

Radio Frequency Electromagnetic Fields

SAFETY INFORMATION

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1 Introduction

All RBSs are Radio Frequency (RF) transmitters. Very high RF exposure levels can be harmful. To protect people against such harmful effects, RF exposure limits with wide safety margins are specified by national and international health authorities.

This document explains how to estimate RF exposure levels and compliance distances (minimum separations between antennas and people) for RBS radio configurations and antennas for which such data is not already specified by Ericsson.

Note that for typical configurations and recommended antennas, Ericsson provides information and specifies compliance distances as part of the Product Data or Technical Product Description for each specific RBS product.

Because it is possible for RF exposure levels to exceed the recommended exposure limits in the areas defined by compliance distances, it is important that RBS antennas are installed so that the general public does not have access to such areas.

For configurations and antennas other than those specified by Ericsson, it is necessary to estimate RF exposure levels and specify the requirements for an RBS antenna site. The methods presented here are used to estimate RF exposure levels and the dimensions of the areas from which the general public must be excluded. The methods are also applicable for determining compliance distances for occupational exposure.

These and other calculation and measurement methods are described in standards such as EN 50383 and EN 50400, IEEE C95.3 and CEPT ECC/REC/(02)04.

1.1 Target Group

This document is intended for engineering personnel who create site installation documentation for RBSs used in the following mobile phone systems:

- GSM
- WCDMA
- LTE

2 RF Exposure Limits

Various national and international RF regulations, safety standards, and recommendations exist that are relevant to RBS RF exposure. The limits defined in these standards are similar and are often based on international guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which is recognized by the World Health Organization (WHO). The guidelines have been incorporated in EU Council recommendation 1999/519/EC.

The ICNIRP has developed basic restrictions for both occupational and general public exposure to electromagnetic fields that must not be exceeded in any near-field or far-field exposure situation. These restrictions are based directly on established health effects. The Specific Absorption Rate (SAR) is used to specify the basic restrictions in the frequency range 10 MHz to 10 GHz. The SAR is a measure of the rate of RF energy absorption by the body, expressed in units of watts per kilogram of tissue (W/kg).

The restrictions are provided to prevent established adverse health effects related to whole-body heat stress and excessive localized tissue heating. Whole-body SAR is averaged over the whole body while localized SAR is defined as the maximum local SAR averaged over any 10 g of tissue.

The restrictions, which are summarized in Table 1 on page 3 below, incorporate a safety factor of about 10 for occupational exposure and about 50 for general public exposure.

Table 1 ICNIRP Basic Restrictions for Occupational and General Public Exposure

Whole-Body SAR (W/kg)		Localized SAR 10g (W/kg)⁽¹⁾	
Occupational Exposure	General Public Exposure	Occupational Exposure	General Public Exposure
0.4	0.08	10	2

(1) The limits provided on localized SAR are for head and trunk tissue. Localized SAR limits for limbs are twice as high.

Reference levels are provided for the purpose of comparison with exposure quantities in air. In the frequency range 10 MHz to 10 GHz the reference levels are expressed as electric field strength (V/m), magnetic field strength (A/m), and power density (W/m²). The ICNIRP power density reference levels for occupational and general public exposure are summarized in Table 2 on page 4 and Table 3 on page 4 respectively.

Table 2 ICNIRP Reference Levels for Occupational Exposure

Occupational Reference Levels Expressed as Power Density		
10 – 400 MHz	400 – 2000 MHz	2000 – 10 000 MHz
10 W/m ²	$f/40 \text{ W/m}^2$ ⁽¹⁾	50 W/m ²

(1) f = frequency in MHz*Table 3 ICNIRP Reference Levels for General Public Exposure*

General Public Reference Levels Expressed as Power Density		
10 – 400 MHz	400 – 2000 MHz	2000 – 10 000 MHz
2 W/m ²	$f/200 \text{ W/m}^2$ ⁽¹⁾	10 W/m ²

(1) f = frequency in MHz

The reference levels, which vary according to frequency, have been chosen to prevent the SAR restrictions from being exceeded. This means that additional safety margins have been introduced. The reference levels apply primarily to whole-body far-field exposure situations, whereas they are very conservative for partial-body near-field exposure situations. Compliance with the reference levels will ensure compliance with the basic restriction. If the measured value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded.

The averaging time is 6 minutes. For exposure periods shorter than the averaging time, exposure levels higher than the basic restrictions or reference levels are accepted provided the average is lower than the limits.

In the case of RF sources with multiple frequencies, the following requirement is specified in the ICNIRP guidelines. For an antenna that operates in n different frequency bands, where S_i is the power density at the i^{th} frequency and $S_{\text{lim},i}$ is the reference level for that frequency, the requirement for total exposure is as follows:

$$\sum_{i=1}^n \frac{S_i}{S_{\text{lim},i}} \leq 1 \quad (\text{Equation 1})$$

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2.1 RF Exposure Calculations

The following formula is used to estimate the free-space far-field power density S (W/m²) in the main direction of an antenna:

$$S = \frac{PG}{4\pi d^2} \quad (\text{Equation 2})$$

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P (W) is the total RMS power fed to the antenna, that is, the sum of all transmitter channels minus feeder and combiner losses. G is the numerical far-field antenna gain relative to an isotropic radiator, and d (m) is the distance from the antenna. PG is the Equivalent Isotropically Radiated Power (EIRP) of the antenna, expressed in watts.

The far field is commonly considered to start at a distance $2D^2/\lambda$ from the antenna, where D is the largest dimension of the antenna and λ the wavelength in meters.

If needed, electric and magnetic field strengths are calculated using the equation $S = E^2/377 = 377H^2$, where 377 (Ω) is the impedance of free space.

The **far-field formula** (equation 2) gives relatively accurate estimations (within ± 3 dB) of the far-field power density in free space without significant reflecting surfaces near the position of exposure prediction. If used in the near field, it significantly overestimates the exposure.

The **near-field formula** below is derived from the so-called cylinder formula, which is used to estimate the average power density closer to the antenna. The near-field formula estimates the maximum power density in the near-field region of an antenna. For an antenna with an azimuthal half-power beam width of Θ degrees, an aperture height of h meters, and a total RMS power feed of P watts, the power density in the main beam direction at a distance of d meters from the antenna is as follows:

$$S = \frac{2P}{\pi dh} \times \frac{180}{\Theta} \quad (\text{Equation 3})$$

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The far-field formula gives good exposure estimates in the far field, while overestimating exposure levels close to the antenna. Similarly, the near-field formula overestimates exposure levels in the far field. An accurate estimation of the real exposure is obtained by using both formulas and applying the lowest value.

For RF exposure determination in other directions, that is, above, below, behind, and at the sides of the antenna, it can be difficult to use analytical expressions, since the near-field radiation properties are usually unknown. Other methods are preferred instead, such as those described in the standards mentioned in section 1.

2.2 Determining Compliance Distances

A compliance distance is a minimum separation allowed between an antenna and a person to ensure that RF exposure limits are not exceeded. To install an RBS antenna correctly, it is important to determine RF exposure compliance distances and ensure that RF exposure levels are below specified limits in areas accessible to the general public.

Compliance distances generally vary in different directions from the antenna. The analytical RF exposure assessment methods described in Section 2.1 on page 4 are used to determine compliance distances for both occupational and general public exposure. In far-field environments without significant reflections, the analytical far-field formula (equation 2) is used. With $S = S_{lim}$, which is the reference level expressed as power density (W/m^2), the compliance distance $d_{compliance}$ (m) in the main beam direction is calculated as follows:

$$d_{compliance} = \sqrt{\frac{PG}{4\pi S_{lim}}} \quad (\text{Equation 4})$$

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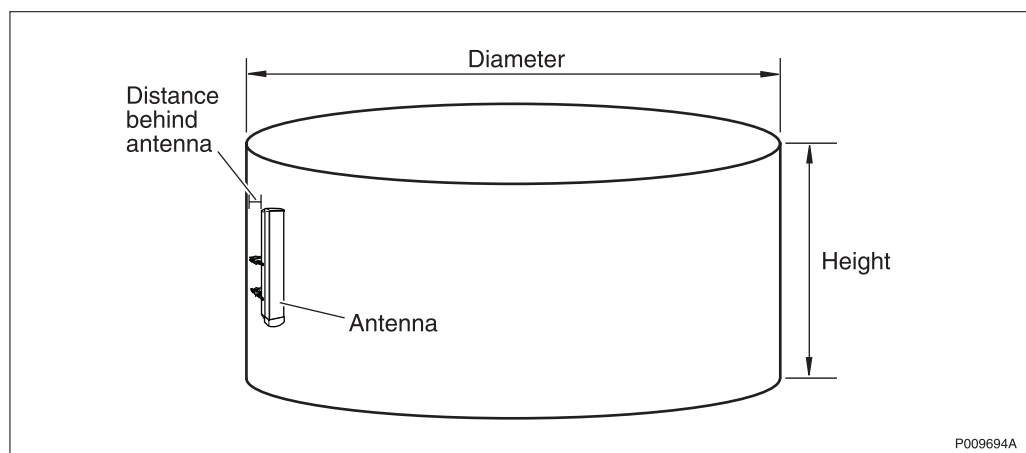
P (W) is the total RMS power fed to the antenna (the sum of all transmitter channels minus feeder and combiner losses) and G is the numerical far-field antenna gain, which is taken from the far-field radiation pattern supplied by the antenna manufacturer.

In most near-field situations, the far-field formula (equation 4) greatly overestimates the compliance distance, and the near-field formula would give a more accurate estimation of the exposure. For an antenna with an aperture height of h meters and an azimuthal half-power beam width of Θ degrees, the expression for the compliance distance in the main beam direction is as follows:

$$d_{compliance} = \frac{2P}{\pi h S_{lim}} \times \frac{180}{\Theta} \quad (\text{Equation 5})$$

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A recommended simple structure to define compliance distances in all directions (a compliance boundary) is a cylinder, *see Figure 1 on page 6*. The analytical assessment methods described are used to estimate the compliance distance in front of the antenna. As a general rule, the compliance distances behind, above, and below the antenna are about 1/20th of the distance in front of the antenna.



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Figure 1 Simple Structure of a Compliance Boundary

2.3 Example Compliance Boundary Determination

The following example of a compliance boundary for the general public is for an antenna operating in the 2100 MHz frequency band. The antenna has a length of 1 meter, an antenna gain of 18 dBi, which corresponds to a numerical gain of 63, a half-power beam width of 60 degrees, and a maximum output power of 40 dBm, which corresponds to 10 W.

$$\text{dBi: } 10 \cdot \log_{10}([\text{numerical antenna gain}]) = [\text{antenna gain in dBi}]$$

$$\text{dBm: } 10 \cdot \log_{10}([\text{power in mW}]) = [\text{power in dBm}]$$

The ICNIRP power density reference level for general public exposure at 2100 MHz is 10 W/m².

The compliance distance in front of the antenna is calculated using both the far-field formula (equation 4) and the near-field formula (equation 5).

Far-field formula:

$$d_{\text{compliance, far-field}} = \sqrt{\frac{10 \cdot 63}{4 \cdot \pi \cdot 10}} = 2.2 \text{ m}$$

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Near-field formula:

$$d_{\text{compliance, near-field}} = \frac{2 \cdot 10}{\pi \cdot 1 \cdot 10} \cdot \frac{180}{60} = 1.9 \text{ m}$$

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The most accurate estimation of the compliance distance for general public exposure in front of the antenna is 1.9 meters in this example.

The cylindrical compliance boundary is estimated using the general rule described in Section 2.2 on page 5. The compliance distance behind, above, and below the antenna is about 1/20th of the distance in front of the antenna.

The diameter of the cylindrical compliance boundary is calculated as the depth of the antenna plus the compliance distance behind and in front of it. Assuming an antenna depth of 10 cm, the diameter of the compliance boundary in this case is 2.1 meters. The height of the cylindrical compliance boundary is calculated as the distance above and below the antenna plus the height of the antenna. The height of the compliance boundary in this case is therefore 1.2 meters.

It is recommended always to round the calculated compliance boundary dimensions upwards.

3 General Public Safety Recommendations

The following recommendations supplement any existing Ericsson-recommended technical or scientific guidelines:

- If compliance boundary or other necessary exposure information is not available, estimate the maximum exposure using the methods described in Section 2.2 on page 5 and consider alternative locations for the antenna installation if the results do not comply with the relevant exposure limits for the general public.
- If non-authorized people have access to the antenna front, raise the installation height of antennas on roofs or walls to at least two meters, or consider directional rooftop antennas pointing away from the building installed near the edge of the roof
- If antennas cannot be raised to the recommended height, restrict access for non-authorized people and consider using signs posted at rooftop entrances or on antenna equipment
- Mount antennas on building facades so that they are inaccessible from windows and balconies
- Avoid installing indoor antennas where they can be easily reached
- Respond to safety concerns by providing relevant information that answers questions regarding RF safety received from local authorities or people living or working near installations

4 References

Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz), International Commission on Non-Ionizing Radiation Protection (ICNIRP), *Health Physics*, vol. 74, no. 4, pp 494–522, April 1998. <http://www.icnirp.de>

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