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**Measurement of radio frequency
electromagnetic fields to determine compliance
with human exposure limits when a base station
is put into service**

Recommendation ITU-T K.100

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Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service

Summary

Recommendation ITU-T K.100 provides information on measurement techniques and procedures for assessing compliance with the general public electromagnetic field (EMF) exposure limits when a new base station (BS) is put into service, taking into account effects of the environment and other relevant radio frequency sources present in its surroundings.

History

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Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service

1 Scope

This Recommendation specifies the measurement procedure to assess compliance with general public electromagnetic field (EMF) exposure limits for a base station (BS) operating in the frequency range 100 MHz-100 GHz when it is put into service in its operational environment.

Simplified assessment procedures are provided to identify those installations that are known to be compliant with EMF exposure limits without measurements.

With its specific focus on measurements, this Recommendation complements the existing ITU-T K-series Recommendations.

Contact currents due to contact with conductive objects irradiated by EMFs, lie outside the scope of this Recommendation. For commercial market BS products, there could be other requirements specified by the manufacturer that might need to be fulfilled. For such types of product testing, this Recommendation also does not apply.

Where national laws, standards or guidelines on exposure limits to EMF exist and provide procedures that are at variance with this Recommendation, the pertinent national laws, standards or guidelines shall take precedence over the procedures provided in this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T K.52] Recommendation ITU-T K.52 (2018), *Guidance on complying with limits for human exposure to electromagnetic fields*.
- [ITU-T K.61] Recommendation ITU-T K.61 (2018), *Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations*.
- [ITU-T K.70] Recommendation ITU-T K.70 (2018), *Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations*.
- [ITU-T K.91] Recommendation ITU-T K.91 (2018), *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields*.
- [IEC 62232] IEC 62232:2017, *Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*.
- [IEC 62479] IEC 62479:2010, *Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz – 300 GHz)*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 actual value: Time-averaged value of transmitted power or equivalent isotropically radiated power (EIRP) of the equipment under test (EUT) using the averaging time specified in the applicable radio frequency (RF) exposure limits, e.g., 6 minutes using [b-ICNIRP] or a conservative value close to it, e.g., 5 minutes using [b-IEC TR 62669].

3.2.2 actual maximum (max) value: Maximum value reached by the actual value when recorded by the EUT during a given period (e.g., week or month).

3.2.3 actual maximum (max) threshold: Threshold value of the actual transmitted power or EIRP configured by the EUT so that the actual maximum does not exceed this threshold during service, for example using transmitted power or EIRP control features and tools implemented in the EUT.

3.2.4 ambient source: A radio frequency (RF) source operating in the frequency range from 8.3 kHz to 300 GHz generating electromagnetic fields other than the emission from the equipment under test (EUT).

3.2.5 assessment domain boundary (ADB): Boundary surrounding an antenna of the equipment under test (EUT) outside of which measurements do not need to be conducted. The ADB defines the maximum possible measurement area where the source is considered to be relevant.

3.2.6 base station (BS): Fixed equipment for radio transmission used in cellular communication or wireless installation for local area networks. For the purpose of this Recommendation, the term base station includes all radio transmitter(s) and associated antenna(s).

3.2.7 compliance boundary (CB): Boundary defining a volume outside which the radio frequency (RF) exposure from the equipment under test (EUT) is below the exposure limit.

3.2.8 domain of investigation (DI): Sub-domain within the assessment domain boundary (ADB) to which the general public have access.

3.2.9 equipment under test (EUT): For the purpose of this Recommendation, the EUT is the base station that shall be put into service, including all transmitting antennas (operating in the frequency range 100 MHz to 100 GHz).

3.2.10 equivalent isotropically radiated power (EIRP): The product of the power accepted by the antenna and the maximum antenna gain relative to an isotropic antenna.

3.2.11 exposure ratio (ER): The assessed exposure parameter at a specified location for each operating frequency of a radio source, expressed as the fraction of the related limit.

For assessment against reference levels:

$$ER = \max [(E/E_{\text{lim}})^2, (H/H_{\text{lim}})^2]$$

In the far-field:

$$ER = (E/E_{\text{lim}})^2 = (H/H_{\text{lim}})^2 = S/S_{\text{lim}}$$

where S , E , and H are the root mean square (r.m.s.) values, respectively, of power density, electric field strength and magnetic field strength measured at frequency f . S_{lim} , E_{lim} and H_{lim} are the corresponding limits at the same frequency.

When exposure is evaluated for a certain frequency band (the total power density or the field strength within the frequency interval $[f_{\min}, f_{\max}]$ is assessed), S_{lim} , E_{lim} or H_{lim} are chosen as the most stringent limits within the band.

3.2.12 far-field formula: Formula that can be used in the far-field to evaluate the power density, S :

$$S = \frac{PG_{\theta,\varphi}}{4\pi d^2}$$

where P is the transmitted power, $G_{\theta,\varphi}$ is the gain of the antenna in the direction (θ, φ) and d is the distance from the antenna to the evaluation point. The associated electric field strength, E , and magnetic field strength, H , can be evaluated as follows:

$$E = \frac{\sqrt{30PG_{\theta,\varphi}}}{d},$$

$$H = \frac{E}{\eta_0},$$

where $\eta_0 \approx 377 \Omega$.

If the power density is evaluated in the direction of maximum antenna gain:

$$S = \frac{EIRP}{4\pi d^2}.$$

3.2.13 isotropic antenna: A hypothetical, lossless antenna having equal radiation intensity in all directions.

3.2.14 main lobe: The radiation lobe containing the direction of maximum radiation. In certain antennas, such as multilobed or split-beam antennas, there may be more than one major lobe.

3.2.15 reactive near-field region: The reactive near field of an antenna with maximum extension D is in this context defined as $\max(\lambda, D, D^2/4\lambda)$ where λ denotes the free space wavelength.

3.2.16 relevant source: A radio source, in the frequency range 8.3 kHz to 300 GHz, which at a given point of investigation has an exposure ratio (ER) larger than 0.05.

3.2.17 side lobe: A radiation lobe in any direction other than the main lobe.

3.2.18 total exposure ratio (TER): The sum of exposure ratios (ERs) of the equipment under test (EUT) and other relevant sources.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADB	Assessment Domain Boundary
AMPS	Advanced Mobile Phone System
BCCH	Broadcast Control Channel
BS	Base Station
CB	Compliance Boundary
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CPICH	Common Pilot Channel

DAB	Digital Audio Broadcasting
DI	Domain of Investigation
DVB-T	Digital Video Broadcasting-Terrestrial
EIRP	Equivalent Isotropically Radiated Power
EMF	Electromagnetic Field
ER	Exposure Ratio
EUT	Equipment Under Test
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GSM	Global System for Mobile Communications
LOS	Line Of Site
LTE	Long-Term Evolution
MCCH	Multicast Control Channel
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency-Division Multiplexing
PBCH	Physical Broadcast Channel
RBW	Resolution Bandwidth
RF	Radio Frequency
r.m.s.	root mean square
SAR	Specific Absorption Rate
SD	Standard Deviation
TACS	Total Access Communications System
TDMA	Time Division Multiple Access
TER	Total Exposure Ratio
TETRA	Terrestrial Trunked Radio
TETRAPOL	Terrestrial Trunked Radio for Police
UMTS	Universal Mobile Telecommunication System
WCDMA	Wideband Code Division Multiple Access
Wi-Fi	Wireless Fidelity

5 Conventions

None.

6 Assessment procedure

6.1 General process

When in a base station (BS), the equipment under test (EUT), is installed and put into service at a site, the procedure described in Figure 6-1 shall be used to assess compliance with exposure limits. In order to allow for accurate and efficient assessments, different routes are possible depending on

the characteristic of the EUT or on the installation type. The compliance assessment process can be implemented using the actual maximum equivalent isotropically radiated power (EIRP) threshold of the BS site or BS site sector sub-divisions and following the guidelines described in [b-IEC TR 62669]. The actual maximum EIRP threshold can be derived from the actual maximum transmitted power using the maximum gain of the antenna or individual antenna beams for massive multiple input multiple output (MIMO).

In some specific cases, compliance with relevant exposure limits can be assessed without the necessity to conduct measurements (e.g., because of the low power transmitted, or because of the position or orientation of the transmitters or antennas with respect to areas accessible to the general public, or because simpler calculation methods can be used [ITU-T K.52]). Both broadband and frequency-selective equipment can be used for the assessment (see clause 10.1). Measurements conducted with broadband equipment, however, might lead to overly conservative results. If the exposure level in areas accessible to the general public is found to be above the limits by means of broadband measurements, then compliance should be verified with frequency-selective equipment. Otherwise, the mitigation techniques described in [ITU-T K.70] shall be applied. The step-by-step procedure of Figure 6-1 is specified in clauses 7 to 11.

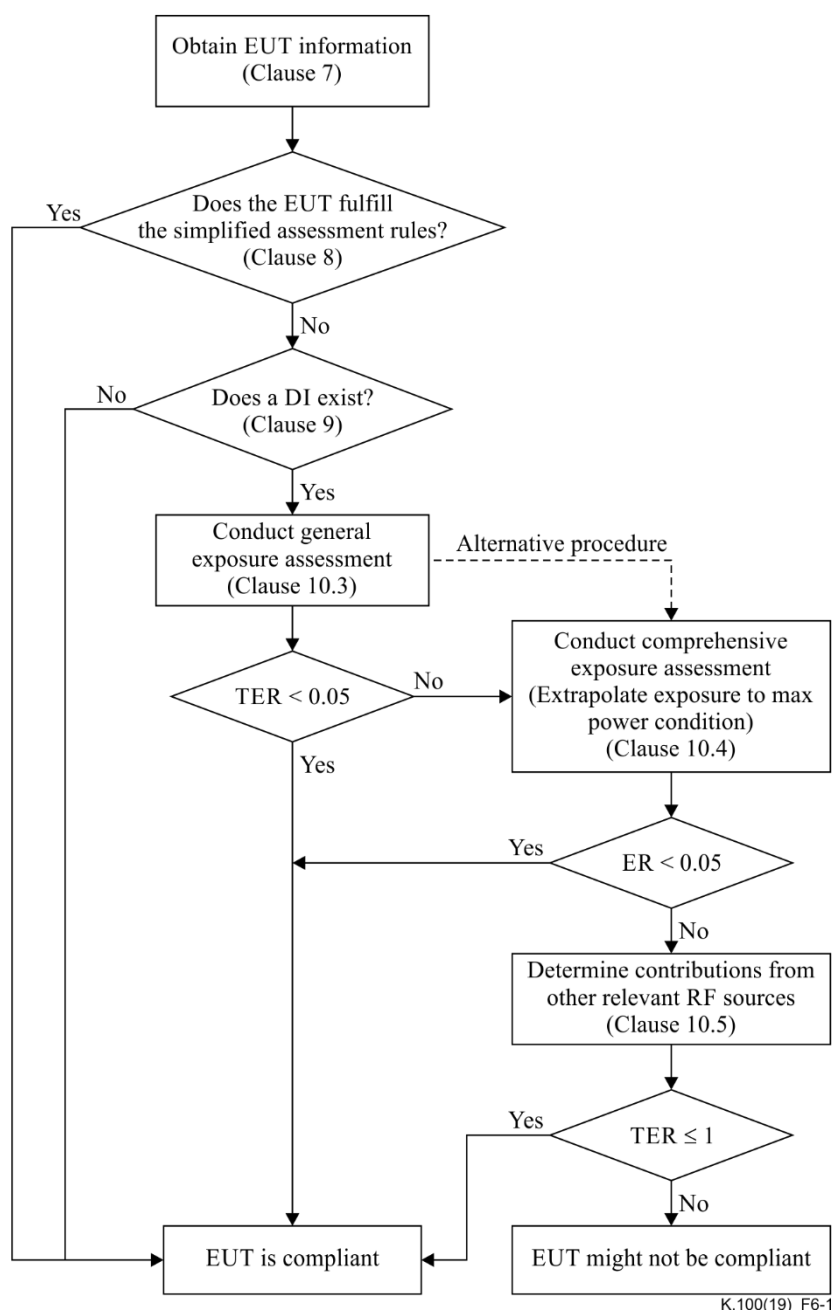


Figure 6-1 – Flowchart describing the measurement procedure specified in this Recommendation

6.2 Method based on the actual maximum transmitted power or EIRP

The method based on actual maximum transmitted power or EIRP provides for more accurate assessment of the real maximum exposure from a base station using the parameters of the site. It avoids the unrealistic over-estimation of other approaches.

[b-IEC TR 62669] provides measurement campaign and simulation results showing that the real time-averaged transmitted power by a base station (BS) during service, called actual transmitted power, is generally below the time-averaged maximum transmitted power.

[b-IEC TR 62669] makes the following recommendations:

- 1) As a conservative approach, the actual maximum EIRP (directly or derived from the actual maximum transmitted power) can be used to determine the RF compliance boundary

provided that the operator is implementing tools ensuring this threshold is not exceeded over time during service.

- 2) These tools can be based on BS counters and features developed by manufacturers to monitor and control the EIRP (directly or derived from the RF transmitted power) and other relevant characteristics of the BS.
- 3) This applies to all types of BS, whether they are using fixed beams or steerable beams like with massive MIMO.
- 4) This applies to BS sector or subdivisions of a BS sector for massive MIMO.

Figure 6-2 shows an example of BS site sector based on the actual max EIRP. The RF exposure compliance boundary is defined based on the actual max EIRP threshold configured by the BS. The BS is implementing monitoring and control tools ensuring that the actual EIRP does not exceed this EIRP max threshold during service. The recording of the actual EIRP over time is summarized in a cumulative distribution function (CDF) that provide the actual max EIRP (100th percentile) and other lower percentiles (95th or 99th)

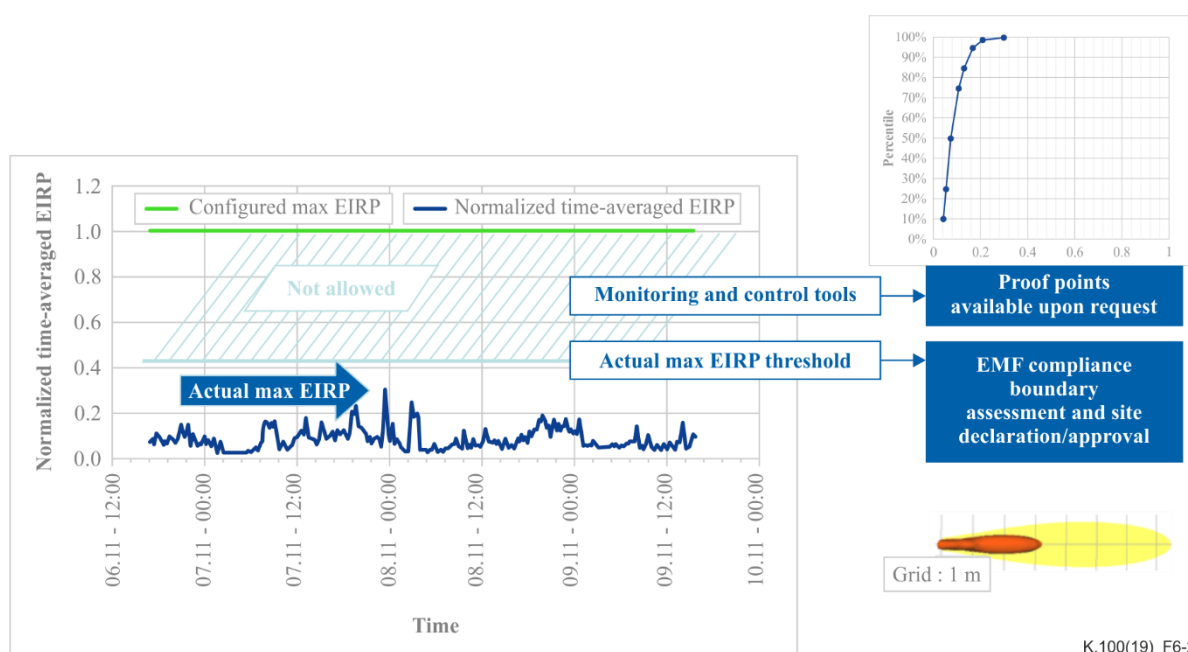


Figure 6-2 – Example of implementation of compliance based on actual max EIRP

The process flow chart for assessing compliance derived from [b-IEC TR 62669] is shown in Figure 6-3.