

International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.52

(06/2021)

SERIES K: PROTECTION AGAINST INTERFERENCE

Guidance on complying with limits for human exposure to electromagnetic fields

Recommendation ITU-T K.52

ITU-T

Recommendation ITU-T K.52

Guidance on complying with limits for human exposure to electromagnetic fields

Summary

Recommendation ITU-T K.52 aims to help with compliance of telecommunication installations and mobile handsets, or other radiating devices used against the head with safety limits for human exposure to electromagnetic fields (EMFs). It presents general guidance, a calculation method and an installation assessment procedure. The assessment procedure for telecommunication installations, based on safety limits provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), helps users determine the likelihood of installation compliance based on accessibility criteria, antenna properties and emitter power. The IEC Standard for the compliance measurement of mobile handsets is recommended.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T K.52	2000-02-25	5	11.1002/1000/4915
2.0	ITU-T K.52	2004-12-14	5	11.1002/1000/7427
2.1	ITU-T K.52 (2004) Cor. 1	2009-05-29	5	11.1002/1000/10020
2.2	ITU-T K.52 (2004) Amd. 1	2013-02-07	5	11.1002/1000/11905
3.0	ITU-T K.52	2014-08-29	5	11.1002/1000/12238
4.0	ITU-T K.52	2016-12-14	5	11.1002/1000/13131
5.0	ITU-T K.52	2018-01-13	5	11.1002/1000/13446
5.1	ITU-T K.52 (2018) Amd. 1	2018-09-21	5	11.1002/1000/13790
6.0	ITU-T K.52	2021-06-29	5	11.1002/1000/14724

Keywords

Basic restrictions, compliance, exposure assessment, exposure level, reference levels.

* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2021

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

		Page
1	Scope	1
2	References.....	1
3	Terms and definitions	2
4	Abbreviations and acronyms	5
5	General principles.....	5
	5.1 Multiple sources and frequencies	6
	5.2 Exposure duration.....	6
6	EMF safety limits	6
7	Compliance of wireless communication devices.....	6
8	Achieving compliance to EMF safety limits for telecommunication installations.....	7
	8.1 Determining the need for assessment for telecommunication equipment.....	7
	8.2 Procedures for EMF exposure assessment	7
	8.3 Exposure level assessment procedure	8
9	EMF evaluation techniques	10
	9.1 Calculation methods	10
	9.2 Measurement procedures.....	12
10	Mitigation techniques	13
	10.1 Occupational zone	13
	10.2 Exceedance zone	13
	Annex A – The application flow chart.....	14
	Annex B – Basic criteria for determining the installation category.....	16
	B.1 Inherently compliant sources.....	16
	B.2 Normally compliant installations	16
	Appendix I – ICNIRP limits	22
	Appendix II – Example of simple evaluation of EMF exposure	23
	II.1 Exposure at the ground level	23
	II.2 Exposure at an adjacent building.....	24
	Appendix III – Example of $EIRP_{th}$ calculation	26
	III.1 The $EIRP_{th}$ values	26
	Appendix IV Rationale for the $EIRP_{th}$ values of Tables in Appendix III.....	33
	IV.1 Inherently compliant sources.....	33
	IV.2 Normally compliant.....	33
	Bibliography.....	35

Introduction

This Recommendation aims to help with compliance of telecommunication installations, such as base stations, and wireless communication devices, such as mobile handsets or other radiating devices used next to the ear or close to the body, with safety limits for human exposure to electromagnetic fields (EMFs). This Recommendation does not set safety limits; it seeks to provide techniques and procedures for assessing the compliance of telecommunication installations and handsets with national or international EMF safety limits.

Recommendation ITU-T K.52

Guidance on complying with limits for human exposure to electromagnetic fields

1 Scope

This Recommendation aims to help with compliance of telecommunication installations, such as base station installations as defined in [IEC 62232], with safety limits for human exposure to electromagnetic fields (EMFs) produced by telecommunication equipment in the frequency range 8.3 kHz to 300 GHz¹. This Recommendation provides techniques and procedures for assessing the radiofrequency (RF) exposure to workers and the general public.

This Recommendation applies to hand-held and body-mounted wireless communication devices used next to the ear or close to the body operating in the frequency range 300 MHz to 6 GHz.

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.

This Recommendation covers the exposure of people present on telecommunication sites, and the exposure of people outside telecommunication sites, to EMF produced by telecommunication equipment and equipment on telecommunication sites.

Contact current exposure, due to contact with conductive objects irradiated by electromagnetic fields, is not covered in this Recommendation.

Exposure due to the use of mobile handsets or other radiating devices, used in close proximity to the human body other than the head, is not covered.

[b-ITU-T Dir. VI] covers safety issues related to people coming in contact with telecommunication circuits exposed to the induction of a.c. electric power or a.c. electrified railway lines.

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.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.100] Recommendation ITU-T K.100 (2018), *Measurement of Radio Frequency Electromagnetic Fields to Determine Compliance with Human Exposure Limits when a Base Station is Put Into Service*.
- [IEC 62209-1] IEC 62209-1:2016, *Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 1: Devices used next to the ear (Frequency range of 300 MHz to 6 GHz)*.

¹ Appendix I also gives the ICNIRP limits for lower frequencies.

- [IEC 62209-2] IEC 62209-2:2010, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz).*
- [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 Terms and definitions

This Recommendation defines the following terms:

3.1 antenna gain: The antenna gain $G(\theta, \phi)$ is the ratio of power radiated per unit solid angle multiplied by 4π to the total input power. Gain is frequently expressed in decibels with respect to an isotropic antenna (dBi). The equation defining gain is:

$$G(\theta, \phi) = \frac{4\pi}{P_{in}} \frac{dP_r}{d\Omega}$$

where:

θ, ϕ : the angles in a polar coordinate system

P_r : the radiated power along the (θ, ϕ) direction

P_{in} : the total input power

Ω : elementary solid angle along the direction of observation.

3.2 average (temporal) power (P_{avg}): The time-averaged rate of energy transfer defined by:

$$P_{avg} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t) dt$$

where t_1 and t_2 are the start and stop time of the exposure. The period $t_1 - t_2$ is the exposure duration time.

3.3 averaging time (T_{avg}): The averaging time is the appropriate time period over which exposure is averaged for purposes of determining compliance with the limits.

3.4 continuous exposure: Continuous exposure is defined as exposure for duration exceeding the corresponding averaging time. Exposure for less than the averaging time is called short-term exposure.

3.5 contact current: Contact current is the current flowing into the body by touching a conductive object in an electromagnetic field.

3.6 controlled/occupational exposure: Controlled/occupational exposure applies to situations where persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Occupational/controlled exposure also applies where the exposure is of transient nature as a result of incidental passage through a location where the exposure limits may be above the general population/uncontrolled limits, as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

3.7 directivity: Directivity is the ratio of the power radiated per unit solid angle over the average power radiated per unit solid angle.

3.8 equivalent isotropically radiated power (EIRP): The EIRP is the product of the power supplied to the antenna and the maximum antenna gain relative to an isotropic antenna.

3.9 exposure: Exposure occurs wherever a person is subjected to electric, magnetic or electromagnetic fields, or to contact currents other than those originating from physiological processes in the body or other natural phenomena.

3.10 exposure level: Exposure level is the value of the quantity used when a person is exposed to electromagnetic fields or contact currents.

3.11 exposure, non-uniform/partial body: Non-uniform or partial-body exposure levels result when fields are non-uniform over volumes comparable to the whole human body. This may occur due to highly directional sources, standing waves, scattered radiation or in the near field.

3.12 far-field region: That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In the far-field region, the field has a predominantly plane-wave character, i.e., locally uniform distribution of electric field strength and magnetic field strength in planes transverse to the direction of propagation.

3.13 general public: All non-workers (see definition of workers in clause 3.27) are defined as the general public.

3.14 induced current: Induced current is the current induced inside the body as a result of direct exposure to electric, magnetic or electromagnetic fields.

3.15 intentional emitter: Intentional emitter is a device that intentionally generates and emits electromagnetic energy by radiation or induction.

3.16 near-field region: The near-field region exists in proximity to an antenna or other radiating structure in which the electric and magnetic fields do not have a substantially plane-wave character but vary considerably from point-to-point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complicated in structure.

NOTE – For many antennas, the outer boundary of the reactive near-field is taken to exist at a distance of one-half wavelength from the antenna surface.

3.17 power density (S): Power flux-density is the power per unit area normal to the direction of electromagnetic wave propagation, usually expressed in units of Watts per square metre (W/m^2).

NOTE – For plane waves, power flux-density, electric field strength (E), and magnetic field strength (H) are related by the intrinsic impedance of free space, $\eta_0 = 377 \, \Omega$. In particular,

$$S = \frac{E^2}{\eta_0} = \eta_0 H^2 = EH$$

where E and H are expressed in units of V/m and A/m, respectively, and S in units of W/m^2 . Although many survey instruments indicate power density units, the actual quantities measured are E or H .

3.18 power density, average (temporal): The average power density is equal to the instantaneous power density integrated over a source repetition period.

NOTE – This averaging is not to be confused with the measurement averaging time.

3.19 power density, peak: The peak power density is the maximum instantaneous power density occurring when power is transmitted.

3.20 power density, plane-wave equivalent (S_{eq}): The equivalent plane-wave power density is a commonly used term associated with any electromagnetic wave, equal in magnitude to the power flux-density of a plane wave having the same electric (E) or magnetic (H) field strength.

3.21 relative field pattern: The relative field pattern $f(\theta, \phi)$ is defined in this Recommendation as the ratio of the absolute value of the field strength (arbitrarily taken to be the electric field) to the absolute value of the maximum field strength. It is related to the relative numeric gain (see clause 3.22) as follows:

$$f(\theta, \phi) = \sqrt{F(\theta, \phi)}$$

3.22 relative numeric gain: The relative numeric gain $F(\theta, \phi)$ is the ratio of the antenna gain at each angle to the maximum antenna gain. It is a value ranging from 0 to 1. It is also called antenna pattern.

3.23 short-term exposure: The term short-term exposure refers to exposure for a duration less than the corresponding averaging time.

3.24 specific absorption (SA): Specific absorption is the quotient of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (ρ_m).

$$SA = \frac{dW}{dm} = \frac{1}{\rho_m} \frac{dW}{dV}$$

The specific absorption is expressed in units of joules per kilogram (J/kg).

3.25 specific absorption rate (SAR): The time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given mass density (ρ_m).

$$SAR = \frac{d}{dt} \frac{dW}{dm} = \frac{d}{dt} \frac{1}{\rho_m} \frac{dW}{dV}$$

SAR is expressed in units of watts per kilogram (W/kg).

SAR can be calculated by:

$$SAR = \frac{\sigma E^2}{\rho_m}$$

$$SAR = c \frac{dT}{dt}$$

$$SAR = \frac{j^2}{\rho_m \sigma}$$

where:

E : the rms value of the electric field strength in body tissue in V/m

σ : the conductivity of body tissue in S/m

ρ_m : the density of body tissue in kg/m³

c : the heat capacity of body tissue in J/kg°C

$\frac{dT}{dt}$: the time derivative of temperature in body tissue in °C/s

J : the value of the induced current density in the body tissue in A/m².

3.26 general population/uncontrolled exposure: General population/uncontrolled exposure applies to situations in which the general public may be exposed, or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure, or cannot exercise control over their exposure.

3.27 workers: Employed and self-employed persons are termed workers, whilst following their employment.

3.28 unintentional emitter: An unintentional emitter is a device that intentionally generates electromagnetic energy for use within the device, or that sends electromagnetic energy by conduction to other equipment, but which is not intended to emit or radiate electromagnetic energy by radiation or induction.

3.29 wavelength (λ): The wavelength of an electromagnetic wave is related to frequency (f) and velocity (v) of an electromagnetic wave by the following expression:

$$\lambda = \frac{v}{f}$$

In free space, the velocity is equal to the speed of light (c) which is approximately 3×10^8 m/s.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BS	Base Station
EIRP	Equivalent Isotropically Radiated Power
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
ICNIRP	International Commission on Non-Ionizing Radiation Protection
SA	Specific Absorption
SAR	Specific Absorption Rate

5 General principles

There are many national and international documents that provide safety limits for human exposure to EMFs. Although these documents differ in particulars, most documents have several basic principles in common. These include the use of basic limits and reference levels, the use of two-tier exposure limits, averaging times, and separate consideration for exposure to low-frequency and high-frequency fields.

Most documents provide safety limits in terms of basic limits and reference (or derived) levels. The basic limits address the fundamental quantities that determine the physiological response of the human body to electromagnetic fields. Basic limits apply to a situation with the body present in the field. The basic limits for human exposure are expressed as the specific absorption rate (SAR), specific absorption (SA) and current density.

As the basic quantities are difficult to measure directly, most documents provide derived (reference) levels for electric field, magnetic field and power density. Reference levels may be exceeded if the exposure condition can be shown to produce SAR, SA, and induced current density below the basic limits. The reference levels apply to a situation where the electromagnetic field is not influenced by the presence of a body.

Most documents use a two-tier limit structure where lower levels are specified for uncontrolled/general public exposure than for controlled/occupational exposure.

It is important to emphasize that exposure limits are not emission limits; they apply to locations accessible to workers or members of the general public. Thus, it is possible to achieve compliance by limiting access to areas where the field limits are exceeded.

5.1 Multiple sources and frequencies

Most documents require that the effects of multiple sources be considered. Due to the different physiological effect of lower-frequency sources and higher-frequency sources, they should be considered separately. At frequencies typically below 10 MHz, the important physiological effects are due to the induced current density, while at frequencies typically above 100 kHz, the important physiological effects are due to the SAR.

To consider the effects of multiple sources, most documents require that the sources be considered in a weighted sum, where each individual source is pro-rated according to the limit applicable to its frequency. Appendix I shows the procedure in the ICNIRP guidelines.

5.2 Exposure duration

Most documents define the exposure limits in terms of quantities averaged over a time period called the averaging time. In case of short-term exposure with duration less than the averaging time, the applicable limit is:

$$\sum_i X_i^2 t_i \leq X_l^2 t_{avg}$$

where:

X_i : the field (E or H) during exposure i

t_i : the duration of exposure i

X_l : the reference limit

t_{avg} : the appropriate averaging time.

The power density limit is:

$$\sum_i S_i t_i \leq S_l t_{avg}$$

where:

S_i : the power density during exposure i

t_i : the duration of exposure i

S_l : the reference limit

t_{avg} : the appropriate averaging time.

6 EMF safety limits

In many cases, local or national regulatory agencies or standards bodies promulgate the EMF safety limits. If such limits do not exist, or if they do not cover the frequencies of interest, then ICNIRP limits (Appendix I) should be used.

7 Compliance of wireless communication devices

For wireless communication devices operating in the frequency range of 300 MHz to 6 GHz, compliance with the ICNIRP safety limits can be achieved by applying the measurement procedures for SAR in [IEC 62209-1] and [IEC 62209-2]. Also, in certain cases, local or national regulatory agencies or standards bodies may recommend national or regional measurement practices in the spirit of [IEC 62209-1] in order to get a SAR value for wireless communication devices used next to the ear.

8 Achieving compliance to EMF safety limits for telecommunication installations

The following steps should be taken to achieve compliance:

- 1) Identify appropriate compliance limits.
- 2) Determine if EMF exposure assessment for the installation of equipment in question is needed. (See clause 8.1.)
- 3) If the EMF exposure assessment is needed, it may be performed by calculations or measurement. This Recommendation presents a risk assessment approach to help the user determine the possibility that EMF exposure limits may be exceeded and help the user select an appropriate method to perform the assessment.
- 4) If the EMF exposure assessment indicates that pertinent exposure limits may be exceeded in areas where people may be present, mitigation/avoidance measures should be applied.

8.1 Determining the need for assessment for telecommunication equipment

Telecommunication equipment should be classified as an intentional or unintentional EMF emitter in accordance with the definitions. Typically, an intentional emitter is associated with an antenna for radiation of electromagnetic energy.

8.1.1 Unintentional emitters

Unintentional emitters may produce EMF due to spurious emissions. There are EMC emission standards that limit the magnitude of these spurious fields. Typically, the fields produced by telecommunication equipment that is an unintentional emitter are significantly below the safety limits established by ICNIRP and national standards. The limits established for EMC compliance are orders of magnitude below the EMF safety limits. Even if equipment exceeds the emission limits at certain frequencies, experience indicates that the fields produced are still orders of magnitude below the safety limits. Thus, telecommunication equipment that is an unintentional emitter does not need an EMF safety assessment to assure compliance with safety limits.

8.1.2 Intentional emitters

Intentional emitters use electromagnetic fields for signal transmission. They produce EMF that may exceed the safety limits in some regions depending on the operating power, gain, frequency, orientation and directivity of the transmitting antenna. It is possible to take into account these parameters, and the operating environment of the installation, to determine the need and the appropriate procedure of exposure assessment. This Recommendation presents a risk assessment approach based on classification of exposure zones. As an example, a base station is an intentional emitter.

8.2 Procedures for EMF exposure assessment

If it is determined that an EMF exposure assessment is needed due to the presence of intentional emitters, it should be performed for all locations where people might be exposed to EMF. The intent of the assessment is to classify potential exposure to EMF as belonging to one of the three following zones:

- 1) **Compliance zone:** In the compliance zone, potential exposure to EMF is below the applicable limits for both controlled/occupational exposure and uncontrolled/general public exposure.
- 2) **Occupational zone:** In the occupational zone, potential exposure to EMF is below the applicable limits for controlled/occupational exposure but exceeds the applicable limits for uncontrolled/general public exposure.
- 3) **Exceedance zone:** In the exceedance zone, potential exposure to EMF exceeds the applicable limits for both controlled/occupational exposure and uncontrolled/general public exposure.

For many installations, the exceedance zone and the occupational zone are not accessible to people, or are only accessible under unusual circumstances, such as a person standing directly in front of the

antenna. The risk assessment procedure presented in this Recommendation is concerned primarily with exposure of the general public, and workers in the course of their normal activities. See Figure 1.

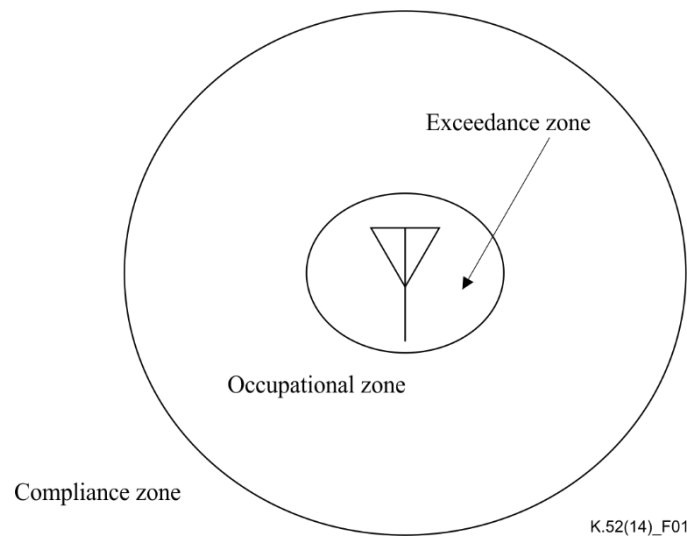


Figure 1 – Figurative illustration of exposure zones

The determination of the exposure zones should follow the methods defined in [IEC 62232].

8.3 Exposure level assessment procedure

[IEC 62232] defines methods for RF exposure evaluation for three main applications:

- Base station (BS) compliance: determination of compliance boundary information for BS before it is placed on the market.
- BS installation compliance: determination of the total RF exposure levels in accessible areas from a BS and other relevant sources before the product is put into service.
- In-situ RF exposure assessment: measurement of RF exposure levels in the vicinity of a BS installation after the product has been installed and is operating

The recommendations in this clause are related to BS installation type application.

The assessment of the exposure level shall consider:

- the worst emission conditions;
- the simultaneous presence of several EMF sources, even at different frequencies.

The following parameters should be considered:

- the maximum EIRP of the antenna system (see the definition for Equivalent Isotropically Radiated Power (EIRP) in clause 3);
NOTE – Maximum EIRP should be calculated for mean transmitter power. For the majority of sources, the mean transmitter power is the nominal (rated) transmitter power. However, there are exceptions. For example, mean transmitter power is less than nominal transmitter power for analogue TV, and is greater than nominal transmitter power for AM DSB.
- the antenna gain G (see definition: antenna gain) or the relative numeric gain F (see definition: relative numeric gain), including maximum gain and beam width;
- the frequency of operation; and
- various characteristics of the installation, such as the antenna location, antenna height, beam direction, beam tilt and the assessment of the probability that a person could be exposed to the EMF.