

**Basic standard to
demonstrate the
compliance of fixed
equipment for radio
transmission
(110 MHz – 40 GHz)
intended for use in wireless
telecommunication
networks with the basic
restrictions or the
reference levels related to
general public exposure to
radio frequency
electromagnetic fields,
when put into service**

The European Standard EN 50400:2006 has the status of a
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National foreword

This British Standard is the official English language version of EN 50400:2006.

The UK participation in its preparation was entrusted to Technical Committee GEL/106, Human exposure to lf and hf electromagnetic radiation, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;
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**Basic standard to demonstrate the compliance of fixed equipment
for radio transmission (110 MHz - 40 GHz)
intended for use in wireless telecommunication networks
with the basic restrictions or the reference levels
related to general public exposure to radio frequency
electromagnetic fields, when put into service**

Norme de base pour démontrer la conformité des équipements fixes de transmission radio (110 MHz - 40 GHz), destinés à une utilisation dans les réseaux de communication sans fil, aux restrictions de base ou aux niveaux de référence relatives à l'exposition des personnes aux champs électromagnétiques de fréquence radio, lors de leur mise en service

Grundnorm zum Nachweis der Übereinstimmung von stationären Einrichtungen für Funkübertragungen (110 MHz bis 40 GHz), die zur Verwendung in schnurlosen Telekommunikationsnetzen vorgesehen sind, bei ihrer Inbetriebnahme mit den Basisgrenzwerten oder den Referenzwerten bezüglich der Exposition der Allgemeinbevölkerung gegenüber hochfrequenten elektromagnetischen Feldern

This European Standard was approved by CENELEC on 2005-12-06. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

This European Standard was prepared by Technical Committee CENELEC TC 106X, Electromagnetic fields in the human environment.

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with the EN have to be withdrawn (dow) 2009-01-01

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

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1 Scope

This basic standard applies to Base Stations as defined in Clause 4, operating in the frequency range 110 MHz to 40 GHz.

The objective of this basic standard is to specify, for such equipment and when it is put into service in its operational environment, the methods to assess the value of the Total Exposure Ratio or to establish whether the Total Exposure Ratio is less than or equal to one in relevant areas where the general public has access.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)
(Official Journal L 199 of 30 July 1999)

EN 50383, Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz)

EN ISO/IEC 17025:2000, General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:1999)

ISO "Guide to the expression of uncertainty in measurement": Ed.1 1995

International Commission on Non-Ionizing Radiation Protection (1998), Guidelines for limiting exposure in time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)
Health physics 74, 494-522

3 Physical quantities, units and constants

3.1 Quantities

The internationally accepted SI-units are used throughout the standard.

<u>Quantity</u>	<u>Symbol</u>	<u>Unit</u>	<u>Dimensions</u>
Electric field strength	E	volt per meter	V/m
Electric flux density	D	coulomb per square meter	C/m ²
Frequency	f	hertz	Hz
Magnetic field strength	H	ampere per meter	A/m
Magnetic flux density	B	tesla (Vs /m ²)	T
Mass density	ρ	kilogram per cubic meter	kg/m ³
Permeability	μ	Henry per meter	H/m
Permittivity	ϵ	farad per meter	F/m
Specific absorption rate	SAR	watt per kilogram	W/kg
Wavelength	λ	meter	m

3.2 Constants

<u>Physical constant</u>	<u>Symbol</u>	<u>Magnitude</u>
Speed of light in a vacuum	c	$2,997 \times 10^8$ m/s
Permittivity of free space	ϵ_0	$8,854 \times 10^{-12}$ F/m
Permeability of free space	μ_0	$4 \pi \times 10^{-7}$ H/m
Impedance of free space	η_0	$120 \pi \Omega$ (approx. 377 Ω)

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1

antenna

device that serves as a transducer between a guided wave (e.g. coaxial cable) and a free space wave, or vice versa. It can be used either to emit or to receive a radio signal. In the present standard, if not mentioned, the term antenna is used only for emitting antenna(s)

4.2

average emitted power

the average emitted power is the time-averaged rate of energy transfer defined by

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

where

$t_2 - t_1$ is the averaging time, t_{avg} defined as a function of frequency in the Council Recommendation 1999/519/EC of 12 July 1999;

$P(t)$ is the power radiated by the antenna at the maximum duty cycle of the equipment

4.3

average equivalent isotropic radiated power (average EIRP)

the product of the power supplied to the antenna and the maximum antenna gain relative to an isotropic antenna

$$P_{aEIRP} = P_{aep} * G$$

where

P_{aep} is the average emitted power;

G is the maximum gain of the antenna relative to an isotropic antenna

4.4

base station (BS)

fixed equipment for radio transmission used in cellular communication and/or wireless local area networks. Point-to-point communication and point-to-multipoint communication equipment integral to the above networks are also included. For the purpose of this standard, the term base station includes the radio transmitter(s) and the associated antenna(s)

4.5**basic restriction**

restrictions on exposure to time - varying electric, magnetic, and electromagnetic fields that are based directly on established health effects. Depending upon the frequency of the field, the physical quantities used to specify these restrictions are current density (J), specific absorption rate (SAR) and power density (S)

4.6**compliance boundary (CB)**

the compliance boundary is defined according to EN 50383

4.7**domain of investigation (DI)**

sub-domain of relevant domain where the general public may have access when the base station is put into service

4.8**electric field strength (E)**

the magnitude of a field vector at a point that represents the force (F) on a small test charge (q) divided by the charge

$$E = \frac{F}{q}$$

Electric field strength is expressed in units of volt per meter (V/m)

4.9**equipment under test (EUT)**

base station that is the subject of the specific test investigation being described

4.10**equivalent free space conditions (EFSC)**

conditions allowing re-use of free space methods defined in EN 50383

4.11**equivalent plane wave power density**

the power per unit area normal to the direction of propagation of a plane wave in free space is related to the electric and magnetic fields by the expression

$$S = \frac{E^2}{120\pi} = 120\pi * H^2$$

4.12**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 the basic restrictions

Between 100 kHz and 10 GHz:

$$ER = MAX \left[\frac{SAR_{wb}}{SAR_{WBL}}, \frac{SAR_{pb}}{SAR_{PBL}} \right]$$

Between 10 GHz and 40 GHz:

$$ER = \left(\frac{S}{SL} \right)$$

For assessments against reference levels:

Between 100 kHz and 40 GHz:

$$ER = MAX \left[\left(\frac{E}{EL} \right)^2, \left(\frac{H}{HL} \right)^2 \right]$$

or between 10 MHz and 40 GHz:

$$ER = \left(\frac{S}{SL} \right)$$

where

ER	is the exposure ratio at each operating frequency for the source;
EL	is the investigation E-field limit at frequency f;
HL	is the investigation H-field limit at frequency f;
SARWBL	is the SAR whole body limit at frequency f;
SARPBL	is the SAR partial body limit at frequency f;
SL	is the equivalent plane wave power density limit at frequency f;
E	is the assessed E-field at frequency f for the source;
H	is the assessed H-field at frequency f for the source;
SARwb	is the assessed whole body SAR at frequency f for the source (EN 50383);
SARpb	is the assessed partial body SAR at frequency f for the source (EN 50383);
S	is the assessed equivalent plane wave power density at frequency f for the source;
f	is each operating frequency of the source.

ER is applicable to limits based on ICNIRP principles

4.13

intrinsic impedance (of free space η_0) η

the ratio of the electric field strength to the magnetic field strength of a propagating electromagnetic wave. The intrinsic impedance of a plane wave in free space (120π) is approximately 377Ω

4.14

isotropy

physical property that is invariant of direction. The axial isotropy is defined by the maximum deviation of the measured quantity when rotating the probe along its main axis with the probe exposed to a reference wave with normal incidence with regard to the axis of the probe. The hemispherical isotropy is defined by the maximum deviation of the measured quantity when rotating the probe along its main axis with the probe exposed to a reference wave with varying angles of incidences and polarization with regard to the axis of the probe in the half space in front of the probe

4.15

linearity

the maximum deviation over the measurement range of the measured quantity value from the closest linear reference curve defined over a given interval

4.16**magnetic field strength (H)**

the magnitude of a field vector in a point that results in a force (F) on a charge q moving with the velocity v

$$F = q(v \times \mu H)$$

The magnetic field strength is expressed in units of amperes per meter (A/m)

4.17**magnetic flux density (B)**

the magnitude of a field vector that is equal to the magnetic field strength H multiplied by the permeability (μ) of the medium

$$B = \mu H$$

Magnetic flux density is expressed in units of tesla (T)

4.18**permeability (μ)**

the magnetic permeability of a material is defined by the magnetic flux density B divided by the magnetic field strength H :

$$\mu = \frac{B}{H}$$

where μ is the permeability of the medium expressed in henry per metre (H/m)

4.19**permittivity (ϵ)**

the property of a dielectric material (e.g., biological tissue). In case of an isotropic material, it is defined by the electrical flux density D divided by the electrical field strength E

$$\epsilon = \frac{D}{E}$$

The permittivity is expressed in units of farad per metre (F/m)

4.20**point of investigation (PI)**

the location within the domain of investigation at which the value of E-field, H-field or power density is evaluated. This location is defined in cartesian, cylindrical or spherical co-ordinates relative to the reference point on the Equipment Under Test as defined in EN 50383

4.21**power density (S)**

the radiant power incident perpendicular to a surface, divided by the area of the surface. The power density is expressed in units of watt per square metre (W/m^2)

4.22**PDMF**

power density multiplication factor

4.23**reference levels**

reference levels are provided for the purpose of comparison with exposure quantities in air. Respect of the reference levels will ensure respect of the basic restriction. In the frequency range 110 MHz to 40 GHz the reference levels are expressed as electric field strength, magnetic field strength and power density values

4.24

reference point

the antenna is referenced by the centre of the rear reflector, in case of panel antennas, and by the centre of the antenna in case of omni-directional antennas. For other configurations, appropriate references must be defined

4.25

relevant domain (RD)

domain surrounding the antenna where the equipment under test may be considered as a relevant source

4.26

relevant source (RS)

a radio source, in the frequency range 100 kHz to 40 GHz, which at a given point of investigation has an exposure ratio larger than 0,05

4.27

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 given mass density (ρ)

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dV} \right)$$

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

NOTE SAR can be calculated by

$$SAR = \frac{\sigma E_i^2}{\rho}$$

where

E_i is r.m.s. value of the electric field strength in the tissue in V/m;

σ is conductivity of body tissue in S/m;

ρ is density of body tissue in kg/m³

4.28

scatter domain (SD)

domain surrounding the antenna where a structure may cause reflected or diffracted fields, interfering with the incident fields and resulting in significant modifications of the compliance boundary estimated in free space according to EN 50383. Structures to be considered are extensive surfaces like walls, not railings, ladders, etc.

4.29

total exposure ratio (TER)

the total exposure ratio is the maximum value of the sum of exposure ratios of the Equipment Under Test and all relevant sources over the frequency range 100 kHz to 40 GHz

$$TER = ER_{EUT} + ER_{RS}$$

where

ER_{EUT} is the assessed Exposure Ratio from the Equipment Under Test;

ER_{RS} is the assessed Exposure Ratio of all the Relevant Sources

4.30

transmitter

device to generate radio frequency electrical power to be connected to an antenna for communication purpose

5 General process

5.1 Alternative routes to determine the total exposure ratio where the general public has access

This standard defines the methods that shall be used to determine, or overestimate, the total exposure ratio in relevant areas where the general public has access. i.e. in the domain of investigation. For this assessment, alternative routes (Figure 1) can be used and any completed route is valid.

Choose either, the general method described in 5.2, or the pre-analysis method according to 5.3.

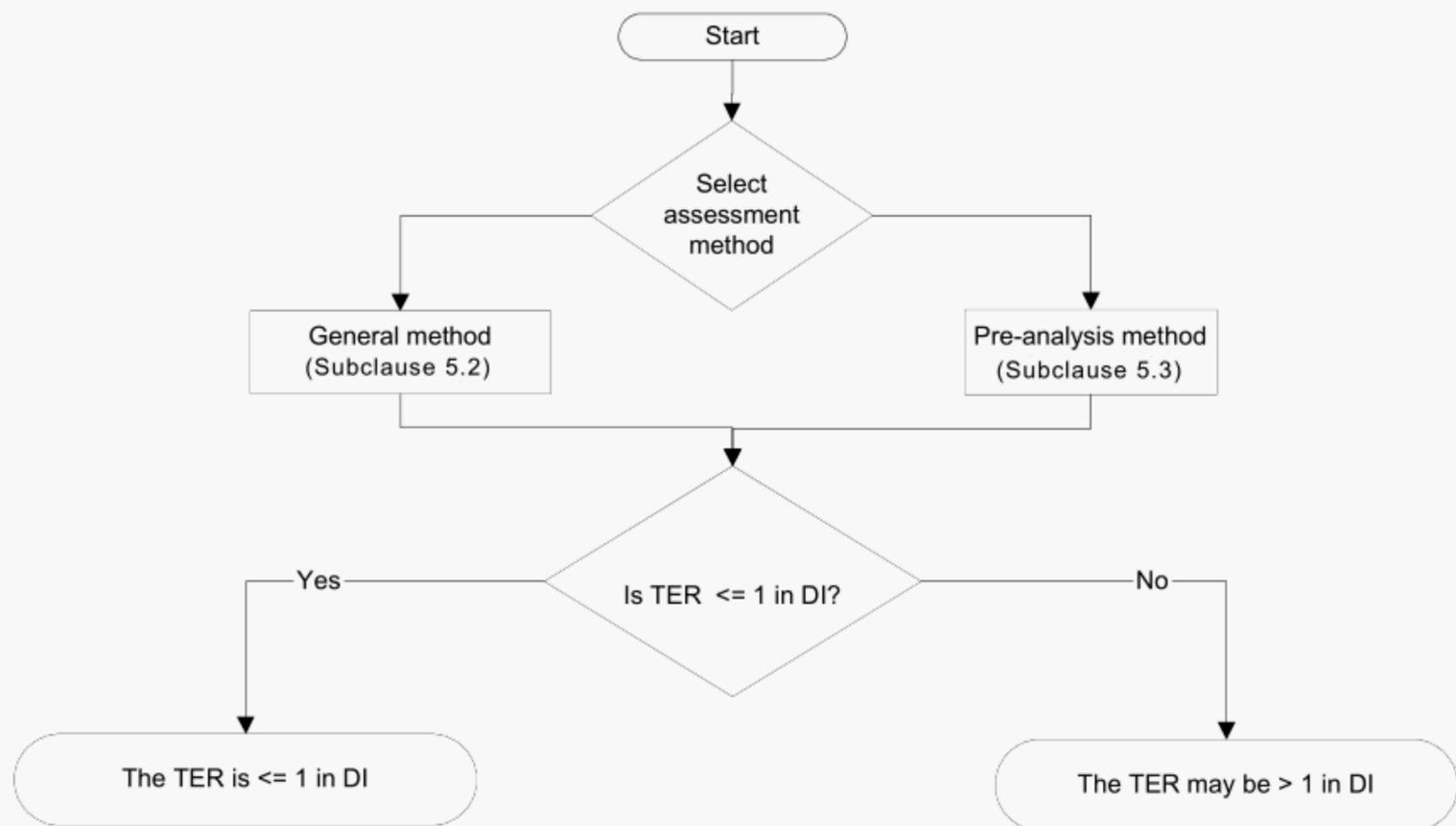


Figure 1 – Alternative routes to determine the total exposure ratio where the general public has access

For sources with time-varying power, the value of the average emitted power at the maximum power setting of the equipment shall be used.

5.2 General method

5.2.1 Description of the general method

The total exposure ratio shall be determined following the process in the flow chart in Figure 2.

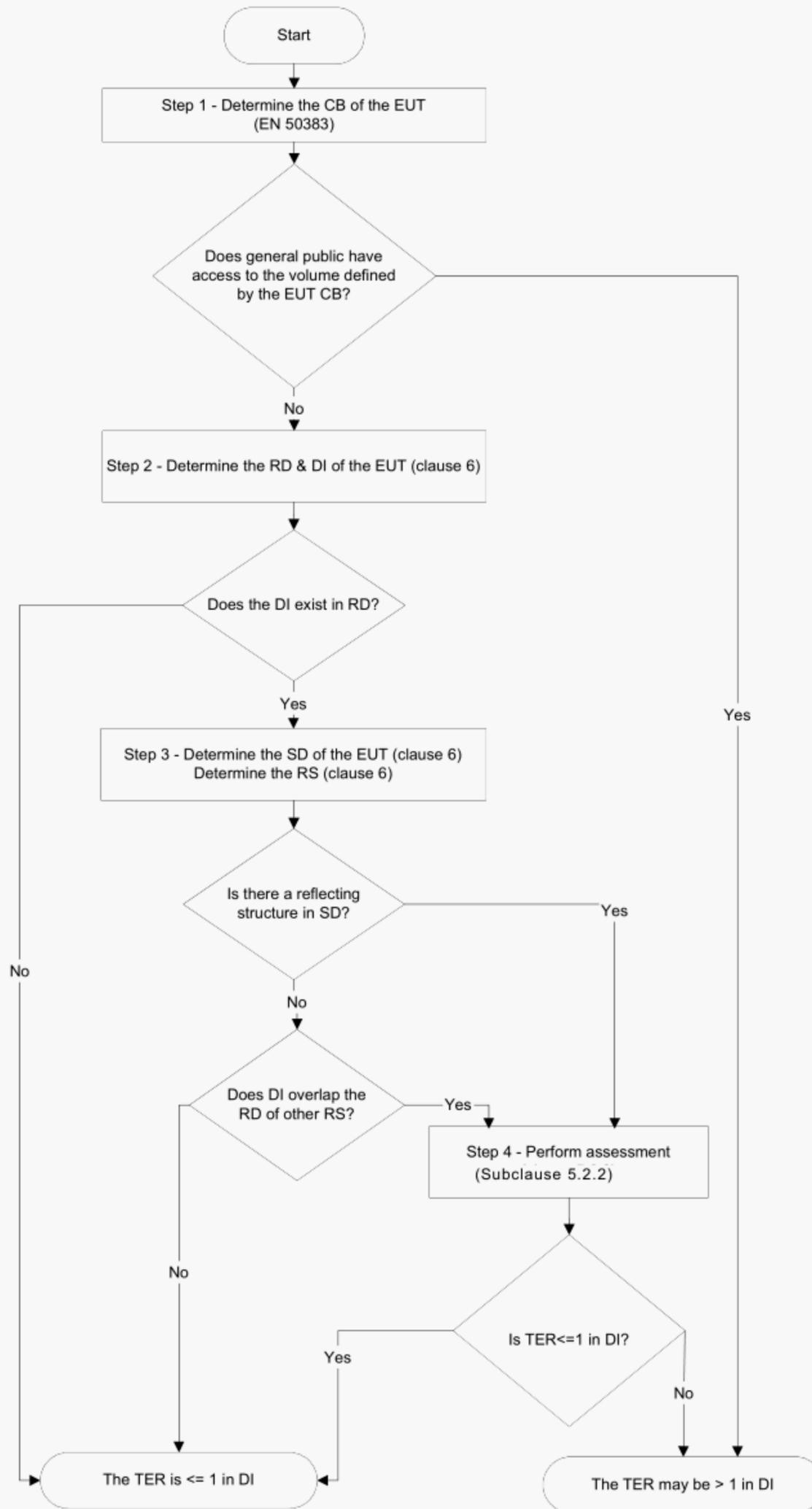


Figure 2 – Overview of the general method to estimate the total exposure ratio

The process described by the four steps below and illustrated in Figure 2 shall be followed in order to determine or overestimate the total exposure ratio in relevant areas where the general public has access.

Step 1 - Evaluate the compliance boundary of the base station according to EN 50383. If the general public has access to the volume defined by the compliance boundary, the total exposure ratio may exceed one in relevant areas where the general public has access.

Step 2 - Determine the relevant domain and the domain of investigation according to Clause 6. If the general public has no access to the relevant domain, i.e. there is no domain of investigation, the total exposure ratio is less than or equal to one in relevant areas where the general public has access.

Step 3 - Determine the scatter domain and the relevant sources according to Clause 6. If there is no structure in the scatter domain and if the relevant domain(s) of other relevant source(s) do not overlap with the domain of investigation, then the total exposure ratio is less than or equal to one in relevant areas where the general public has access.

Step 4 - Assess total exposure ratio by measurements or calculations according to 5.2.2 in order to determine the total exposure ratio in relevant areas where the general public has access.

5.2.2 Comprehensive total exposure ratio assessment

The comprehensive total exposure ratio assessment determines the maximum total exposure ratio in relevant areas where the general public has access (i.e. in the domain of investigation).

Assessment shall be carried out in particular close to any physical boundary that limits the general public access to the area around the Equipment Under Test and/or the relevant sources (see Figure 3).

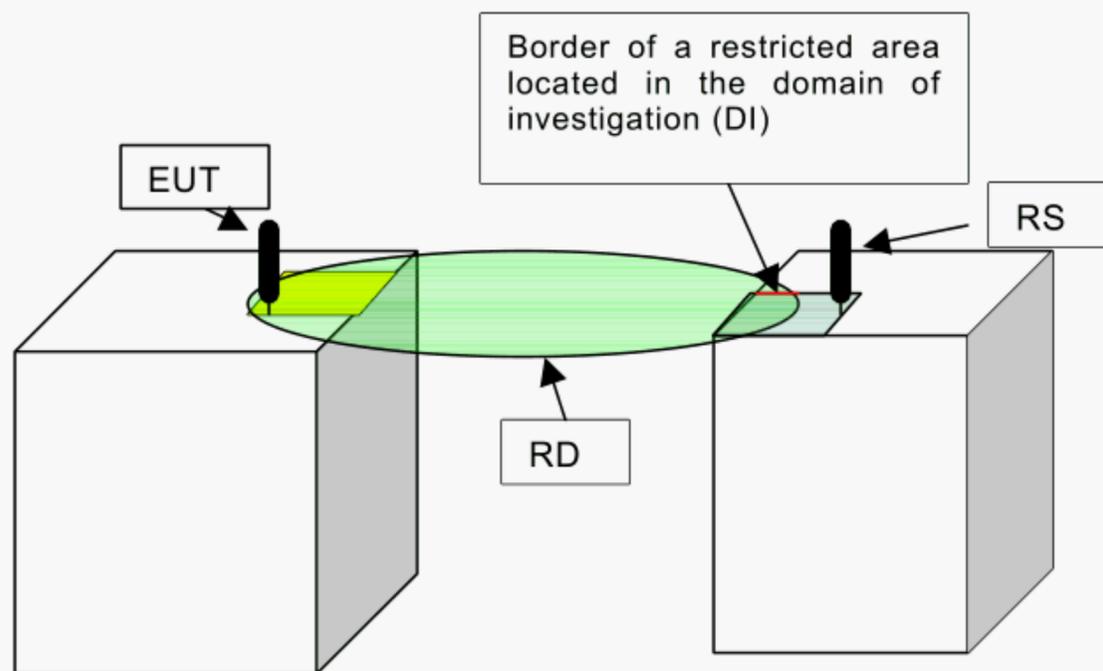


Figure 3 – Borders of a restricted area located in the domain of investigation

The total exposure ratio shall be assessed at points of investigation using measurement and/or calculation methods described in Clauses 7, 8 and 9. The sampling step shall not be larger than the values defined in Table 1.

Table 1 – Maximum sampling step versus frequency

Frequencies	< 80 MHz	80 MHz – 900 MHz	900 MHz – 3 000 MHz	> 3 GHz
Steps	Max (λ , $d/40$)	Max (2 m, $d/40$)	1 m	0,5 m

d is the distance (m) from the point of investigation to Relevant Source – Annex D.

The calculation and measurement methods depend on the position of the point of investigation relative to the source antenna. Each point of investigation is located in the reactive near-field or the radiating near-field or the far-field regions of the antenna (EN 50383). In the radiating near-field and the far-field, calculations and measurements can be used to estimate the E-field, H-field or power density. In the reactive near-field, it is recommended to use specific absorption rate measurements, carried out according to EN 50383.

At each point of investigation, the assessed total exposure ratio shall be the maximum value of the total exposure ratios determined at each of three heights above a general public walkway (Figure 4).

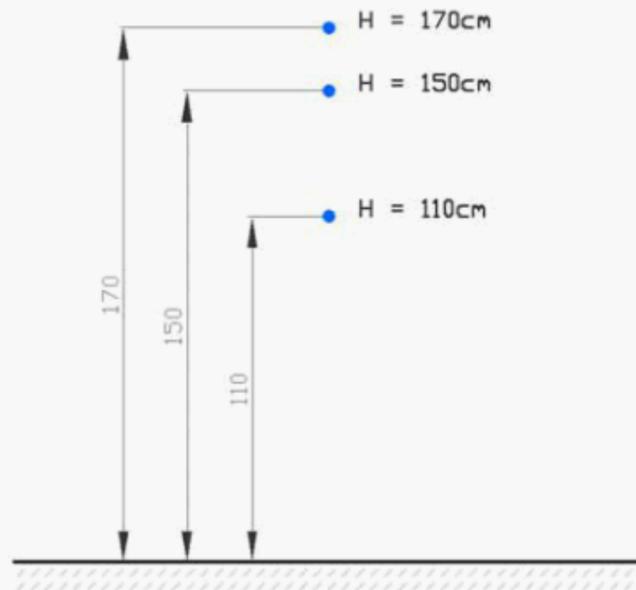


Figure 4 – Location of the three assessments for each point of investigation

5.3 Pre-analysis method

The pre-analysis method enables a set of guidelines and associated constraints to be defined that together assure that the total exposure ratio is less than one in relevant areas where the general public has access.

This method shall be validated using the approaches described in Clauses 5, 6, 7, 8 and 9 and shall take into account defined RF sources ¹⁾ and significant variables in the local physical environment.

The guidelines ²⁾ shall specify constraints

- to address scattering objects,
- on the influence of relevant sources on the general public access restrictions for the Equipment Under Test,
- on the influence of the Equipment Under Test on existing relevant sources' general public access restrictions.

Provided these guidelines and the associated constraints are satisfied, the total exposure ratio is less than or equal to one in relevant areas where the general public has access.

1) Defined RF sources may be restricted to the EUT alone or may include specific relevant sources according to the associated constraints.

2) See Annex A for guideline examples.

6 Determination of domains and relevant sources

6.1 Principle of relevance

The principle of relevance establishes the conditions under which a radio source is considered relevant such that account has to be taken of the contribution of that source when assessing RF exposure. A radio source is considered to be relevant in locations where its exposure ratio is greater than 0,05.

This principle is applied in three ways:

- to define the area outside which the contribution to the total exposure ratio from the Equipment Under Test in service need not be considered either for its compliance or its possible effect on other sources' compliance;
- to establish if the exposure ratio from each individual radio source is relevant and needs to be considered as a contributor to the total exposure ratio;
- to establish whether RF fields from the Equipment Under Test, when reflected by nearby structures, may increase by a significant amount the exposure ratio within the compliance boundary of the Equipment Under Test.

6.2 Determination of domains

6.2.1 Relevant domain

6.2.1.1 General procedure

The relevant domain shall be determined using the calculation or measurement methods described in Clauses 7 and 8. At the relevant domain boundary, the exposure ratio from the Equipment Under Test shall be less than or equal to 0,05.

6.2.1.2 Simplified procedure

If the compliance boundary has been determined with respect to reference levels and according to EN 50383, the relevant domain boundary can be derived by multiplying the smallest distance between the radiating part of the antenna and the compliance boundary by a factor of 5 in a given direction (Annex C).

6.2.2 Scatter domain

6.2.2.1 General procedure

The scatter domain shall be determined using the calculation or measurement methods described in Clauses 7 and 8 or in EN 50383. At the scatter domain boundary, the Equipment Under Test exposure ratio shall be less than or equal to 0,1 (Annex C).

6.2.2.2 Simplified procedure

If the compliance boundary has been determined with respect to reference levels and according to EN 50383, the scatter domain boundary can be derived by multiplying the smallest distance between the radiating part of the antenna and the compliance boundary by a factor of 3 in a given direction (Annex C).

6.2.3 Domain of investigation

The domain of investigation is the sub-domain of the relevant domain where the general public may have access (Figure 5).

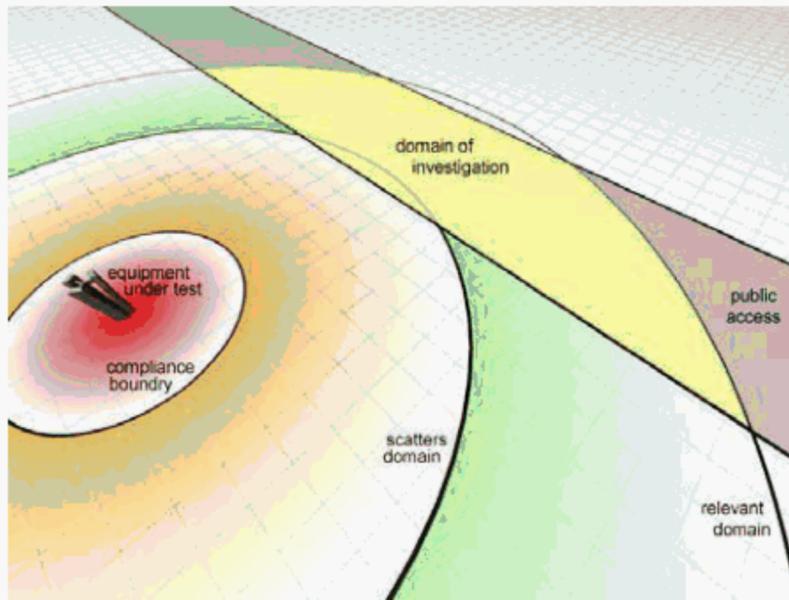


Figure 5 – Representation of the relevant domain, domain of investigation, scatter domain and the compliance boundary surrounding the antenna

6.3 Determination of relevant sources

Radio sources in the frequency range 100 kHz to 40 GHz that have an exposure ratio of greater than 0,05 (6.1) in the domain of investigation shall be considered a relevant source.

A source is a relevant source if its relevant domain intersects the domain of investigation of the Equipment Under Test. Relevant sources shall be determined using measurement and/or calculation (Clauses 7 and 8).

A relevant source may be considered as

- a single (modulated) frequency,
- combined power over bandwidth of similar sources – e.g. (88 – 108) MHz,
- the combined power from a given antenna, location or mast.

To perform this estimation it is necessary to acquire sufficient information about radio sources. Reasonable endeavours shall be applied to identify all nearby sources and to determine data required to perform the exposure assessment. The following guidance is offered on procedures that can be used.

National database:

Where there is a national database (acknowledged by the appropriate licensing authority) providing the parameters for radio sources, this may be used. If such a database provides further information on the Exposure Ratio from one or all radio sources near the Equipment Under Test, then this data may be used as part of an exposure assessment.

Visual inspection:

Nearby antennas will be visible in many instances, for example broadcast masts, radars and cellular installations. Although it is noted that small unobtrusive antennas that have been designed to harmonize with the surroundings may require some searching work.

Spectrum measurement:

In some instances, measurement can be used to identify RF sources. This search may be limited to frequencies below 6 GHz.

Dialogue:

A dialogue with the responsible operator is frequently necessary in order to determine the operating parameters. Information about the responsible operator may be obtained from national administrations, regional governments and operators who maintain various databases that give details of radio transmitters within a particular locality or this information can be obtained directly from a landlord or site owner.

Use of national permit data:

If information is still not complete, then an estimation based on licence data (e.g. power / EIRP) may be used as provided by the licensing authority and reasonable assumptions made to ensure an overestimation of the exposure ratio.

7 Calculation specifications

7.1 General

This section describes the alternative calculation methods that shall be used to estimate the exposure ratio. The flow chart in Figure 6 describes the calculation methodology. Calculation shall be performed at maximum operating power (e.g. maximum traffic conditions).

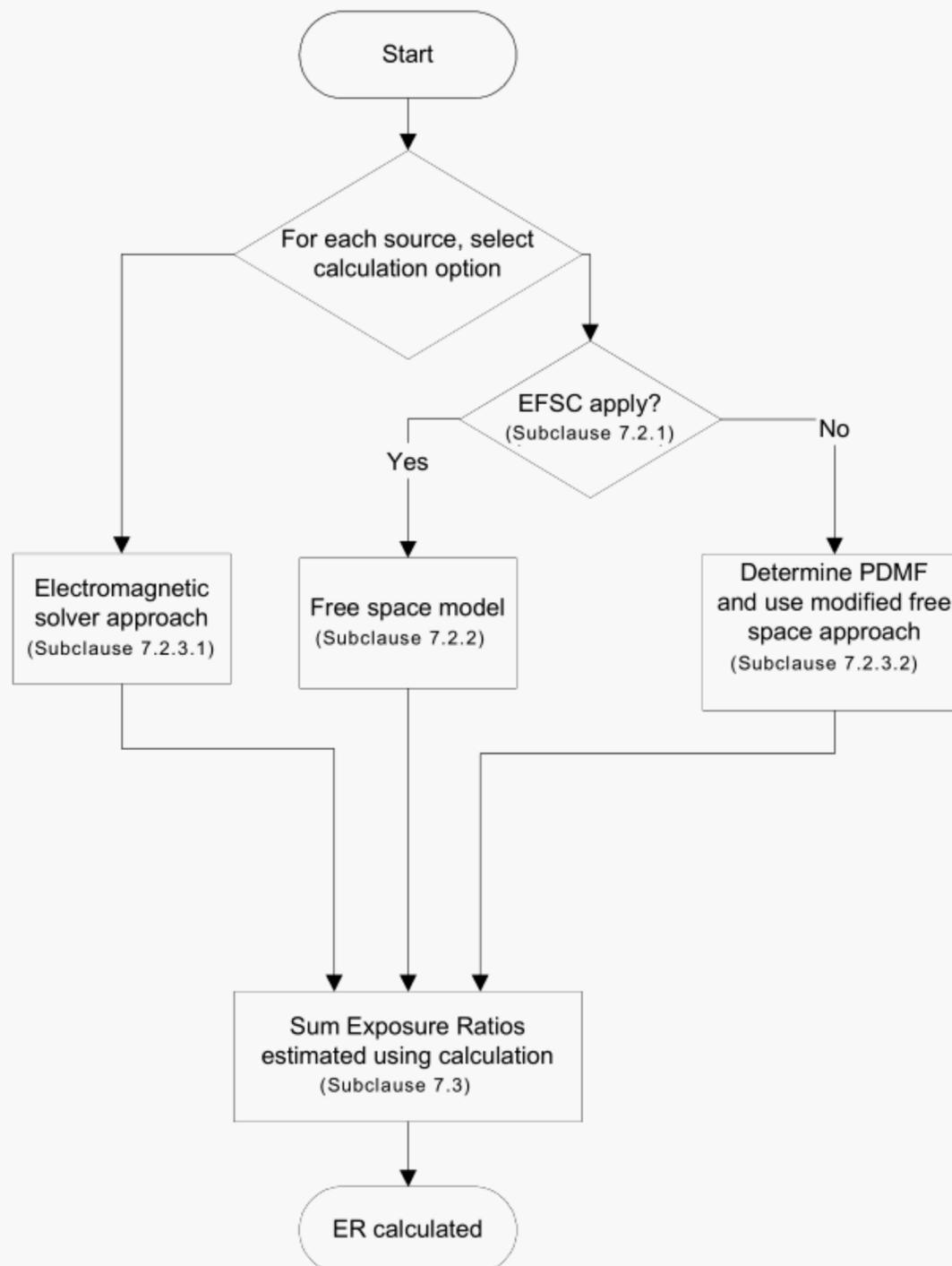


Figure 6 – Calculation methodology

7.2 Calculation methods

7.2.1 Definition of equivalent free space conditions

A point of investigation is deemed to be in equivalent free space conditions of a relevant source if there are no significant reflecting or diffracting structures (Annex C) in the scatter domain of the relevant source.

7.2.2 Calculation methods in equivalent free space conditions

The calculation methods shall be those described in EN 50383, e.g. Free space model. If other methods are used, they shall be well documented and the validity demonstrated.

7.2.3 Calculation methods when equivalent free space conditions do not apply

7.2.3.1 Electromagnetic solver approach

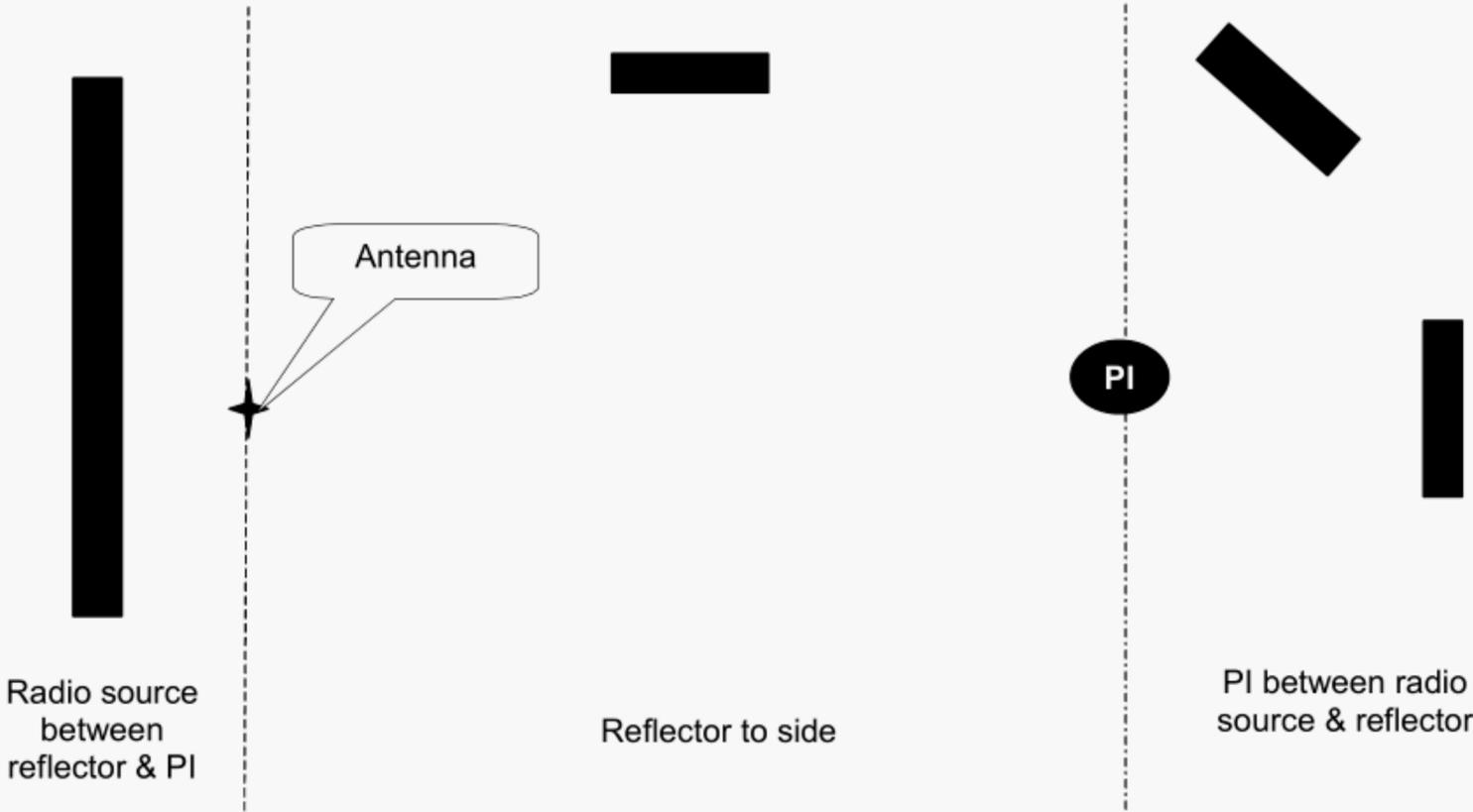
Several methods such as the finite difference time domain, physical optics, uniform theory of diffraction, geometrical optics or other approaches can be used to estimate and/or overestimate the electromagnetic field strength (EN 50383).

The method used shall be well documented and validated.

7.2.3.2 Modified free space approach

The source exposure ratio can be overestimated by using the exposure ratio estimated in free space multiplied by a factor, the power density multiplication factor (PDMF) (Annex C).

The power density multiplication factor for each source shall be determined using Figure 7 and the methodology described in Figure 8.



Plan view



Elevation view

Figure 7 – Configurations used to identify positions of reflectors

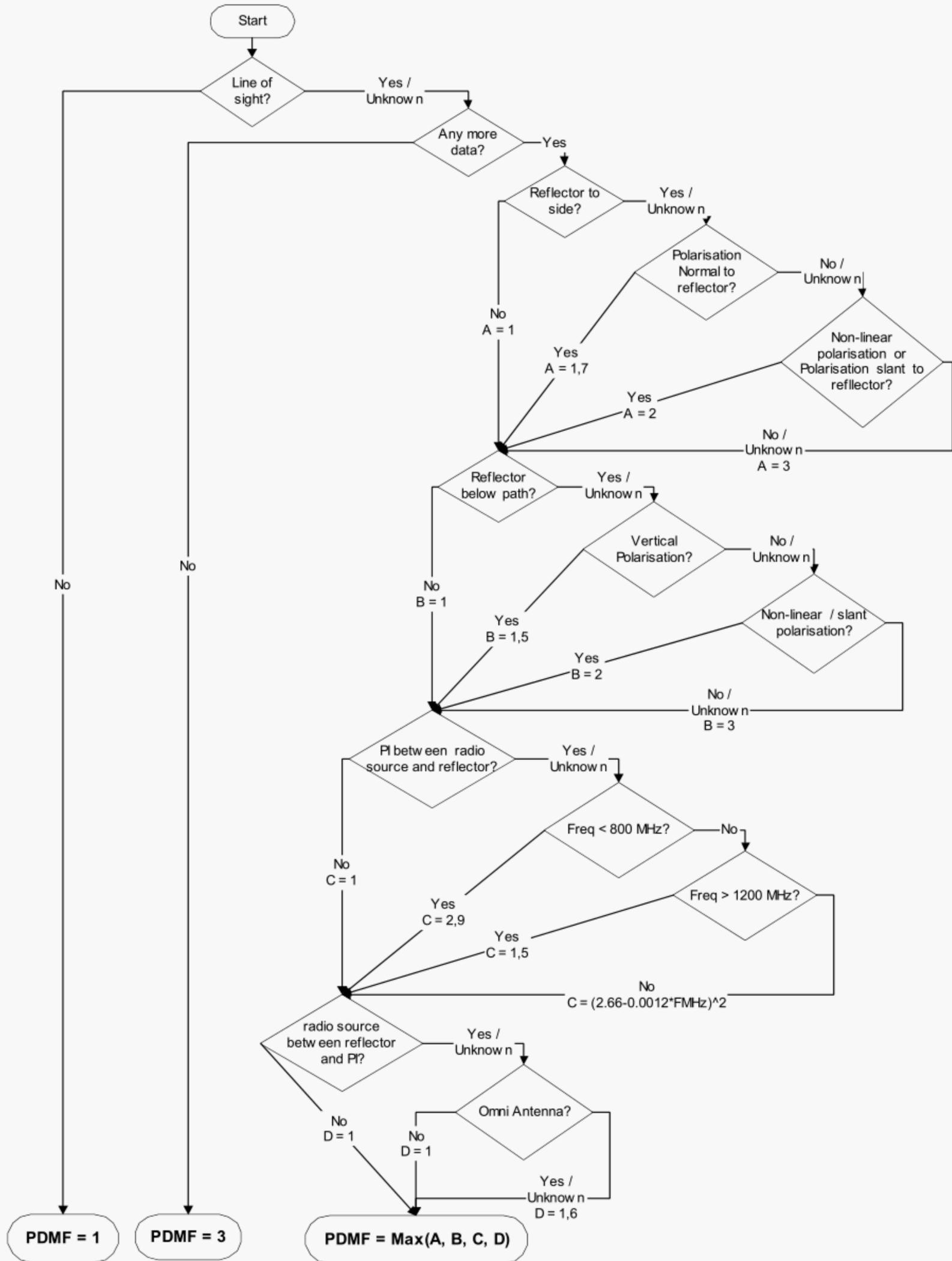


Figure 8 – Establishing the PDMF

7.3 Summation of exposure ratio estimated using calculation

Where the exposure ratio for N sources, ER_i , has been determined according to 7.2.2 and 7.2.3.1 then the combined exposure ratio from all such sources, ER^a is given by

$$ER^a = \sum_{i=1}^N ER_i$$

where the exposure ratio from M sources has been determined according to 7.2.3.2.

The combined exposure ratio from all such sources, ER^b is given by

$$ER^b = \sum_{i=1}^M ERfs_i * PDMF_i$$

where

$ERfs_i$ is the exposure ratio estimated in free space (7.2.2) for the i^{th} source;

$PDMF_i$ is the power density multiplication factor for the i^{th} source (7.2.3.2).

The exposure ratio assessed using calculation, $ER^{\text{calculated}}$, is then given by

$$ER^{\text{calculated}} = ER^a + ER^b$$

In accordance with Clause 5, at each point of investigation, $ER^{\text{calculated}}$ shall be assessed in three points and the maximum value taken.

8 Measurement specifications

8.1 General requirement

Frequency selective or broadband measurement equipment, including one or several E-field or H-field probes, can be used to determine the measured exposure ratio, ER^{measured} .

The measurement equipment shall be calibrated as a complete system at the measurement frequencies according to EN 50383. The calibration shall take into account the high crest factor of some signals or combinations of signals.

If a non-isotropic probe is used, then several directions have to be considered and isotropy has to be evaluated. For instance, if a single dipole antenna is used, then the measurements have to be carried out in three orthogonal directions.

If an isotropic probe is used, then only a single measurement is required.

In either case, the isotropy shall be analysed according to EN 50383 and the isotropy deviation shall be less than 2 dB for frequencies higher than 110 MHz.

For frequency selective measurement :

- the sensitivity shall be evaluated at the relevant measurement frequencies, resolution and video bandwidths;
- the minimum detection limit shall be lower than 0,05 V/m and the maximum detection limit shall be higher than 100 V/m.

For broadband measurement :

- the minimum detection limit shall be lower than 1 V/m and the maximum detection limit shall be higher than 100 V/m.

8.2 Exposure ratio measurement

8.2.1 Basic requirements

Measurement shall be performed either when the base station and relevant sources are all operating at their maximum emitted power, or using a technique allowing extrapolation of exposure to the maximum emitted power condition (e.g. maximum traffic conditions).

Depending on the particular conditions for the measurement, either broadband or frequency selective equipment can be used. Frequency selective measurements generally give a more precise estimation of the exposure ratio. An exposure ratio assessment according to 8.2.2 using broadband probes will overestimate the exposure ratio.

There shall be a minimum of 1 m separation between the measurement probe and the operator and/or reflecting structures.

8.2.2 Conditions for the use of broadband measurements

a) Predominant radio source

A broadband probe can be used to determine exposure ratio and total exposure ratio if there is a predominant radio source. A radio source shall be considered as predominant if it can be assumed, by application of the methods described in 6.3, that the contribution of other sources is 13 dB below the level of the radio source under test.

b) Detecting relevant sources

A broadband probe can be used to determine $ER^{measured}$ in the range defined by the sensitivity of the equipment and up to 0,05 provided the broadband measurement equipment has the capability to take into account the frequency dependence of the exposure limits. If the instrument makes a frequency-independent integration of the exposure, the measurement range shall extend up to 40 GHz or at least the maximum frequency of a Relevant Source determined according to 6.3.

c) Exposure overestimation

If the measured value is more than 13 dB below the lowest applicable exposure limit, then taking into account traffic variations and power control, the $ER^{measured}$ shall be deemed to be less than one.

8.2.3 Conditions for the use of frequency selective measurement

The measured field strength level related to a radio source shall include the total power of the signal. The resolution bandwidth of the measurement system shall be wider than the occupied bandwidth of the signal. Otherwise, all the contributions in the occupied bandwidth of the signal shall be summed to find the amplitude value ³⁾.

In the case of a signal with its power spread over a bandwidth wider than the resolution bandwidth, a total power summation, taking into account the shape of the resolution bandwidth filter, must be applied.

The resolution bandwidth (RBW) and video bandwidth (VBW) shall be justified ⁴⁾.

For signals having large crest factor, the use of a peak detector is not recommended since it leads to large bias.

8.3 Summation of exposure ratios estimated using measurement

Where the exposure ratio has been measured using a broadband approach (8.2.2), this gives $ER^{measured}$ directly.

Where the exposure ratio for N sources, ER_i , has been measured using a frequency selective approach (8.2.3), $ER^{measured}$ is given by:

$$ER^{measured} = \sum_{i=1}^N ER_i$$

In accordance with Clause 5, at each point of investigation, $ER^{measured}$ shall be assessed in three points and the maximum value taken.

8.4 Uncertainty

The uncertainties shall be estimated in compliance with methods described in EN 50383.

The expanded uncertainty with a confidence interval of 95 % (ISO "Guide to the expression of uncertainty in measurement") shall not exceed 3 dB for power density.

3) If there are many channels in a given system (e.g. FM), the exposure ratio is to be estimated using a large resolution bandwidth that covers all the channels, i.e. the exposure ratio is the sum of the exposure ratios of all channels in that system. Even if some channel(s) of that system when considered in isolation may not to be a relevant source according to 6.1, this process assures that the SUM of such negligible exposure ratios for that system is also negligible or is included in the total exposure ratio in accordance with 6.1.

4) Recommended RBW, VBW for different radio services:

Radio Services	RBW (kHz)	VBW (kHz)
FM	100	30
AM	10	10
TV video	1 000	300
TV audio	30	30
GSM	200	300
UMTS	5 000	3000 <

The contributions of each component of uncertainty shall be registered with their name, probability distribution, and sensitivity coefficient and uncertainty value. The results shall be recorded in a table as described in Table 2. The combined uncertainty shall then be evaluated according to the following formula:

$$u_c = \sqrt{\sum_{i=1}^m c_i^2 \cdot u_i^2}$$

where c_i is the weighting coefficient (sensitivity coefficient).

The expanded uncertainty shall be evaluated using a confidence interval of 95 %.

Table 2 – Uncertainty assessment

	Description (Subclause)	Uncertainty value %	Probability distribution	Divisor	c_i	Standard uncertainty %
Measurement equipment						
	Calibration		Normal	1 or k	1	
	Isotropy		Normal	1 or k	1	
	Linearity		Rectangular	$\sqrt{3}$	1	
	Measurement device		Normal	1 or k	1	
	Noise		Normal	1	1	
	Power chain		Normal	1	1	
Physical parameters						
	Drifts in output power of the EUT, probe, temperature and humidity	5 %	Rectangular	$\sqrt{3}$	1	
	Perturbation by the environment		Rectangular	$\sqrt{3}$	1	
Post-processing						
	Contribution of post-processing		Rectangular	$\sqrt{3}$	1	
	Combined standard uncertainty		$u_c = \sqrt{\sum_{i=1}^m c_i^2 \cdot u_i^2}$			
	Expanded uncertainty (confidence interval of 95 %)		Normal			$u_e = 1,96 u_c$

The value of the divisor, k, depends on the calibration.

9 TER assessment

The total exposure ratio at the point of investigation is the sum of exposure ratios assessed using calculation $ER^{calculated}$ (7.3) and those assessed using measurement $ER^{measured}$ (8.3).

Since the exposure ratio from the Equipment Under Test and relevant radio sources have either been assessed by measurement or calculation, the total exposure ratio (4.28) is correctly given by this sum.

10 Exposure assessment report

The assessment report shall

- identify the Equipment Under Test,
- identify who has done the assessment,
- record when the assessment was performed,
- record the assessment methods used or explicitly reference such methods,
- record the relevant source considered and associated parameters,
- record site access restrictions,
- record calibration details for any instrumentation used,
- include the value of parameters used in the assessment and any assumptions made,
- record the results of total exposure ratio measurements and calculations including the point(s) of investigation used.

The above requirements may be addressed in part by pre-analysis reports.

Annex A (informative)

Examples of pre-analysis design guidelines

A.1 Purpose

This annex gives examples of design guidelines for the Equipment Under Test compliance assessment to be determined by pre-defining a set of build guidelines.

Methodologies are described for

- installations designed inclusive of a specified exposure ratio (ER_x) for other radio sources (Clause A.2),
- installations with combined or merged non compliance zones (outside these zones exposure ratio is less than or equal to 1), which can be inclusive of a specified exposure ratio allowance (ER_x) for other radio sources (Clause A.3),
- installation designed so that a minimum build height is maintained at all distances from the antenna less than the boresight limit distance, which can be inclusive of combined or merged non compliance zones and a specified exposure ratio allowance (ER_x) for other radio sources (Clause A.4),
- low power installation less than 10 W EIRP (Clause A.5).

A.2 Installations designed inclusive of a specified exposure ratio allowance for other radio sources

Clause 8 of EN 50383 provides methods for calculating the electromagnetic fields from antennas. Compliance to RF exposure recommendations is assured in the region around the antenna where $S \leq S_{Limit}$

$$\frac{S_{(x,y,z)}}{S_{Limit}} \leq 1$$

where

$S_{(x,y,z)}$ is the power density calculated according to EN 50383 and x,y,z are the principle dimensions around the Equipment Under Test antenna, for simplicity these are not shown in further representations of S;

S_{Limit} is the limit value of power density.

In the case of multiple emissions, where there are n contributing sources, including the equipment under test, the total power density is summed such that:

$$\sum_{i=1}^n \frac{S_i}{S_{i\ Limit}} \leq 1$$

The total exposure ratio allowance of 1 can be apportioned between the Equipment Under Test and n-1 other contributing radio sources

$$\frac{S}{S_{Limit}} + \sum_{i=1}^{n-1} \frac{S_i}{S_{i\ Limit}} \leq 1$$

such that

$$\frac{S}{S_{Limit}} \leq 1 - ER_x \text{ and } \sum_{i=1}^{n-1} \frac{S_i}{S_{i\ Limit}} \leq ER_x$$

where

S_i and $S_{i\ Limit}$ are the power density and power density limits respectively from the i th radio source.

ER_x , which represents the exposure ratio from sources other than the Equipment Under Test, can be derived from available data, measurement or calculation and is typically in the range 0,05 to 0,2. Higher values may be found near to high power broadcast transmitters and radar stations. Hence:

$$\frac{S}{S_{Limit} \cdot (1 - ER_x)} \leq 1$$

Therefore, in order to maintain compliance installations may be designed according to EN 50383 with S_{Limit} modified to $S_{Limit} \cdot (1 - ER_x)$.

A.3 Combined compliance boundaries

An RF source compliance boundary is affected by other RF sources as shown in Figures A.1 and A.2. From the examples in Figures A.1 and A.2, the extent to which antenna compliance boundary A is extended by the presence of antenna B is determined by their relative RF parameters the most significant being their relative EIRP.

The compliance boundary around Antenna A is also affected to a lesser degree by antenna C, and any other close RF sources.

If the RF sources are sufficiently close, the areas enclosed by the compliance boundaries can be seen to merge, as shown in Figure A.2. In this case, the compliance boundary of the Equipment Under Test and merged sources can be designed as if they were a single RF source.

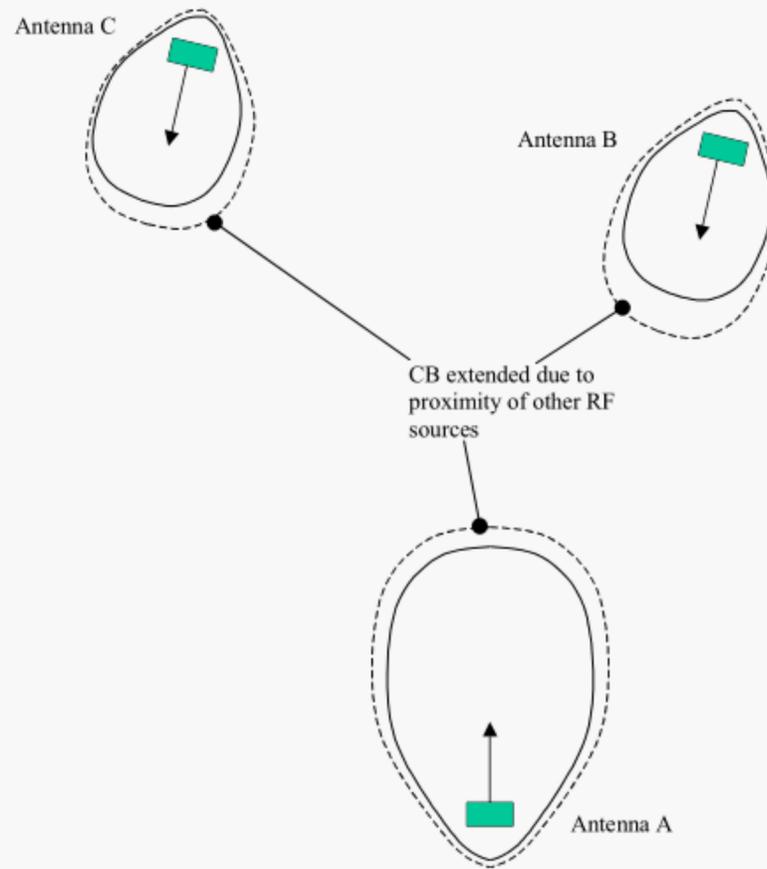


Figure A.1 – Compliance boundary extension due to proximity of other RF sources

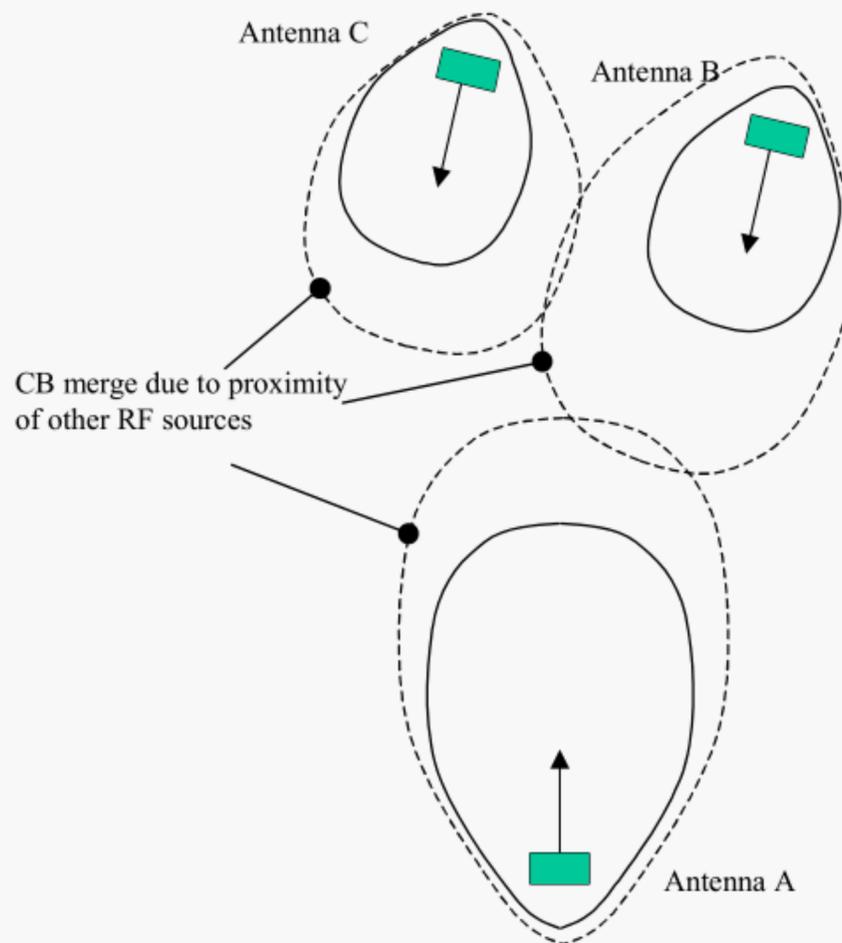


Figure A.2 – Compliance boundaries merging due to proximity of other RF sources

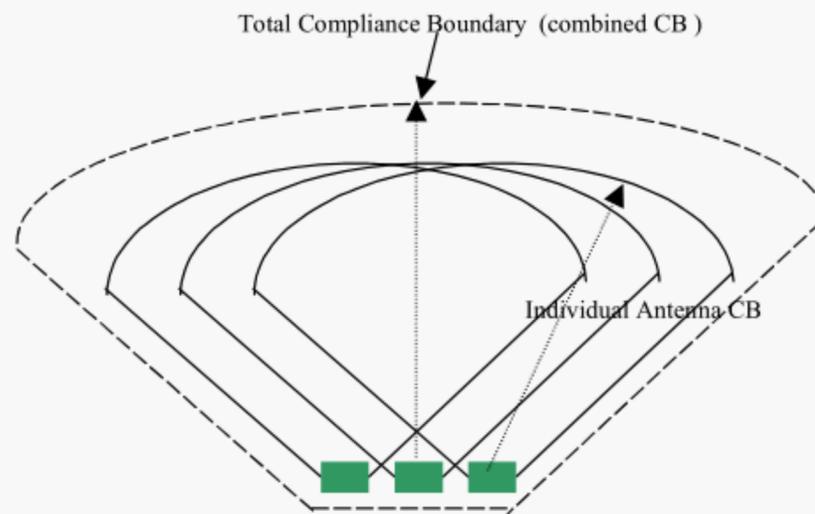


Figure A.3 – Combined compliance boundaries around antennas on a head frame.

In the case of a shared head frame, the compliance boundaries around individual antennas may be summed to give a combined compliance boundary. The general procedure for calculating the combined area enclosed by the compliance boundary is:

Step 1 - Calculate/obtain the worst-case compliance boundary distances for the Equipment Under Test and other RF sources which may be considered to be in the merged compliance boundary. For example, other cellular operators on the rooftop or mast and whose operational parameters or worst-case limit distances are known. When sites are shared by more than one operator, mutual agreement of compliance boundary distances should be obtained and communicated to other parties (e.g. site provider) where appropriate.

Step 2 - Determine if the antennas are sufficiently close to be considered as a single RF source. For example, Table A.1 shows multiplication factors used to determine if the horizontal separation between cellular transmit antennas is sufficient for them to be considered independent. Based on the configuration of the antennas in question, as illustrated in Table A.1, the boresight limit distance is multiplied by the appropriate factor. If the horizontal separation between the cellular antennas in question is greater than this distance or the angular displacement between them is greater than in Table A.1, the antennas are considered independent.

Step 3 - If the horizontal separation between the cellular antennas in question is less than the calculated distance or the angular displacement between them is less than in Table A.1, the merged compliance boundary distances may be summed in a particular direction according to the following methods.

In the radiated near-field limit distances add linearly (cylinder model)

$$D = \sum d_n$$

In the far-field the following formula may be applied:

$$D = \sqrt{\sum d_n^2}$$

where

D is the total compliance boundary distance for all antennas considered;

d_n is the compliance boundary distance around an individual antenna.

Adding compliance boundary distances assumes that all antennas have similar near/far crossover characteristics. If the antennas near/far crossover distances are substantially different an iterative summing process is required that calculates the power density for each antenna in the near-field and far-field and then sums the power densities such that at the limit distance D:

$$1 \leq \sum \frac{S(D)_{\min}}{S_{\text{limit}}}$$

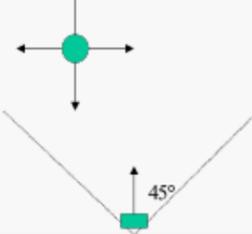
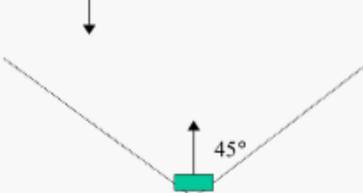
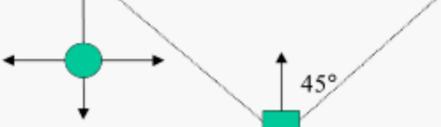
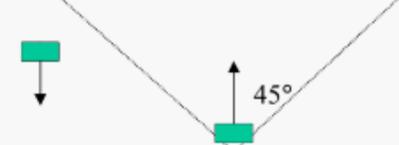
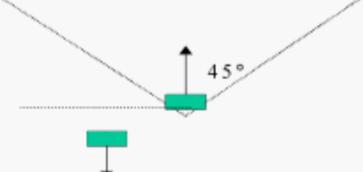
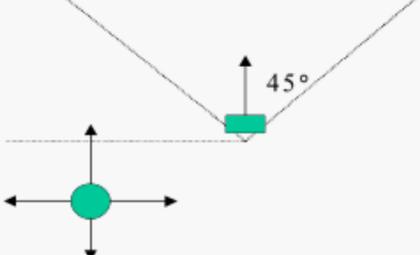
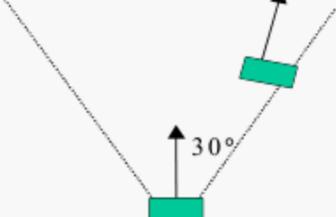
where

$S(D)_{\min}$ is the minimum of the power density at distance D for each antenna, calculated in the near-field and far-field in accordance with EN 50383;

S_{limit} is the RF compliance power density reference level.

However, if the other RF sources (in the example antennas B and C) are at a distance (from antenna A), greater or equal to that calculated using the appropriate multipliers in Table A.1, the non-compliance zones do not merge and the Equipment Under Test (antenna A) can be deemed independent.

Table A.1 – Table of figures showing minimum distances separation multipliers

Figure / Orientation and antenna type	<u>Top View</u>	Horizontal separation ^a multiplier (NB: must be multiplied by maximum single-operator boresight limit distance ^b)
Omni to Omni		x 5
Omni within an arc of angle $\pm 45^\circ$ from the boresight of a Sector antenna		x 5
Sector antenna within an arc of angle $\pm 45^\circ$ from the boresight of a Sector antenna		x 5
Omni within an arc of angle between 45° to 90° from the boresight of a Sector antenna		x 3
Sector antenna within an arc of angle between 45° to 90° from the boresight of a Sector antenna		x 3
Sector antenna within an arc of angle $> 90^\circ$ from the boresight of a Sector antenna		x 0
Omni antenna within an arc of angle $> 90^\circ$ from the boresight of a Sector antenna		x 3
Sector antennas pointing generally in the same direction to within $\pm 30^\circ$		x 1,2
<p>^a The horizontal separation distance is applicable to antennas overlooking each other at angles in the unobstructed vertical plane ≤ 45 degrees for antennas up to 2 m in length and ≤ 25 degrees for antennas greater than 2 m in length; otherwise the vertical separation distance required for EMC applies. The 45 or 25 degree unobstructed vertical plane criteria need only be considered for a horizontal separation distance up to [twice] the applicable limit distance of the rear antenna.</p> <p>^b Single-operator distance refers to the greater of the two distances.</p>		

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A.4 Installation designed so that a minimum build height is maintained at all distances from the antenna less than the compliance boundary distance

For an antenna or group of antennas, a "Build Height", H , may be derived from geometry, so that the exposure ratio is less than or equal to 1 in all areas below the antenna.

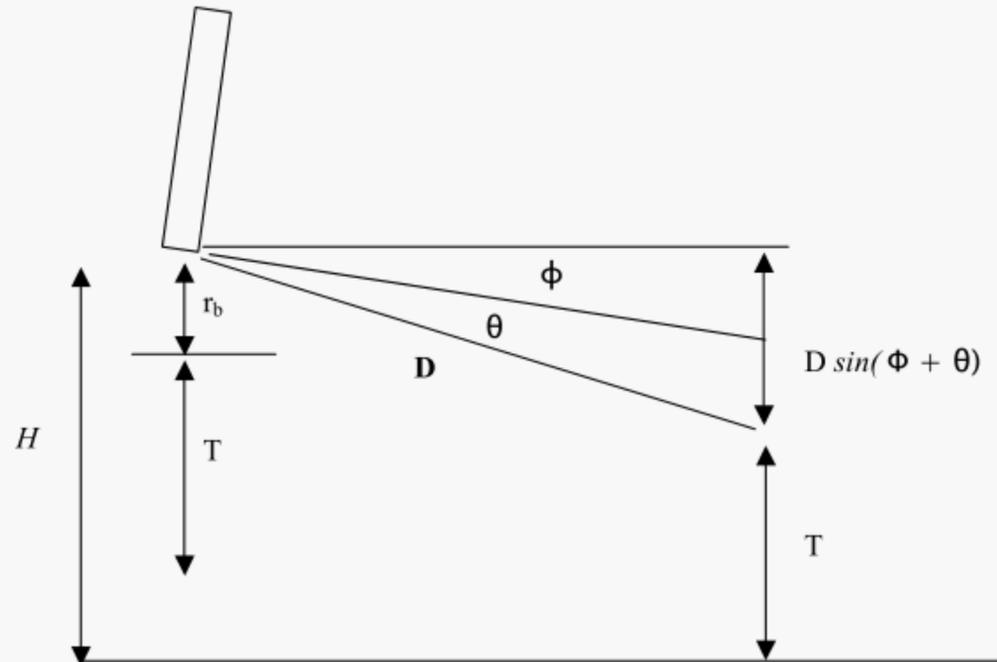


Figure A.4 – Significant parameters relating to antenna positioning and orientation

It may be conservatively assumed that the boresight compliance boundary distance D applies from the lower and upper edges of the antenna at an angle to the horizontal of (half - 3 dB beamwidth) plus (Maximum design down tilt). From the geometry in Figure A.4, the minimum build height, H , is given by:

$$H = T + \text{Max}[r_b, D * \sin(\phi + \theta)]$$

where

- T is the maximum human height (2 m);
- r_b is the compliance boundary distance directly below the antenna, inclusive of consideration of side lobes;
- D is the total boresight compliance boundary distance;
- θ is the half - 3 dB beamwidth;
- ϕ is the maximum design downtilt (electrical plus mechanical).

The horizontal compliance boundary may be conservatively maintained at D (since the horizontal compliance boundary distance is at maximum value of D when tilt=0).

Compliance is assured if a minimum height of H above local ground is maintained at all distances from the antenna as far as the boresight compliance boundary distance D .

The compliance boundary distance D may also take account of the case of combined compliance boundary distance as described in Figures A.2 and A.3.

A.5 Equipment Under Test with less than 10 W average EIRP

This clause is based on the related limit specified in Council Recommendation 1999/519/EC (Annex II).

It is assured that the total exposure ratio is less than or equal to one where the general public have access where

- the average EIRP is less than 10 W,
- the lowest frequency transmitted is above 800 MHz,
- the Equipment Under Test is installed according to the manufacturer's installation instructions to ensure compliance (e.g. by testing according to EN 50383) subject to
 - a minimum separation of 2,5 m to antennas with averaged emitted power more than 20 mW and an average EIRP less than 10 W; and/or,
 - the exposure ratio from other relevant sources ER_x being accounted for by an increased separation of the radiating part of the Equipment Under Test antenna to the general public compared to the compliance boundary taking into account directivity, CB_{factor} according to Table A.2
 and,
 - the influence of the exposure ratio from the Equipment Under Test on nearby radio sources has been considered.
- if the Equipment Under Test is located more than 2 m from the nearest general public access control (inside or outside the compliance boundary of the nearby radio source) then no further assessment is required. Otherwise, a special assessment is needed.

RATIONALE:

The exposure ratio for this product will be less than 5 % at distances greater than 2 m and its compliance boundary will be less than 0,5 m.

For nearby antennas with averaged emitted power more than 20 mW and with less than 10 W average EIRP, a separation of 2,5 m therefore assures that the exposure ratio from the Equipment Under Test is less than 0,05 at the compliance boundary of the other antenna and vice-versa.

If the Equipment Under Test is installed near to radio sources above 10 W average EIRP, there is a trade off between the increase in separation and the allowance for the exposure ratio from other relevant sources ER_x .

Since the ER_{EUT} falls approximately linearly with the distance squared, a multiplication factor, CB_{fact} , can be defined to estimate ER_{EUT} at a distance CB_{fact} times the distance between the compliance boundary and the antenna for a given direction.

$$ER_{EUT} \leq \frac{1}{CB_{fact}^2}$$

For $TER \leq 1$ to be true:

$$ER_x \leq 1 - ER_{EUT} \quad \text{and:} \quad ER_x \leq 1 - \frac{1}{CB_{fact}^2}$$

Table A.2 shows typical values.

Table A.2 – Values for the compliance boundary factor and exposure ratios

CB_{factor}	ER_{EUT} less than or equal to	ER_x less than or equal to
1,1	0,83	0,17
1,2	0,69	0,31
1,4	0,51	0,49
1,6	0,39	0,61
1,8	0,31	0,69
2	0,25	0,75
3	0,11	0,89
4	0,06	0,94
5	0,04	0,96

For example, if it can be shown that the ER_x is less than 0,75, within the domain of investigation of the Equipment Under Test, then the general public shall not be able to access a volume defined by compliance boundary extended by a factor of 2 taking into consideration direction.

Annex B (informative)

Simplified procedure to determine scatter domain and relevant domain boundaries

B.1 Introduction

By applying the following assumptions:

- field strength is inversely proportional to distance from emitting antenna for far-field case;
- exposure ratio is directly proportional to field strength squared for a single frequency;
- reflecting structures do not reflect more than 100 % of the incident field,

this annex shows that

- the scatter domain boundary can be derived by multiplying the smallest distance between the radiating part of the antenna and the compliance boundary by a factor of 3 in a given direction, and
- the relevant domain boundary can be derived by multiplying the smallest distance between the radiating part of the antenna and the compliance boundary by a factor of 5 in a given direction.

B.2 Analysis

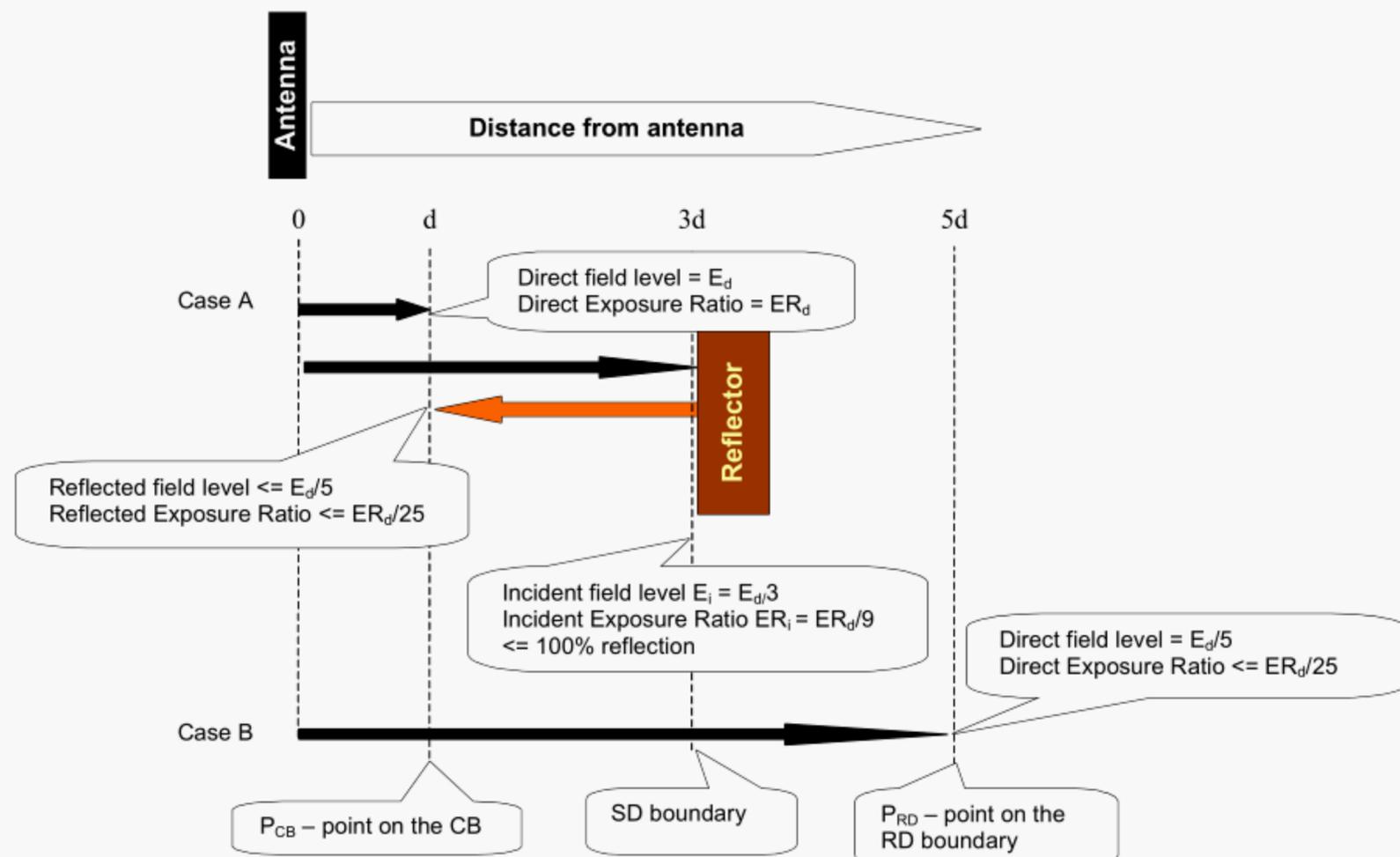


Figure B.1 – Relative field and exposure ratio relationships near an emitting antenna

Consider Figure B.1 with an emitting antenna at distance 0, compliance boundary at distance d and for case A a reflecting structure at $3d$ or for Case B a point P_{RD} at $5d$.

For a given direction, the emissions from the antenna result in a field E_d at point P_{CB} a distance d from the antenna. If E_d is equal to E_L , the maximum field allowed in relation with reference levels, then by definition point P_{CB} is on the compliance boundary and the exposure ratio at that point, ER_d , will be 1 from:

$$ER_d = \left(\frac{E_d}{E_L} \right)^2$$

For case A, E_i , the incident field to the reflecting structure received directly from the antenna is $E_d/3$ based on assumption a) above. If the reflecting structure reflects the field without loss (assumption c) above) the reflected field will also have magnitude $E_d/3$. For point P_{CB} , the reflected field appears to come from an antenna distance $5d$ ($3d$ to the reflecting structure + $2d$ back to point P_{CB}). In this case, the reflected field level at P_{CB} will be $E_d/5$ and the Exposure Ratio from the reflected field ER_r is $ER_d/25$ from:

$$ER_r = \left(\frac{E_d * \frac{1}{5}}{E_L} \right)^2 = 0,04$$

This is 4 % of the compliance limit and is less than the 5 % of the compliance limit and therefore the reflecting structure at distance $3d$ is not considered to be a relevant source. The 4 % value and the 100 % reflection make this a conservative simplification for defining the scatter domain boundary.

It can also be seen that the exposure ratio of the incident field on the reflecting structure is

$$ER_r = \left(\frac{E_d * \frac{1}{3}}{E_L} \right)^2 = ER_d / 9 = 0,111$$

Therefore, it is also acceptable to consider the scatter domain boundary to be defined as the boundary where the Equipment Under Test exposure ratio is less than 0,1 measured or as calculated in free space.

For case B, for a point P_{RD} at a distance $5d$ from the antenna, the direct field level is $E_d/5$ and the exposure ratio (as in case A) $ER_d/25$. Again, this is 4 % of the compliance limit and is less than the 5 % (6.1) and therefore at this distance the emitting antenna is no longer considered a relevant source. The 4 % figure makes this a conservative simplification for defining the relevant domain boundary.

Annex C (informative)

Calculations under non-equivalent free space conditions

C.1 Introduction

The power density from a radio source as observed at a point of investigation is modified by reflection from structures, such as buildings. Calculations for this can be made, but to be accurate it is necessary to have precise knowledge of many parameters, such as

- accurate topographical features of the objects relative to the radio source,
- degree of roughness of the features,
- thickness of the walls,
- surface conductivity,
- surface permittivity,
- frequency and band width of the transmissions.

A number of approaches have been developed to model the electromagnetic field parameters in complex environments. These are outlined in EN 50383 although it is often impractical to make these calculations. Study has shown ⁵⁾ that a free space multiplier of 2 has been evidenced, but even higher could be expected. This Annex provides factors with which to multiply the power density calculated according to free space, power density multiplication factor (PDMF), to give a safe power allowing for the cluttered environment for individual frequency bands. For a specific frequency band, radio source, point of investigation only the highest power density multiplication factor is required. Further, the means to combine a number of frequencies in a cluttered environment is also considered.

The theoretical background for the power density multiplication factors is the Fresnel reflection coefficients, examples of which are shown in the graphs below. However, it should be realised that these results come from the assumption that the reflecting surface is infinite in extent, thick and smooth. Real structures are, of course, not like this but the differences from the ideal should only reduce the magnitude of the reflected signal. A computer program has been run to test other conditions than those shown in the graphs. The differences are not great - largely because frequency differences tend to be balanced by changes in conductivity. The phase of the reflected wave for parallel polarisation is 180° from the incident wave. For normal polarisation the phase change of 180° occurs for grazing angles less than the Brewster angle (angle of large reduction in reflection coefficient). Then at this angle there is a rapid change such that the reflected wave is in phase with the incident wave.

5) A UTD/FDTD Investigation on Procedures to Assess Compliance of Cellular Base-Station Antennas With Human-Exposure Limits in a Realistic Urban Environment: Bernardi, Cavagnaro, Cicchetti, Pisa, Piuze, and Testa: IEEE Transactions On Microwave Theory And Techniques, Vol. 51, no. 12, December 2003.

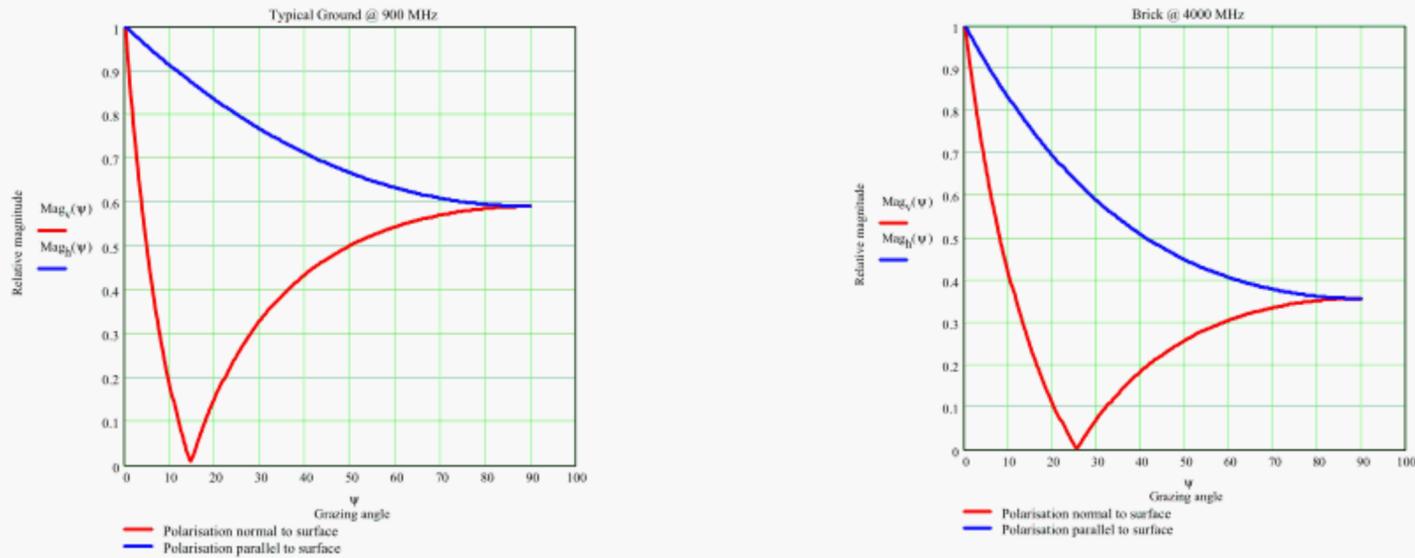


Figure C.1 – Relative magnitude of reflected ray for polarisation normal and parallel to reflecting surface

C.2 Determination if an object is a significant reflector

A key issue is to determine whether an object needs to be considered as a significant reflecting structure. This potentially is a complex consideration; however for the purposes of this annex, the following guidelines may be used to *exclude* a structure from consideration if one or more of the following conditions can be shown to apply:

- the structure is not in line of sight from both the point of investigation and the radio source (i.e. intervisible);
- the maximum projected dimension (m) of the structure in the direction of the of point of investigation is less than $Size_{MAX}$ where:

$$Size_{max} = \sqrt{D\lambda}$$

where

- D is the distance (m) from the radio source and the structure
- λ is the wavelength (m) of the radio source under consideration

NOTE According to physical optics, a factor 2 would normally be applied inside the square root – but with some additional restrictions. For simplicity, this factor is removed here to ensure a conservative assessment;

- the geometry of the reflecting plane, point of investigation and radio source is such that the reflected ray is directed away from the point of investigation.

C.3 Determination of power density multiplication factor in several domains

C.3.1 No line of sight from the radio source to the point of investigation

When the structure is just about to obstruct line of sight the power is reduced to a quarter if the only mechanism were that of diffraction, but power in these domains is often enhanced by reflections from other surrounding structures. It is reasonable to assume field strengths of about half that of free space could be achieved by such reflections. Thus, if phase addition between the reflected field and the diffracted field occurs the power density would still be less than calculated for free space. Thus the power density multiplication factor is:

$$PDMF_{31} = 1$$

C.3.2 Reflecting surface to the side of the direct path from radio source to point of investigation

If the path difference between direct and reflected wave is less than 0,25 wavelength with a small grazing incidence, a similar phase relationship exists over a wide set of frequencies and large area; the power will be less than free space. The reflected and direct waves will not be in phase until the path difference is greater than 0,5 wavelengths. However, short path differences are not a practical condition because the reflection would have to be from a wall that was only about 3 m from the transmitter boresight. This is not a practical condition because such a wall would reduce the base stations coverage. Thus for both coverage and health compliance reasons such a site should not be planned.

If the grazing angle on the reflecting surface is greater than 15° and less than 45°, the reflection coefficient applicable is highly dependent on polarisation.

C.3.2.1 Polarisation normal to reflecting surface

As can be seen from the diagrams the electric field reflection coefficient should always be less than 0,35. If we now allow a small amount for the surface not being smooth and for the extra distance travelled by the reflected ray an electric field relative to the direct ray a safe power density multiplication factor is:

$$PDMF_{321} = 1,7$$

C.3.2.2 Polarisation parallel to reflecting surface

In this case, examination of Figure C.1 gives an electrical field reflection coefficient of less than 0,85. Again allowing for imperfect surface and path difference a reflected ray a value relative to the direct ray of 0,75 is applicable. Thus a safe power density multiplication factor is:

$$PDMF_{322} = 3$$

C.3.2.3 Polarisation slant to reflecting structure / non-linear polarisation

The wave should be considered in two components, namely, normal and parallel. However, there is not only a magnitude difference but also a phase difference in the components. The phase difference will have the effect of putting the field maxima at different locations for each polarisation component and thus reducing the magnitude of the resultant effect. The complications of this case requires a cautious approach, therefore a safe power density multiplication factor is:

$$PDMF_{323} = 2$$

C.3.3 Reflecting surface below the direct path from source to point of investigation

The grazing angles within the relevant domain will be limited, at close to 20°. Those greater than this will be inapplicable because of the vertical radiation pattern of the transmit antenna and those much smaller than this will be beyond the relevant domain.

C.3.3.1 Vertical polarisation

The reflection coefficient is very small (close to the Brewster angle), which allows the use of a small power density multiplication factor, but to be entirely on the safe side the power density multiplication factor is

$$PDMF_{331} = 1,5$$

C.3.3.2 Horizontal polarisation

The electric field reflection coefficient can be as high as 0,9 with a phase change of 180°. As previously stated, if the path difference between direct and reflected wave is less than 0,25 wavelength and small grazing incidence, a similar phase relationship exists over a wide set of frequencies and large area. This applies to members of the general public standing on the reflecting plane. However, we should allow for a person elevated above the ground plane. In this case, there will be a reduction due to reflection coefficient, extra path difference for the reflected wave and vertical radiation pattern of the antenna. Thus a safe power density multiplication factor is:

$$PDMF_{332} = 3$$

C.3.3.3 Slant / non-linear polarisation

For a slant on non-linear polarised antenna, the vertical component will contribute little. Thus a safe power density multiplication factor is:

$$PDMF_{333} = 2$$

C.3.4 Point of investigation between the radio source and reflecting surface

This category covers other reflections that can reach the point of investigation due to the angle of the reflecting surface, not just those reflections directly behind the point of investigation. In this case, the angle between the ray and reflecting surface is greater than 45°.

The reflection coefficient should be less than 0,7 and the phase change will be near 180°. For a point of investigation close to the reflecting surface there will be a reduction relative to free space, but when the path difference is greater than 0,5 wavelengths a reduced peak field strength can occur, for extra distance travelled by the reflected ray.

As the frequency is increased through resonance, the human body will absorb energy from incident electromagnetic fields less efficiently and the penetration depth reduces. From the exposure guidelines, a transition occurs between 800 MHz and 1 200 MHz. Between these frequencies the guidelines show an interpolation that is linear in electric field strength.

C.3.4.1 Frequencies below 800 MHz

Below 800 MHz the standing wave pattern is slow moving in space relative to the size of the upright human body and power absorbed by the body is related to resonance. From the graphs it can be seen that the electric field reflection coefficient will be less than 0,7 times. Thus the power density multiplication factor is:

$$PDMF_{341} = 2,9$$

C.3.4.2 Frequencies above 1 200 MHz

Above 1 200 MHz, the safety standards imply that absorption at the surface of the human body is the dominant mechanism. The power density from the direct wave will be incident on a different side of the body to a reduced reflected wave. Thus the power density multiplication factor is:

$$PDMF_{342} = 1,5$$

C.3.4.3 Frequencies between 800 and 1 200 MHz

For a frequency F (MHz), for linear interpolation of electric field, the power density multiplication factor is

$$PDMF_{343} = (2,66 - 0,0012 * F)^2$$

C.3.5 Radio source between reflecting surface and the point of investigation

Power on a reflecting surface behind the radio source will be small if the antenna has a substantially directional radiation pattern. Thus, reflection from such surfaces will be irrelevant. For an antenna that is approximately omni-directional such reflections could be relevant, but it would be a badly designed base station if these reflection surfaces were close to it. The result of these reflections would be equivalent to altering the antenna's radiation pattern. For ripples in such a pattern to exceed 7 dB, for such reasons, would be a bad design.

For an omni-directional antenna, the power density multiplication factor is:

$$PDMF_{351} = 1,6$$

For a directional antenna, the power density multiplication factor is:

$$PDMF_{352} = 1$$

C.3.6 Power density multiplication factor for use in summing multiple bands

For the purpose of this calculation, a "band" is deemed to be a set of frequencies within 15 % of a centre frequency. For a set of transmissions received at a point of investigation more than one band will not be in a standing wave maximum from any given radio source. The rest will be spread across all the possibilities from maximum to cancellation. For those cases where free space applies or where there is no line of sight from the radio source to the point of investigation this can be represented by

$$PDMF_{36} = \text{Min}[PDMF_x, 1,5]$$

Where $PDMF_x$ is the value determined in Clause C.3.

C.4 Establishing total exposure ratio from a set of transmissions on different frequencies

The algorithm to combine the calculated exposure ratios from Equipment Under Test and relevant sources, ER_{calc} , for a point of investigation is:

Establish the applicable power density multiplication factor $PDMF_{app}$ for each relevant frequency band from Clause C.3 above.

Determine the free space E-field for each frequency band emitted by the Equipment Under Test [EN 50383] and hence the free space exposure ratio, ERfs.

For each band, establish the value of the individual modified exposure ratio, ER_{mod} , from:

$$ER_{mod} = ER_{fs} * PDMF_{app}$$

Establish which frequency band, b_{max} , has the highest value of ER_{mod} , $ER_{mod}_{b_{max}}$ then determine ER_{Calc} , considering C.3.6

$$ER_{Calc} = ER_{mod}_{b_{max}} + \sum_{i=2}^M ER_{fs_i} * PDMF_{36_i}$$

Annex D (informative)

Selection of points of investigation for distant radio sources

D.1 Objective

The objective of this annex is to define a basis for selecting a minimum number of points of investigation to establish the highest anticipated exposure ratios for radio sources generally well removed from the base station.

D.2 Principles

A point of investigation is deemed to represent conservatively the maximum exposure ratio for a relevant source over an area defined by a circle of radius δr provided

- the selected point of investigation is substantially in the clear of the local clutter relevant to the domain of investigation,
- the variation of the exposure ratio is less than 5 % due to the difference in path length,
- the directivity of the radio source antenna is based on free-space propagation.

D.3 Establish δr with respect to distance to radio source

D.3.1 Consider change of field strength with distance

Given free-space propagation, we need to establish the minimum ratio of distance between two points of investigation and the distance to a radio source that results in a 5 % change in exposure ratio.

The power density, S from the remote radio source is defined by

$$S = \frac{A}{r^2} \quad (\text{D.1})$$

where

r is the distance to the remote source;

A is a constant

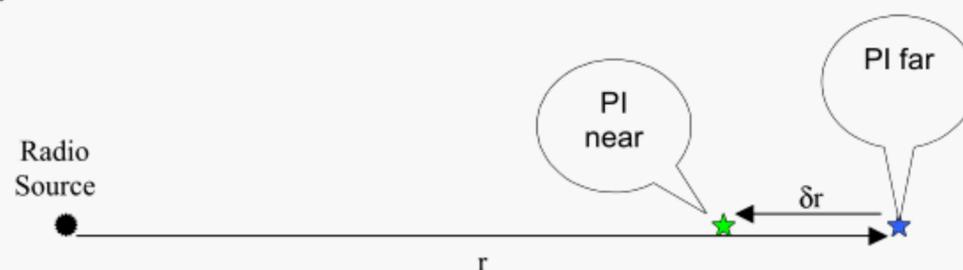


Figure D.1 - Change of field strength with distance

Consider Figure D.1, moving a small distance δr towards the source (most critical condition) then the power density will increase by δS such that:

$$S + \delta S = \frac{A}{(r - \delta r)^2} \quad (\text{D.2})$$

For a 5 % increase in S over distance δr :

$$\frac{S + \delta S}{S} = 1,05 \tag{D.3}$$

From Equations D.1 and D.2 in Equation D.3:

$$\frac{r^2}{(r - \delta r)^2} = 1,05 \tag{D.4}$$

The ratio, X, required is defined as

$$X = \frac{r}{\delta r} \tag{D.5}$$

Substituting for X in Equation D.4 and solving gives X = 41,5.

For a real (and probably cluttered) environment the power density S decays with a power factor for r in Equation D.1 greater than 2. For two points of investigation oriented in any other direction, S changes more slowly with δr . Therefore, a factor of **40** is appropriate for simplicity.

D.3.2 Consider variation of field strength due to antenna directivity

Now consider Figure D.2, for two points of investigation at constant r but varying direction θ relative to the radio source.

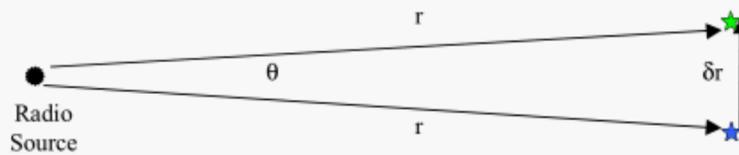


Figure D.2 - Variation of field strength due to antenna directivity

For a source at a distance 40 times the separation between two points of investigation:

$$r = 40\delta r \tag{D.6}$$

and

$$\theta = 2 * \text{Tan}^{-1} \left(\frac{\delta r / 2}{40\delta r} \right) = 1,4 \text{ _ Deg.} \tag{D.7}$$

This is small enough to be disregarded except for highly directional antenna sources deployed at the higher microwave frequencies. In those cases, the clutter variation is likely to be dominant and the maximum gain condition applicable for the domain of investigation should be used.

D.3.3 Example 1

In a domain of investigation of 15 m by 20 m, the maximum distance, d, between any two points:

$$d = \sqrt{15^2 + 20^2} = 25 \text{ m}$$

For a radio source to be assessed based on a single point of investigation, it must be a distance r, from the domain of investigation where:

$$r = 40 * 25 = 1\,000 \text{ m}$$

D.3.4 Example 2

For a selected point of investigation 2 km from the nearest radio source under investigation, an assessment is valid for the parts of a domain of investigation extending to a distance d from the point of investigation:

$$d = 2\,000 / 40 = 50\text{ m}$$

D.4 Selecting points of investigation

For the set of radio sources to be considered, choose a point in the clear above the clutter as near as possible to the domain of investigation. e.g. on roof top and/or in domain of investigation away from local clutter, or for calculation purposes at a point above the domain of investigation where equivalent free space conditions apply.

If it is representative for all radio sources based on the criteria in this Annex, then this may be used for assessment by measurement or calculation.

For any radio sources not completely covered by this "master" point of investigation, select additional points of investigation

- between the source and the domain of investigation, or
- additional point of investigation in the clear, including the nearest point on the domain of investigation to the source, such that criteria in this annex are met.

Annex E
(informative)

A-deviations

A-deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CENELEC national member.

This European Standard does not fall under any Directive of the EC.

In the relevant CENELEC countries these A-deviations are valid instead of the provisions of the European Standard until they have been removed.

Clause Deviation

General **Switzerland**

(Ordinance relating to Protection from Non-Ionising Radiation, SR 814.710 of 23 December 1999 (as of 1 February 2000))

This product standard must not be applied to installations which are covered by the Ordinance relating to Protection from Non-Ionising Radiation, i.e. stationary transmission installations for mobile telecommunication systems and wireless local loops, as well as transmission installations for broadcasting and other wireless applications as far as the compliance testing with the installation limit values of the Ordinance is concerned.

Germany

(Ordinance concerning the Controls for the Limitation of Electromagnetic Fields (BEMFV) issued by virtue of this Act on 20 August 2002)

This standard shall not be applied to fixed equipment for radio transmission (110 MHz – 40 GHz) intended for use in wireless telecommunication networks which fall into the scope of this standard when put into service. For these equipment and installations the requirements of the following ordinance apply in Germany and must be fulfilled.

Italy

The basic standard EN 50400, which establishes procedures for the assessment of the conformity of the products considered in EN 50401 to the limits prescribed in this standard, based on the European Recommendation 1999/519, cannot be applied in Italy.

In fact, in Italy the problem of the human exposure to electromagnetic fields produced by the radio stations considered in EN 50400 and EN 50401 when put into service is regulated by the Law n° 36/2001 and the Ministerial Decree 8th July 2003 (published on the Italian Official Journal n° 199 of August 28 2003), that establish limits much more stringent than those of the European Recommendation.

The procedures prescribed in EN 50400 are not suitable to verify the conformity of the radio stations to the limits prescribed by the Italian legislation.

