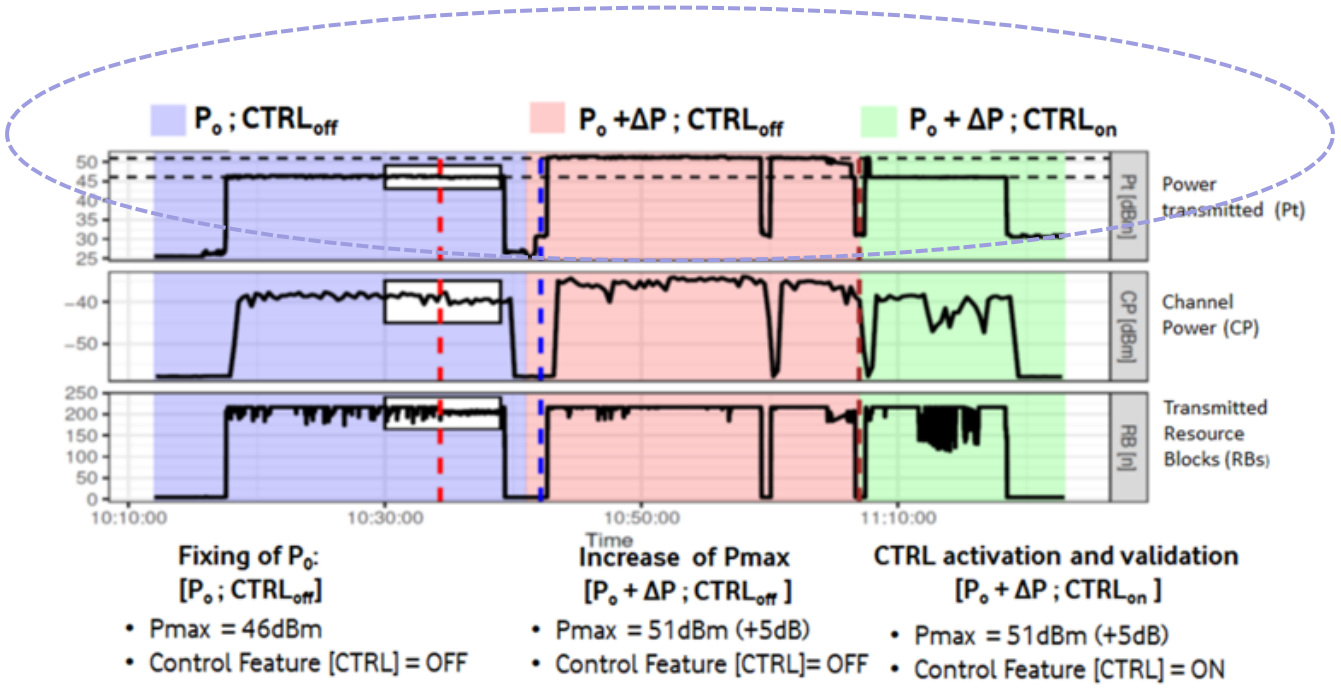


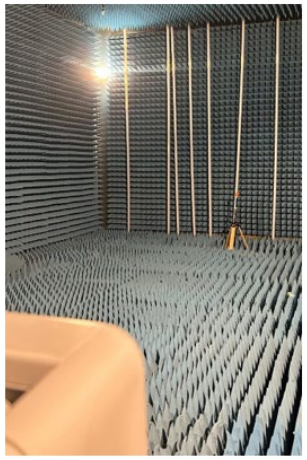
Figure C.9 – Power transmitted by the massive MIMO antenna (top trace), channel power (ChP) measurements (middle trace) and transmitted resource blocks (RBs) (bottom trace)

Extracts from Annex C.5.4 IEC 62232:2022

IEC 62232 – Product installation compliance (6.2)

Actual maximum approach – MCF validation case study C (IEC TR 62669 Clause 13)

(a) Outdoor test configuration



(b) Test configuration in an anechoic chamber

Figure 34 – OTA configurations used for MCF validation

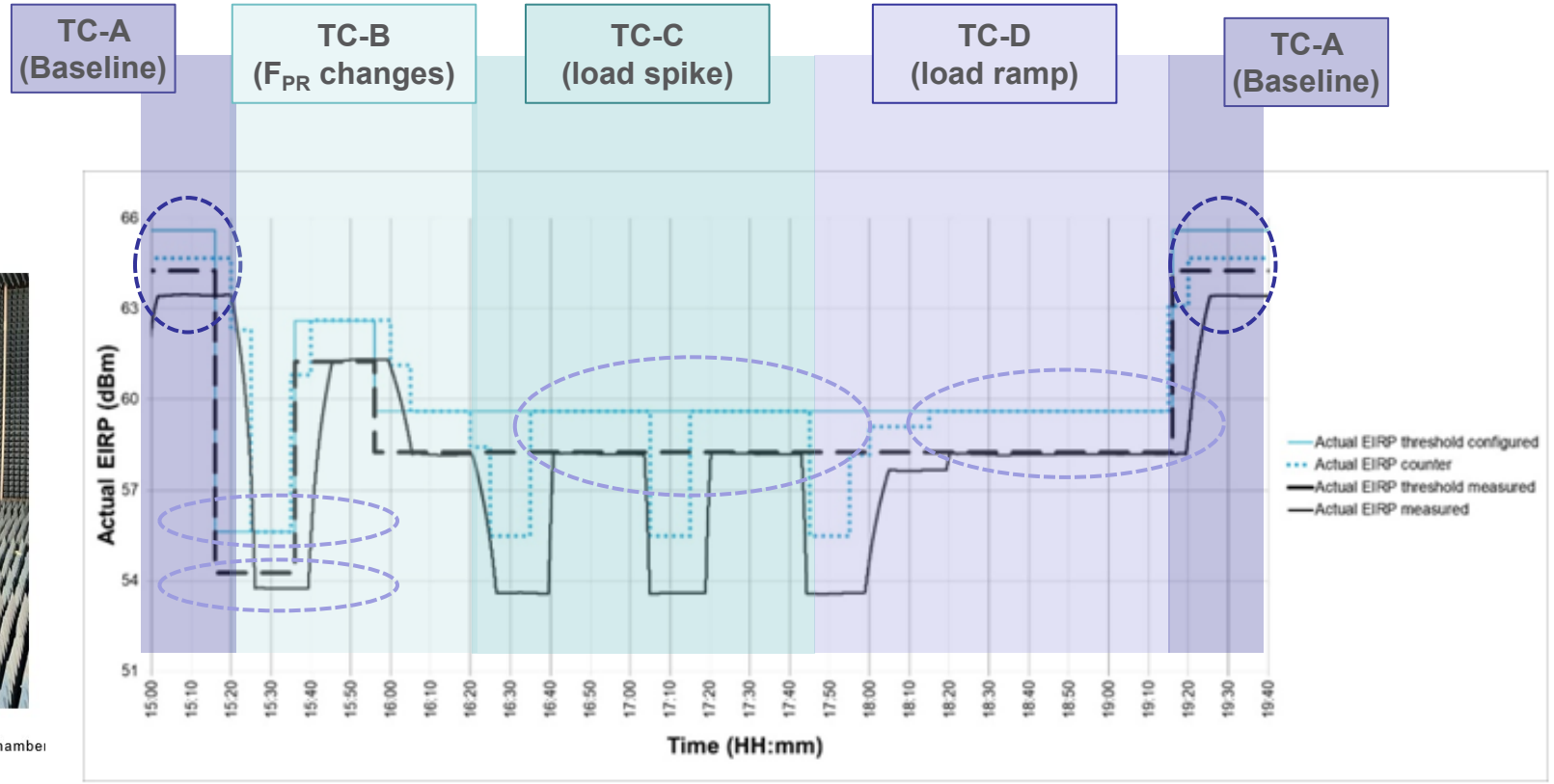
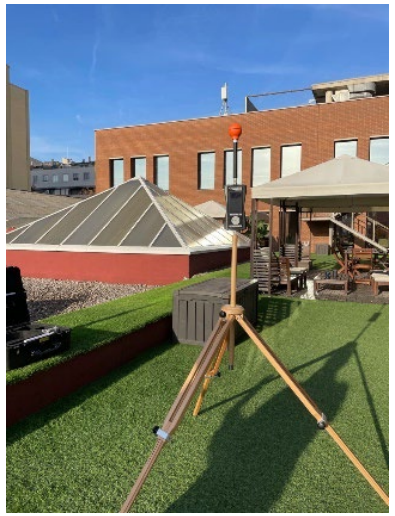


Figure 35 – Example of actual EIRP control OTA validation test results with one segment, including recorded counters and measurement results using a broadband probe

IEC 62232 – In-situ RF exposure evaluation or assessment process (6.3) Global process

- [Extract from 6.3.1] In-situ measurements are performed for multiple objectives, such as:
  - to determine if the RF exposure levels from the EUT and ambient sources are in **compliance with applicable regulations or exposure limits**, as observed or extrapolated to maximum or actual maximum levels; or
  - to obtain the RF exposure levels **for use when presenting results** even if they are well below the applicable exposure limits.



Extract from IEC TR 62669
Figure 76

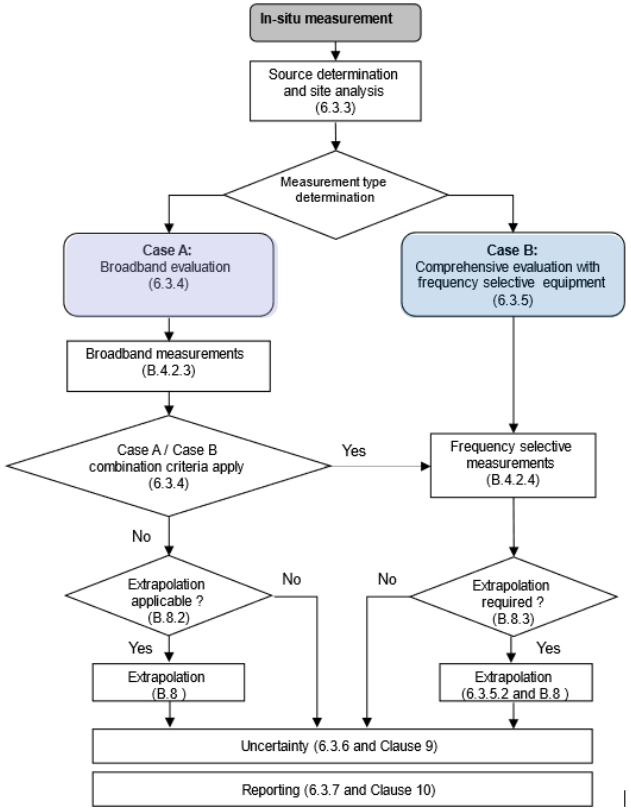
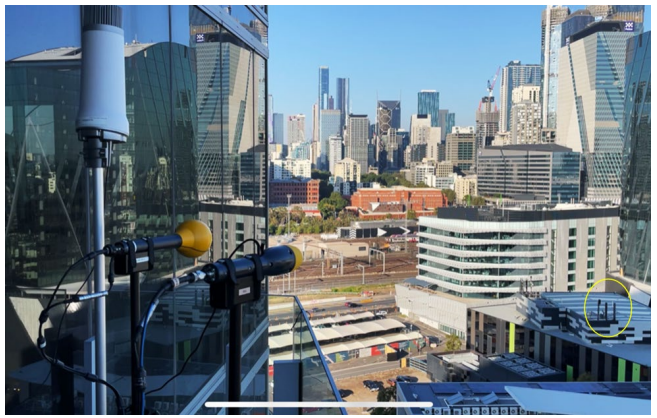


Figure 15 – In-situ RF exposure evaluation or assessment process flow chart



Extract from IEC TR 62669
Figure 54

IEC 62232 – In-situ RF exposure evaluation or assessment process (6.3)
IEC TR 62669 – Small cells case studies (Clause 14)

Case study A

Figure 37 – Illustration of small cells integration in street furniture

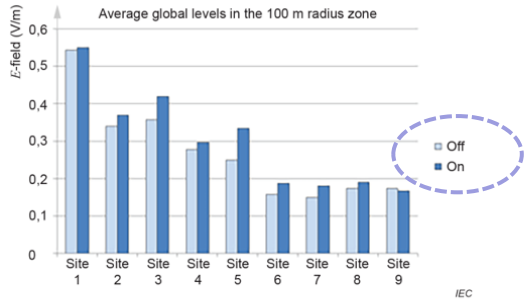


Figure D.1 – Mean value of electric field strength measurements with broadband equipment at intermediate points for each site

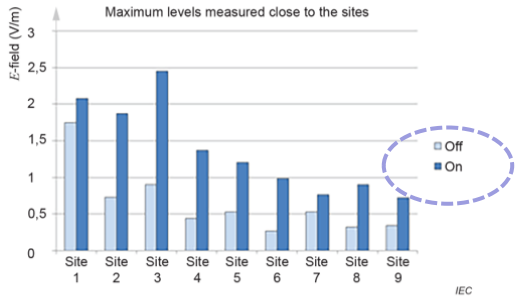


Figure D.2 – Maximum global electric field strength values measured in close proximity to the sites

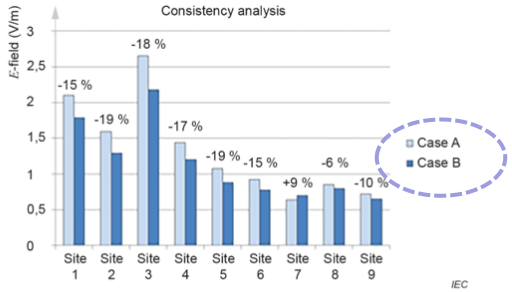


Figure D.3 – Consistency analysis between Case A and Case B (without extrapolation) results

Case study B

a) Indoor b) Outdoor 2 m to 4 m c) Outdoor > 4 m

Figure 38 – Photographs of typical examples of the three small cell site groups

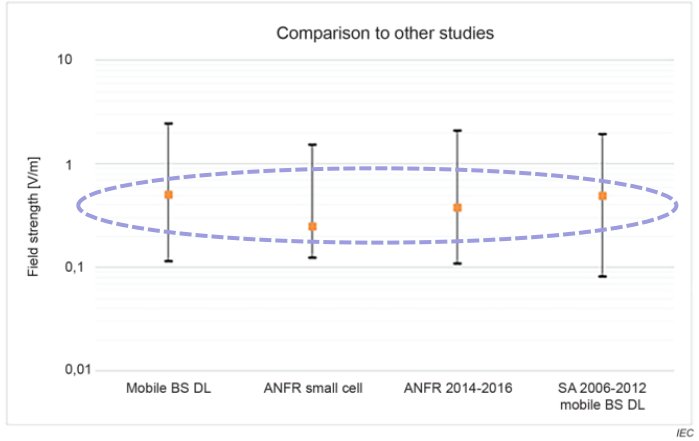


Figure D.10 – Comparison between Campaign B results and other countrywide measurement campaigns

IEC 62232 – In-situ RF exposure evaluation or assessment process (6.3)
IEC TR 62669 – Millimeter wave BS case study B (Clause 15)

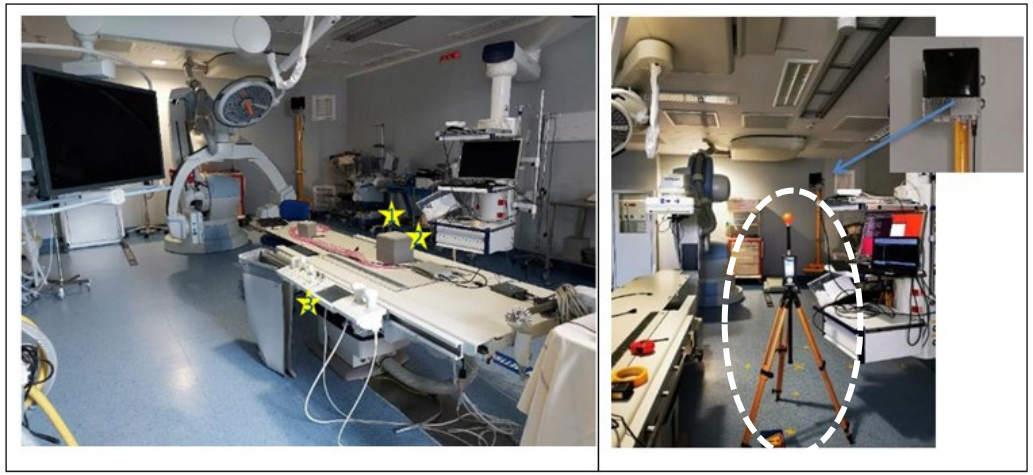


Figure 43 – Measurement locations

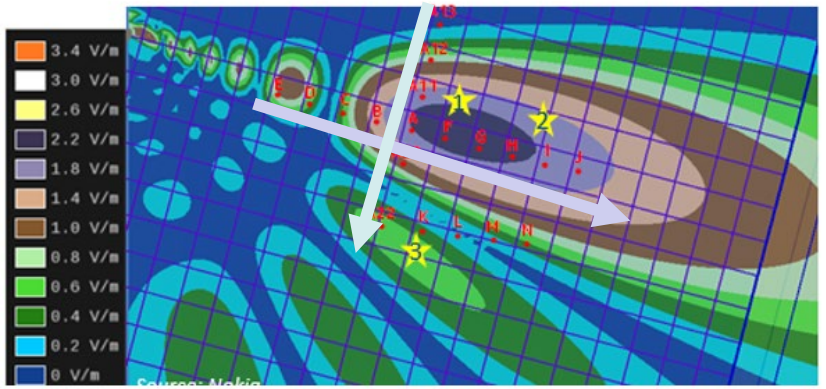


Figure 44 – MEP scan grid at 1,5 m above ground superposed with modelling results

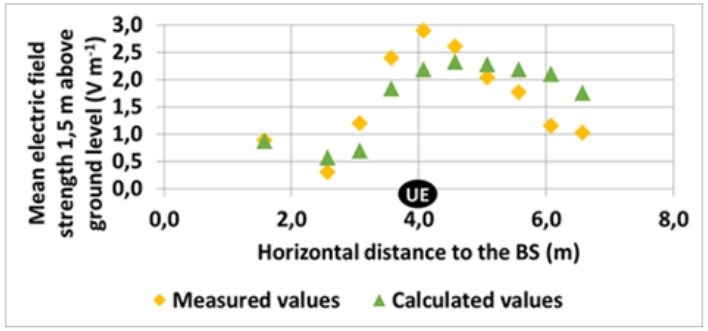


Figure 47 – Comparison of measurement and modelled results in the boresight direction

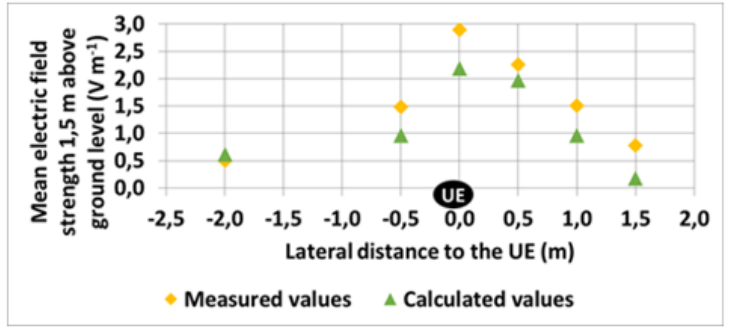


Figure 48 – Comparison of measurement and modelled results in the direction perpendicular to boresight

IEC 62232 – In-situ RF exposure evaluation or assessment process (6.3)
IEC TR 62669 – Millimeter wave BS case study D (Clause 14)

Figure 56 – Example of test case representing family with teenagers and guests during a weekend stay

Figure 57 – Example of test case representing tech intensive usage

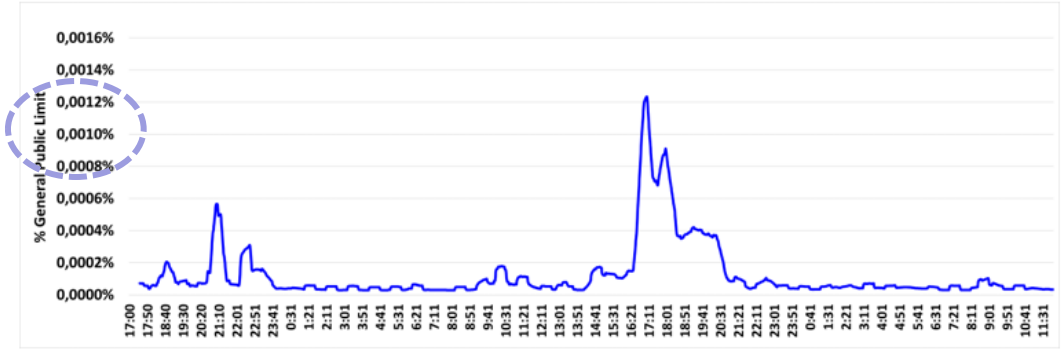


Figure 58 – Measured RF exposure levels (30-minute time-averaged) – family with teenagers

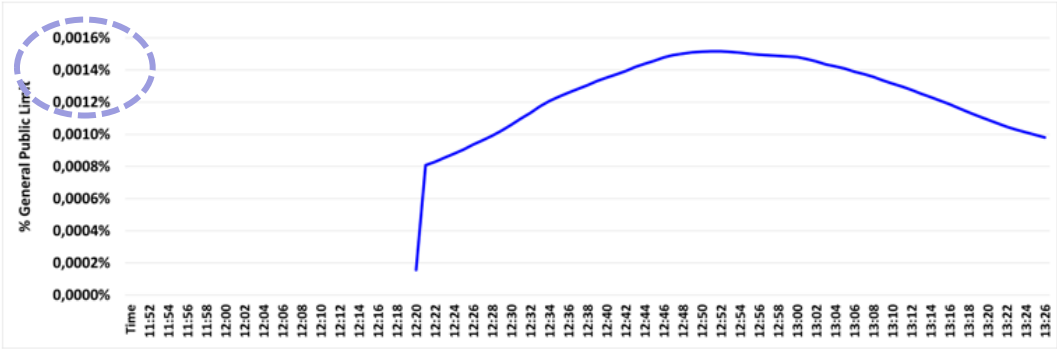


Figure 59 – Measured RF exposure levels (30-minute time-averaged) – tech intensive usage

IEC 62232 – In-situ RF exposure evaluation or assessment process (6.3)
IEC TR 62669 – Macro BS case studies (Clause 16)

Case study B (comparison)

Figure 69 – View from the measurement locations to the BS site A

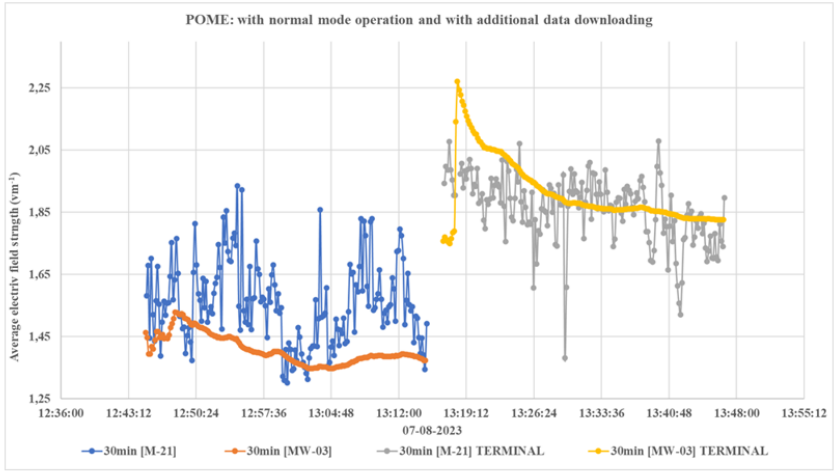
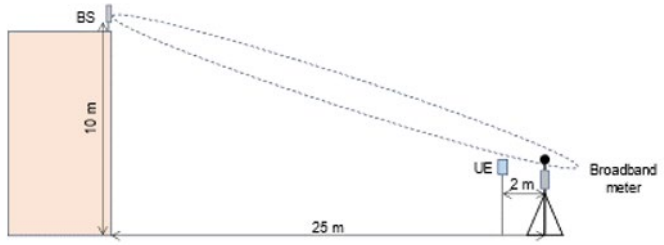
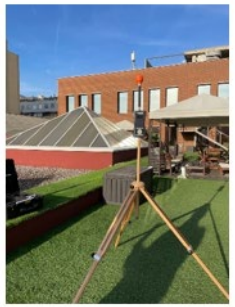


Figure 72 – Measurement results in POME-3 – comparison between the normal operation mode (left) and the forced data transmission mode (right)

Case study C (broadband)



a) schematic view



b) picture

Figure 76 – BS, UE and broadband meter positioning

Table 57 – Summary of measured levels and BS performance parameters

BS load	Typical load
Average RMS E field	2,57 V m^{-1}
Equivalent Power density	0,017 W m^{-2} (0,2 % of the general public limit [1])
Configured maximum transmitted power	73 W
Throughput	236 Mbps

IEC 62232 – In-situ RF exposure evaluation or assessment process (6.3) Extrapolation principles

- [Extract from 6.3.5.2] Extrapolation of the configured maximum or actual maximum RF exposure
- When implementing control features If the aim is to evaluate the maximum RF exposure conditions taking into account traffic, transmitted power and beam steering (e.g. massive MIMO) variations, then the evaluation result data shall be extrapolated. Extrapolation shall apply only to sources of interest, see 6.3.5.1.
- Extrapolation shall be performed from **measurement of stable (i.e. time independent) reference signal(s) or channel(s)** as specified in B.8.3 and Annex E. (…)
- The extrapolation factor shall be evaluated as specified in Clause B.8 based on
  a) either the configured maximum transmitted power or EIRP, or
  b) the actual maximum transmitted power or EIRP value(s) configured in the BS if the actual maximum approach is implemented as specified in 6.2.3 and 8.4.

IEC TR 62669
Clause 17
Case study D
(comparative)

Figure 94 – Measurement situation at site A

Figure 95 – Measurement situation at site B

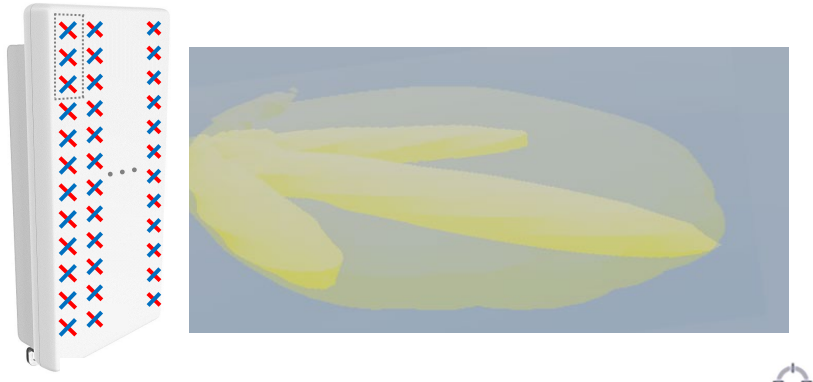
Figure 96 – Measurement situation at site C

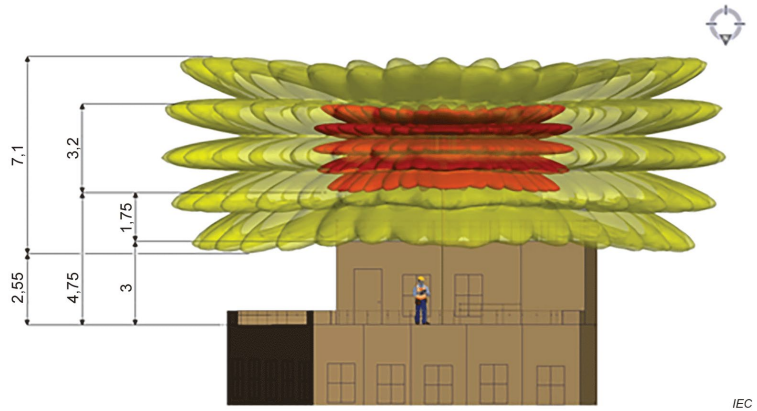
Figure 97 – Measurement situation at site D

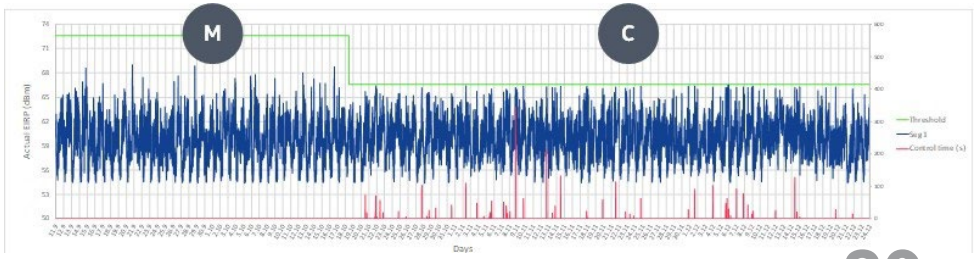
Summary – IEC 62232:2022 Ed. 3.0 standard

IEC 62232:2024 **Ed. 4.0** publication is expected by the end of 2024
I has the same technical content, includes only minor error corrections
and editorial updates to improve readability and alignment with TR 62669 Ed. 3.0)

- IEC 62232:2022 Ed. 3.0 & Ed. 4.0
  - "Determination of RF field strength, power density and SAR in the vicinity of base stations for the purpose of evaluating human exposure"
  - Referenced in many countries/regions (totally or partially)
- Scope
  - Specify both measurements and computation techniques for assessing RF exposure from base stations
  - Extended frequency range up to 300 GHz
  - Compatible with multiple applicable exposure limits, including ICNIRP-1998, ICNIRP-2020, IEEE C95.1:2019 and SC6:2015
- Content
  - Product compliance boundaries
  - Product installation compliance boundaries (including pre-existing exposure)
  - Methods for implementing the actual maximum approach and validating monitoring and control features
  - Measurement methods (in-situ compliance, extrapolation, features validation)
  - Computation methods







Summary – IEC TR 62669 implementation case studies

- IEC TR 62669:2019 Ed. 2.0 (published)
  - ❑ “Case studies supporting IEC 62232 - Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure”
  - ❑ Describes examples of exposure assessment campaigns performed at various stages of the implementation IEC 62232:2022
  - ❑ 16 case studies from 8 national committees

- IEC TR 62669 Ed. 3.0 (to be published 1H-2025)
  - ❑ **Additional** case studies addressing
    - The actual maximum approach: implementation and validation
    - Extrapolation techniques of 5G massive MIMO signal
    - Emerging laboratory measurement methods related to ICNIRP 2020
  - ❑ 30+ case studies from 13 national committees
  - ❑ Planned adoption in 2024 and publication in 2025