Draft Guidelines for Complying with Limits for Human Exposure to Electromagnetic Fields(Base Station Antennas and Mobile Telephones/ Terminals)

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1.0 Scope

These guidelines deal with the compliance of telecommunication installations, equipment and mobile handsets with safety limits for human exposure to electromagnetic fields (EMFs) produced by telecommunication equipment in general but the subject matter specifically considers mobile telecommunication equipment such as base stations, handsets/terminals etc. Based on the safety limits provided by ICNIRP, the guidelines provide a calculation method, and an installation assessment procedure as well as techniques and procedures for assessing the severity of field exposure and for limiting the exposure to workers and the general public to these fields, if the limits are exceeded. The guidelines also cover the exposure of people, present on telecommunication sites, and the exposure of people outside telecommunication sites, to EMF produced by telecommunication equipment along with guidance to the users to determine the likelihood of installation compliance based on accessibility criteria, antenna properties and emitter power etc.

1.1 Introduction

Mobile radio communication is a very effective means of communication among the masses in the 21st century because it does not hamper the freedom of movement. In India, the growth of mobile telephones is very high and it is expected that it may cross 250 Million subscribers by the end of year 2007 and 500 Million subscribers by the end of year 2010. The enormous growth of mobile communications is contributing comprehensively to the overall economic growth of the country. One of the effects of the growth of mobile communications on population is exposure to the Electromagnetic Fields produced by the base station antennas normally mounted on cellular mobile towers and by handheld mobile telephone sets/ terminals.

1.2 Terms & Definitions

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.

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.

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.

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.

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.

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.

General public: All non-workers are defined as the general public.

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

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.

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.

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

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 is the rms value of the electric field strength in body tissue in V/m
- σ is the conductivity of body tissue in S/m
- ρ_m is the density of body tissue in kg/m^3
- c is the heat capacity of body tissue in J/kgºC
- $\frac{dT}{dt}$ is the time derivative of temperature in body tissue in ºC/s
- J is the value of the induced current density in the body tissue in A/m^2

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.

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

1.3 Cellular Mobile Telephone system Network Architecture

A generic Cellular Mobile Telephone System Architecture is depicted in Figure

The brief details of various subsystems are given below for reference:

(a) **MSC/VLR**

MSC (Mobile Switching Center) is responsible for call establishment, route selection, call control, radio resource allocation, mobility management, location registration and channel handoff in switching areas. In addition, it generates bill information, coordinates services between it and the PSTN.

VLR (Visitor Location Register) acts as a dynamic database and stores the temporary information (all data necessary to set up call connections) about the users roaming to the local MSC area.

-**(b) HLR/AUC**

HLR (Home Location Register) is responsible for storing subscription information (telecom service subscription information and user status), RS location information, MDN, IMSI (MIN), etc. The AUC (Authentication Center) is physically combined with the HLR. It is a functional unit of the HLR, specially dedicated to the security management of the system.

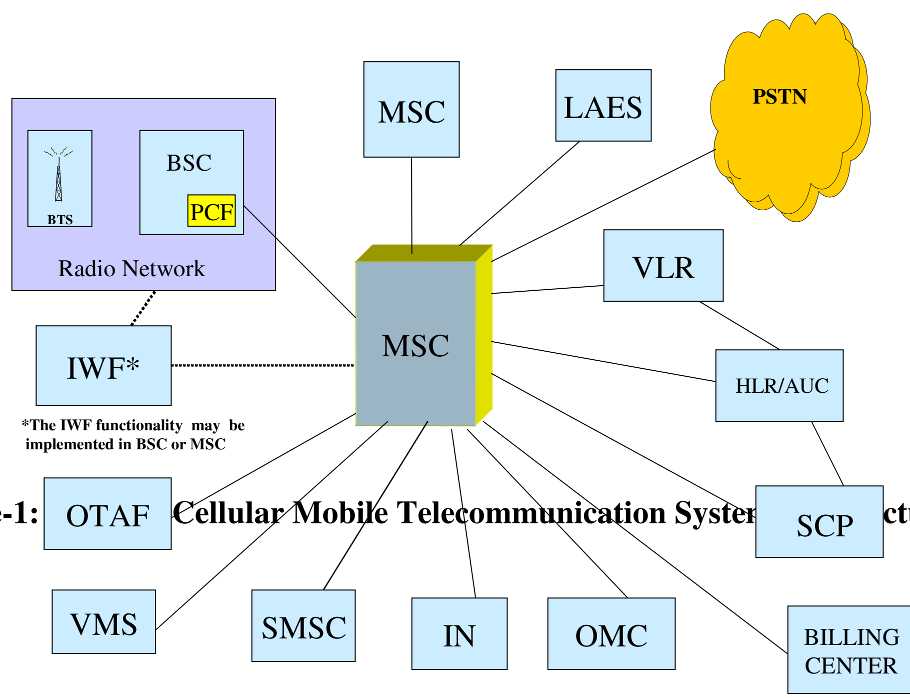
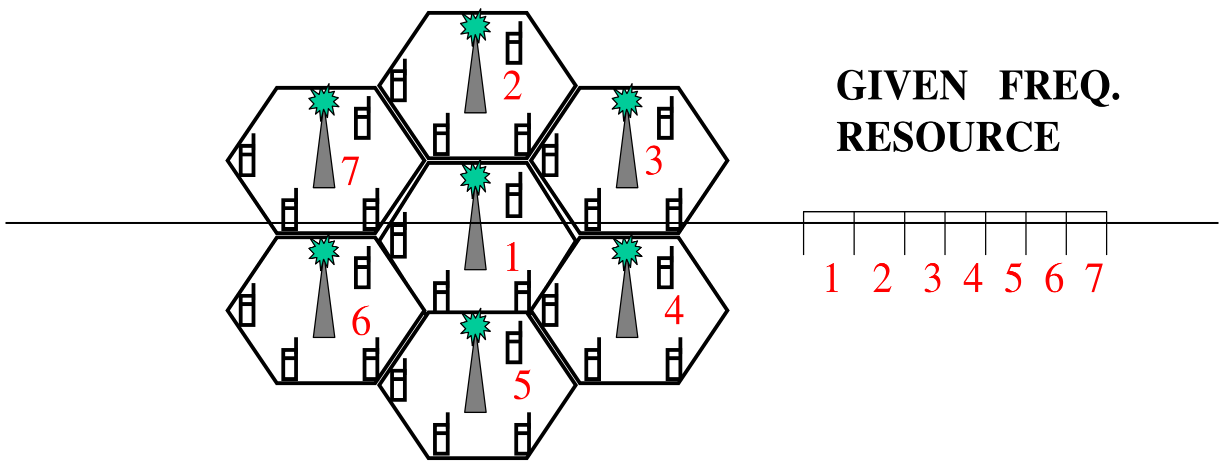


Figure-1: Cellular Mobile Telecommunication Syster cture

MOBILE COMMUNICATION



A CLUSTER OF CELLS

Figure 2: Cellular Structure of Base Station Sites

(c) Operations and Maintenance Centre (OMC)

The Operations and Maintenance Centre (OMC) allows the centralized operation of the various units in the system and the functions needed to maintain the sub systems. The OMC provides the dynamic monitoring and controlling of the network management functions for operation and maintenance. The overall objective of OMC is that neither equipment failure nor human error in the OMC implementation should render the OMC and /or the part of the network it supervises, out of service.

(d) Base Transceiver Station (BTS)

It is a multiple circuit transceiver which shall radiate to cover a cell or a sector. It consists of radio modules, base band signal processor, network interface, antenna, feeder etc. It can be co-located with BSC or remotely located. BTS split mounting arrangements with tower mountable RF components such as PAs , LNAs, Filters etc. are also acceptable. BTS shall be connected to BSC through suitable interface(s).

(e) Base Station Controller (BSC)

It is responsible for inter - connection between the BTS and the Switching Centre and it provides control and management for one or more BTSs. It assigns traffic channels to individual users, monitors system performance and provides interface between the BTS and the Switching Centre. BSC performs the radio processing functions such as management of the radio resources, radio channel management, local connection management etc. It also processes information required for decision on handover of calls from one BTS to another. BSC can be either co-located with the MSC or located at a different location connected to the MSC through suitable interfaces.

1.4 In India, Mobile phone systems typically operate in 800, 900 and 1800 MH frequency bands. The 3rd Generation (3G) systems are likely to be deployed in 1.9 & 2 GHz bands also. The RF fields of such mobile systems are quite different from ionizing radiation of X-rays or gamma rays. Unlike ionizing radiation, RF fields cannot cause ionization or radioactivity in the body and because of this reason, RF fields are called non-ionizing.

Mobile phone handsets and base stations present quite different exposure situations. The handset transmits RF energy only while a call is being made, apart from infrequent signals used to maintain links with nearby base stations, whereas base stations continuously transmit signals. The details are as follows:

Handsets: Mobile phone handsets are low-powered RF transmitters, emitting maximum powers up to 2 watts. The RF field strength (and hence RF exposure to a user) falls off rapidly with distance from the handset. Therefore, the RF exposure to a user of a mobile phone located 10s of centimetres from the head (using a "hands free" appliance) is far lower than to a user who places the headset against the head.

Base stations: Base stations transmit power levels depending on the size of the region or "cell" that they are designed to service. A typical Base station antenna has about 20-30 cm width and 1.5 metre length, mounted on a building or a tower at a height of 15- 40 metres above ground. The antenna emits RF beams that are typically very narrow in the vertical direction but quite broad in the horizontal direction. Because of the narrow vertical spread of the beam, the RF field intensity at the ground directly below the antenna is low. The RF field intensity increases slightly as one moves away from the base station and then decreases at greater distances from the antenna".

1.5 As radio waves provide signal connectively in mobile telephones, there is exposure to electromagnetic radiations. The World Health Organization (WHO) established the International EMF Project in 1996 to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. It has been mentioned in the Fact Sheet No. 304 of WHO that considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks, of the order tens of milliwatts to picowatts & below, cause adverse health effects. As regards mobile handsets, they are used in close proximity to the human body & head and radiate up to 2 watt power.

WHO further suggests that National authorities should adopt international standards such as ICNIRP guidelines to protect their citizens against adverse levels of RF fields. As per these guidelines, the main physical effect of exposure to EMFs at frequencies above 100 KHz is heating of tissues. Further, the exposure metric for restricting exposure to fields of frequencies between 100 KHz and 10 GHz is Specific energy Absorption Rate (SAR), unit W kg-1. For frequencies between 10 and 300 GHz, because of diminishing penetration into the body, the exposure metric is incident power density, unit W m-2.

1.6 General Principles

At International level, the ICNIRP has issued "Guidelines for Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (Up to 300 GHz)". The ICNIRP guidelines are based on short-term immediate health effects caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF.

1.6.1 The ITU-T has issued Recommendation K.52 on this subject entitled "Guidance on Complying with Limits for Human Exposure to Electromagnetic Fields". The safety limits for human exposure are given in terms of **Basic Restrictions and Reference Levels**.

Basic Restrictions: These Restrictions on exposure to time varying electric, magnetic and electromagnetic fields, are based directly on established health effects. The **Basic Restrictions,** which shall not be exceeded, are given in terms of the currents density in the body(J), power density (S), or in terms of rate at which RF electromagnetic energy is absorbed in the body. The latter is expressed, more precisely, as Specific Absorption Rate (SAR) i.e. the rate of RF energy absorption per unit mass in the body and it has units of Watt per Kilogram (W/kg).These Limits are given in T**able 1.1/K.52** of ITU-T Rec. K.52, and are primarily used for testing EMF compliance for mobile handsets, hand-held and body-mounted wireless communication devices that are operated in close proximity to human body.

Reference Levels: These levels are provided for practical exposure assessment purpose to determine whether the Basic Restrictions are likely to be exceeded. These are derived from relevant basic restrictions using measurement and/or computation techniques and some address perceptions and adverse indirect effects of EMF. The derived quantities are electric field strength (E), magnetic field strength (B), power density (S), and current flowing through limbs (I-L). These Limits are given in Table 1.2/K.52 of ITU-T Rec. K.52, and are primarily used for testing EMF compliance for devices/equipment(e.g. Base Station etc,) that are not operated in close proximity to human body, i.e. other than mobile handsets, hand-held and body-mounted wireless communication devices.

Reference Levels are defined because in practice, the direct measurements of Basic Restrictions such as SAR are feasible only under laboratory conditions. The Recommended maximum exposure levels in terms of unperturbed electric and magnetic field strength as well as power density are therefore given in addition to the SAR limits. These maximum field intensities are levels which would generate a SAR or induced body current no greater than the basic restrictions.

Compliance with the reference level will ensure compliance with the relevant basic restriction. However when a reference level is exceeded, it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary.

1.6.2 The ICNIRP guidelines use a two-tier limit structure where lower levels are specified for uncontrolled/general public exposure than for controlled/occupational exposure. The occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. The general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals. In many cases, members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure. It is these considerations that underlie the adoption of more stringent exposure restrictions for the general public than for the occupationally exposed population.

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."

1.6.3 Multiple sources and frequencies

In real world environment, there is exposure to multiple EMF sources and the effects of the same is required to be considered. Typically, at frequencies below 10 MHz, the effects on the body are due to the induced current density, while above 100 kHz, the important effects are due to the SAR.

The effects of multiple sources is considered as a weighted sum, where each individual source is pro-rated according to the limit applicable to its frequency. **Appendix A** shows illustrative examples in this regard.

1.6.4 Exposure duration

The exposure limits are defined as quantities averaged over a time period, called the averaging time. Fort 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 is the field (E or H) during exposure I, t_i is the duration of exposure i

X_l is the reference limit, t_{avg} is the appropriate averaging time

The power density limit is:

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

where:

S_i is the power density during exposure I, t_i is the duration of exposure i

S_l is the reference limit, t_{avg} is the appropriate averaging time

1.7 Concept of Conformity Assessment Body (CAB)

Recognizing the importance of scientific measurements to establish that EMF safety guidelines be followed to this effect, it is required to use the concept of Conformity Assessment Body (CAB) which will perform the measurement functions & provide certification thereof.

Hence it would be necessary for telecom authorities to make it mandatory for all transmitting devices to secure certification in respect of compliance with the said EMF safety guidelines.

1.8 The guidelines in this document have two parts. The Part -1 deals with the subject matter related to Base Stations whereas Part -2 with Mobile Phones/ Terminals.

Part –I: Base Stations

2.0 Introduction

In India, over 200 million mobile phones are working as of Aug. 2007 and the market is still growing rapidly. The target for mobile phones by the year 2010 is 500 million, Accordingly, there will be increase in the number of base stations. In multi-operator operator environment, there are more than 1,25,000 base stations in operation in India, with each cell site holding one or more base stations. Base stations use RF powered antennas that communicate with users' handsets.

The coverage of any service area through radio cellular system is provided by a network of Base Transceiver Stations (BTS) or Base Stations, each with a certain coverage area (cell). A BTS provides transmission and reception for radio systems. Depending on parameters such as transmitter power and coverage area, normally 3 types of cell architectures are used:

Macro-cells provide the main structure for the coverage a service area. The BTS for macro-cells have power outputs of tens of watts and communicate with phones in a large area. For example, a typical macro-cell may have about 20 W power, 17 dB antenna gain and a coverage area of about 5 kilometers in a city. In highway/rural environment, the power may go up to 37 W with about12-15 km coverage.

Micro-cells are used to infill and improve the main network, especially where the volume of calls is high. The micro-cell base stations emit less power (around 5-20W) than those for macro cells and their range is from a few hundred meters up to 1 km.

Pico-cell base stations have a lower power output (less than 5 W but mostly about 100s of mw) than those of micro-cells and are generally sited inside buildings."

2.1 Evaluation of Compliance with EMF Safety Limits: The assessment, testing and measurement methods at telecom installations/ base stations to verify compliance with EMF exposure safety limits will be as per ITU-T Rec. K.52, ITU-T Rec. K.61, and IEC 61566 etc., including the following brief requirement and evaluation steps:

2.1.1 The below mentioned steps would 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 2.1.2)
3) If the EMF exposure assessment is needed, it may be performed by calculations or measurement. This risk assessment approach may be used 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.

2.1.2 Determining the need for assessment for telecommunication equipment

This classification of intentional or unintentional EMF emitter is made in accordance with the definitions. An intentional emitter is normally associated with an antenna for radiation of electromagnetic energy.

2.1.2.1 Unintentional emitters - telecommunication equipment

Normally, the fields produced by such telecommunication equipment are due to spurious emissions and are much below the safety exposure limits. Though, it may exceed the emission limits at certain frequencies, the fields produced are still significantly below the safety limits. Therefore, the equipment under this category do not need an EMF safety assessment to assure compliance with safety limits.

2.1.2.2 Intentional emitters- telecommunication equipment

These emitters use EM fields for signal transmission and 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. These parameters and the operating environment of the installation determine the need and the app*ropriate proce*dure of exposure assessment.

2.1.3 Brief Procedures for EMF exposure assessment

EMF exposure assessment is made if the intentional emitters are present, and conducted for all locations where people might be exposed to EMF in course of their normal activities. All such exposures to EMF pertain to one of these three zones (See Figure below).

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.

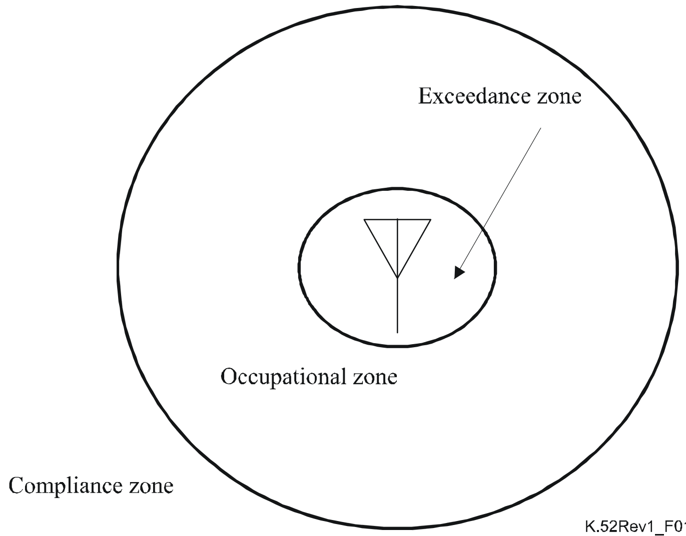


Figure – Figurative illustration of exposure zones

2.1.4 Exposure level assessment procedure

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 (Equivalent Isotropically Radiated Power) of the antenna system. Here, maximum EIRP should be calculated for mean transmitter power, which normally is nominal (rated) transmitter power.
- the antenna gain *G* or the relative numeric gain *F*, 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.

2.1.4.1 The installation classification scheme

The classification of the installation is made on the basis of the ICNIRP limits whereas the criteria are based on a conservative estimate of the likely EMF exposure in the various situations. Each emitter installation should be classified into the following three classes:

1) **Inherently compliant**: Inherently safe sources produce fields that comply with relevant exposure limits a few centimetres away from the source. Particular precautions are not necessary.

   Emitters with maximum EIRP of 2 W or less are classified as inherently compliant. No further action is deemed necessary.

If the total radiating power is 100 mW or less and the antenna(s) are low-gain small-aperture microwave or millimeter-wave antennas, the emitter can be regarded as inherently compliant. No further action is deemed necessary.

In addition, where the emitter is so constructed that access to any area where exposure limits may be exceeded is precluded by the construction of the radiating device, is classified as inherently compliant

2) **Normally compliant**: Normally compliant installations contain sources that produce EMF that can exceed relevant exposure limits. However, as a result of normal installation practices and the typical use of these sources for communication purposes, the exceedance zone of these sources is not accessible to people under ordinary conditions. Examples include antennas mounted on sufficiently tall towers or narrow-beam earth stations pointed at the satellite. Precaution may need to be exercised by maintenance personnel who come into the close vicinity of emitters in certain normally compliant installations.

   The suggested criteria for determining if an installation is normally compliant comprises three installation characteristics: the accessibility and the directivity of the antenna, the frequency of the radiated field. These characteristics are described in B.2.1, B.2.2 and B.2.3 of **Appendix B**.

3) **Provisionally compliant**: These installations require special measures to achieve compliance. This involves determination of the exposure zones and measures presented in ITU Rec. K.52 & K.61.

2.1.4.2 Procedure for determining installation class

Each installation should be categorized into one of the installation classes defined in 2.1.4.1. For providing a particular telecommunication service, normally the use is made of a limited set of antennas & associated equipment with well-defined characteristics. Further, installation and exposure conditions for many emitter sites are likely to be similar. Therefore, it is possible to define a set of reference configurations, reference exposure conditions and corresponding critical parameters that will enable convenient classification of sites.

2.1.4.3 Calculation methods

In the reactive near-field region, the electric and magnetic fields must be considered separately whereas in far-field region, either of the two is sufficient for compliance measurement.

2.1.5 Mitigation techniques

To control EMF exposure in locations, accessible to people, where the EMF exceeds human EMF exposure safety limits, restricting access to such areas be used where other installations characteristics cannot be changed.

2.1.5.1 Occupational zone

If the EMF exceeds the limits for uncontrolled/general public exposure but does not exceed the limits for occupational exposure, then access to the general public should be restricted, but workers may be permitted to enter the area. Physical barriers, lockout procedures or adequate signs can accomplish the access restriction. Workers entering the occupational zone should be informed.
It is recommended not to locate a permanent workplace within the occupational zone.

2.1.5.2 Exceedance zone

Where the EMF exceeds the limits for occupational exposure, access to workers and the general public should be restricted. If it is necessary for workers to enter the area, steps to control their exposure should be taken. Such steps include:

- temporarily reducing the power of the emitter;
- controlling the duration of the exposure so that time-averaged exposure is within safety limits;
- shielding or use of protective clothing.

2.1.6 Field regions

The properties of EM Fields need to be taken into consideration for their measurement and evaluation. For example:

- measurement of both the electric and magnetic components may be necessary in the non-radiating near field region;
- for numerical prediction: the far-field model usually leads to an overestimation of the field if applied in near field regions.

Therefore, it is important to be aware of the boundaries of each field region before starting a compliance procedure.

I) Near Field Region

i) Reactive near-field zone : It is immediately surrounding the antenna where reactive field predominates and typically extends to a distance of one wavelength from the antenna.

ii) Reactive – radiating near-field region

The transitional region wherein the radiating field is beginning to be important compared with the reactive component. This outer region extends to a few (e.g., 3λ) wavelengths from the electromagnetic source.

iii) Radiating near-field (Fresnel) zone

The region of the field of an antenna between the reactive near-field and the far-field region and wherein the radiation field predominates. Here, the electric and magnetic components can be considered locally normal; moreover the ratio E/H can be assumed constant (and almost equal to Z_0, the intrinsic impedance of free space). This region exists only if the maximum dimension D of the antenna is large compared with the wavelength λ.

II) Far Field Zone-Radiating

The region of the field where the angular field distribution in essentially independent of the distance from the antenna and the radiated power density [W/m^2] is constant. The inner boundary of the radiating far-field region is defined by the larger between 3λ and $2D^2/\lambda$ (i.e., the limit is $2D^2/\lambda$ if the maximum dimension D of the antenna is large compared with the wavelength λ). In the far-field region the field components are transverse and propagate as a plane wave.
The above regions are shown below (where D is supposed to be large compared with the wavelength λ).

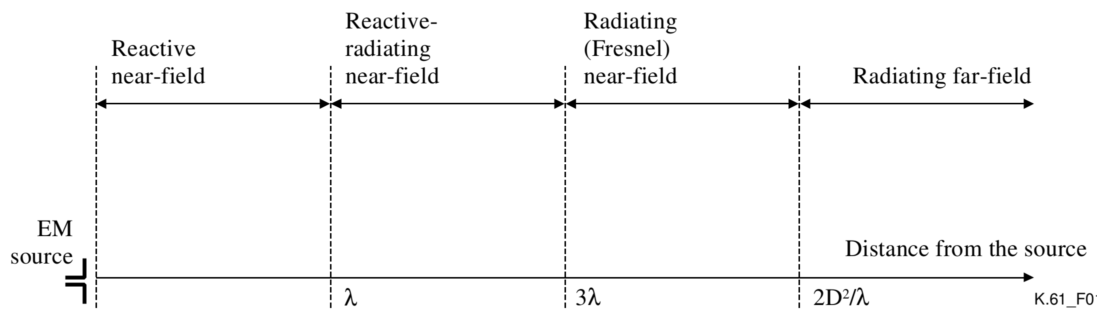


Figure 1/K.61 – Field regions around an EM source (the antenna maximum dimension *D* is supposed to be large compared with the wavelength λ)

2.1.6.1 Shadowing and Scattering

The EMF strength varies with spatial position due to the effect of reflection and scattering about adjacent conducting structures. The scale of this variability is a function of the wavelength. It is important to consider this variability to determine the locations of maximum exposure and use spatial averaging as appropriate.

2.1.6.2 Variability of the source

Telecommunication sources are sometimes variable. Variability of transmitted power and antenna pattern is especially important. This variability presents a special challenge for measurements since the exact state of the transmitter at the time of measurement may not be known.

As regards **power variability,** the maximum total radiated power from the transmitter must be taken into account. .

Antenna variability is important when active antennas are used that that can dynamically vary their radiation pattern.

The effect of **Intermittent sources** that operate in regular or irregular manner is also considered.

2.2 Based on international guidelines & best practices, some measures for base station antenna siting are given below:

i) In general, a base station antenna should be at least 3 m away from the nearby building and should not face any floor of the nearby building at the same height as that of the antenna, which is not more than 3 meter away. Further, the lower end of the antenna should be at least 3 meter above the ground or roof, as applicable. The relevant details will be as per ITU-T Rec. K.52."

ii) In case of multiple transmitter sites at a specific locality, sharing of a common tower infrastructure should be explored, as far as possible, which can be coordinated through a nodal agency.

iii) Access to base station antenna sites should be restricted for the general public by suitable means such as wire fencing, locking of the door to the roof etc. Clear exclusion zones should be in place around all mobile phone base station antennas to prevent the public from exposure to radio frequency radiation above ICNIRP guidelines, as reproduced in Annex-1 of this document(These exclusion zones, related to an area, are directly in front of and at the height of the antenna).
Further, O&M personnel should strictly follow the procedures, prescribed by the manufacturer, for handing the equipment."

iv) Sign boards/ Warning Signs are to be provided at Base Station antenna sites which should be clearly visible and identifiable . A warning sign should be placed at the entrance of such zone , wherein the survey has shown that RF levels exceed the values specified in Annex 1.

The sign board should be clearly visible and identifiable and may contain the following or other similar text:

1) Danger ! RF radiations, Do not enter !
2) Restricted Area

The colour code mav be as follows :

Symbol–red text against white background

Some more relevant details are to be included in this regard.

v) A national database be set up, developed and maintained by the designated authority, giving details of all base stations and their emissions, such as their location, the height of the antenna, the frequency and modulation characteristics, and details of power output. And these details be available on the website of the designated authority in a phased manner, within a period of say 3 years.

vi) An independent audit of emissions be established to give the public confidence that base stations conform to approved guidelines. To start with, this exercise may be focused on those base stations/ telecom installations that may attract high public concern due to their location. It is suggested that after a certain no. of surveys (say 500) have been undertaken, the results be examined to identify any emerging trends and decisions may then be taken on how to progress the audit. The result from the surveys be published on the website of the designated authority.

vii) It is imperative that RF power outputs of base stations be kept to the lowest possible levels commensurate with effective service provisioning in order to ensure that the risk of interference within the network and with other radio networks is minimized. Though the levels of power output may go up and down during the day (depending on factors such as the number of people using their phones at any one time and the distance they are from the base station), the base stations emission should, at all times, remain within the ICNIRP guidelines & as per limits given in ITU-T Rec. K.52, for public exposure.

As all base stations shall meet the ICNIRP guidelines, all applicants should include with their applications a statement that self-certies to the effect that the base station, when operational, will meet the ICNIRP guidelines & ITU-T Rec. K.52. Where a base station is added to an existing mast or site, the operator should confirm that the cumulative exposure will not exceed the ICNIRP guidelines & ITU-T Rec. K.52 limits. The proforma of this self certificate may be as given below:

Declaration of Conformity with ICNIRP Exposure Guidelines & ITU-T Rec. K.52

(Service Provider's Name)
(Service Provider's Address)

Declares that the proposed equipment and installation as attached planning application at:

(Address)…………………………………………………………………………

is designed to be in full compliance with the requirements of the Electromagnetic Fields (EMF) public exposure guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and ITU-T Rec. K.52 (12/2004) titled "Guidance on complying with limits for human exposure to electromagnetic fields (0 Hz to 300 GHz)".

* Reference: ……………………………………………………………………………...

Date: …………………….

Signed: ……………………..

Name: …………………………………..

Position: …………………………………

(Footer – Service Provider's name and registered number/office etc.)

3. Measurement and numerical prediction methods

A measurement or more accurate calculation can help in determining the compliance with the prescribed limits. It is especially useful in complex scattering environments or for environments with a number of significant sources of EM radiation. The brief details are given here. For complete information, please refer to ITU-T K.61

3.1 Measurement Approaches

The measurement problem typically approaches one of the following case:

1) The source of the EMF and at least some of its characteristics are known. The EMF from other sources is negligible for compliance considerations. The objective is to determine the compliance zones for this known source.

2) The sources of the EMF are not known. The objective is to determine compliance in a particular location, or to survey the EM fields in the out-band region to confirm that other EM sources can be neglected.

3) The objective is to determine compliance in a particular location, and if non-compliance is found, to determine the relative contribution of the sources to the non-compliance.

In Case 1, the emission frequency band should be known precisely. The transmitted power, polarization and the antenna pattern may be known approximately. Thus, the measurements can focus onto the frequency range of interest. ITU-T Rec. K.52 should be used to obtain an estimate of the filed strength in order to determine appropriate instrumentation.

In Case 2, a survey of the entire frequency spectrum may be required. An alternative is measurements with wideband probe that integrates various frequencies. Case 3 is an extension of Case 2. If the initial measurement indicates non-compliance, frequency selective measurements, using an antenna and spectrum analyzer for example, are needed.

3.2 Measuring Instruments

The measuring instruments should be selected on the basis of the following important parameters:

i) Frequency range

There are two classes: broadband and narrow-band.

1) Broadband devices (such as the commonly used electric and magnetic probes) do not give information on frequency spectrum. Nevertheless frequency selective measurements on large bands are possible by using small broadband antenna (e.g., bi-conical, horn, etc.) or more sophisticated and expensive devices.
2) Narrow-band devices are generally antennas with flat antenna factors over limited spectrum ranges (e.g., the dipole antennas) and can be used for frequency selective measurement.

As regards the use of probe for conducting measurement, general consideration is to use broadband wherever possible (it is simpler and shorter), but often a frequency selective measurement is required (in general when it is not possible to distinguish one main source and when the measurement results need an elaboration to be compared with an RMS limit).
Selective measurement is usually necessary in case of:

– multiple sources with different limits;
– multiple sources to which different measurement techniques are recommended (e.g., Post-processing for GSM or others); or
– it is necessary to determine relative contribution of multiple sources.

ii) Antenna directivity

The antenna response may be isotropic or directional.
For isotropic devices, the response is expected to be independent of the direction of the incident EMF.
For directional devices, the response is expected to be dependent of the direction of the incident EMF. Directional devices are generally polarized and have an axial symmetry in the radiation pattern. Thus proper device rotations are necessary for the field reconstruction.

iii) Quantity measured

Either the electric field or the magnetic field is generally measured. The distinction is important in case of reactive field region.
In the far-field region, it is possible to measure either the electric or the magnetic field component and determine the equivalent power density. However, measurement devices for the electric field component are usually preferred. The equivalent power density within the far-field region is obtained from the measured field by calculation.

- multiple sources with different limits;

- multiple sources to which different measurement techniques are recommended (e.g., Post-processing for GSM or other); or

- it is necessary to determine relative contribution of multiple sources.

iv) Device selection

The choice of devices for EMF measurement is determined by some factors, for instance:

– the existing standard to be complied with (e.g., limits may be frequency-dependent;)

– the number and the characteristics of EMF sources; and

– the field regions (i.e., reactive near-field, radiating near-field, far-field) in which the measurements are made.

The choice of measurement equipment is strongly related to the measurement procedure. The accuracy of measurement results depends on measurement procedures as well as on the characteristics of the measurement instruments used.

3.3 Compliance with the limit

Frequency-selective or directional measurements are needed to identify the contribution of individual sources. For example, a combination of antenna and a spectrum analyzer allows for a more precise measurement of individual frequency, direction and polarization field components.

For Base stations for radio-mobile systems, all radio channels should be occupied during the measurement. If measurements with all channels occupied are not possible, then the extrapolation procedure as per ITU T K.61 to be used.

4. Safety procedure for operators, Public and maintenance personnel from Electromagnetic fields

The operators and maintenance personnel, dealing with radio frequency devices/equipments, especially with antennas of base stations installed on towers and at any other out door site, should be protected from the RF exposure, particularly above the ICNIRP occupational levels. It is recommended that operators and maintenance personnel should be educated for possible hazards from these devices/equipments. Further, it should be ensured that all safety measure, as prescribed by the manufacturer of the equipment for handing such equipments/devices, should be strictly followed, including the measures given below:

i. The operators and maintenance personnel should be aware of the potential hazards of Electromagnetic fields.

ii. Care shall be taken to ensure that all people are clear of any direct beam of an Electromagnetic field device before it is switched on for test or maintenance purposes.

iii. Instructions and procedures for repair, maintenance and operation of a device, as specified by the manufacturer or an authorized agency, shall be readily available to, and be followed by operators and maintenance personals.

iv. Testing of a device, either before or after completion of any repair work, shall be carried out after protective shields, waveguides and other components have been replaced in their designated locations.

v. The correct operation of all safety interlocks shall be tested and operators shall not tamper with any safety interlock.

vi Sufficient training should be imparted to personnel working in EMF area.

vii Immediate action is to be taken in case of suspected exposure exceeding the limits specified in relevant recommendations.

viii. Appropriate health surveillance shall be carried out by the employer.

Part –II: Mobile Phones / Terminals

5. Introduction

Mobile phones are now an integral part of modern telecommunications. They are very popular and play an important & useful role in today's life because they allow the people to maintain continuous communication without limiting freedom of movement. They use different technologies such as GSM, CDMA etc., to transmit and receive radio frequency signals via an antenna mounted inside or on the exterior of the mobile telephone hand set and typically emit up to 2 W of power. For limiting exposure from such devices, International Commission on Non Ionizing Radiation Protection (ICNIRP) guidelines of 1998 are available for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz) and have been taken as reference and followed (Annex1).

6 SAR Measurement System

The measurement shall be carried out as per IEC 62209-1 (2005). The brief details are given here.

6.1 A SAR measurement system shall be composed of a phantom, electronic measurement instrumentation, a scanning system and a device holder and should work at least in frequency range 300 MHz - 3 GHz . The test shall be performed using a miniature probe that is automatically positioned to measure the E-field distribution in a phantom mode representing the human head exposed to EM fields, produced by wireless devices. The measuring Instrument shall have clear indication to show the measured parameters. i.e. SAR, from the minimum range of .02 - 100 W/kg.

The SAR test shall be performed in a chamber with ambient noise within.012 W/kg (3 % of the lower detection limit of 0.4 W/kg). The effects of reflections, secondary RF transmitters, etc. shall be smaller than 3% of the measured SAR.

The scanning of an E-field probe is carried out within two bisected phantom (shell and liquid) halves or a full –head phantom with an opening on the top. The phantom model shall use material with dielectric properties similar to those of head tissues. The Specific Anthropomorphic Mannequin (SAM) standard phantom shall be used for the handset SAR measurements.

The scanning system, holding the probe, shall be able to scan the whole exposed volume of the phantom in order to evaluate the three –dimensional SAR distribution. The mechanical structure of the scanning system shall not interface with the SAR measurements. The scanning system shall be correlated with the phantom using at least three references point on the phantom, with these points defined by the user or system manufacturer.

7. Considering the international guidelines & best practices, the following measures are mentioned for use of mobile phones/Terminal in different operating environments:

i) The Specific Absorption Rate (SAR) value for each hand set should be provided by the manufacturers as a menu option on the screen of the phone and as a label on the phone along with the corresponding ICNIRP limit for public confidence building. The same should be accessible to the customers on the website as well as in the user's manual, as per ICNIRP guide lines. This is as per international approach taken in the year 2000 and agreed upon by manufacturers.

ii) Mobile phones may interfere with the functionality of certain electro-medical devices, such as cardiac pacemakers and hearing aids and therefore it is recommended to observe suitable operating measures.

Persons using medical aids such as pace makers, defibrillators, hearing aids cochlear implants and other implants etc., should maintain adequate separation between the phone and the pacemaker site to minimize the risk of interference. In the case of pace-makers, minimum 20 cm separation be maintained when phone is switched on & one should not carry it in breast pocket and in case of any suspected interference, the phone be switched off immediately. Further, holding the phone to the ear, opposite the side of the body where the pacemaker is implanted, will add some extra distance between the pacemaker and the phone. Another option is the use of personal hands-free kits and similar accessories to increase the separation between the phone and hearing aid.

iii) The use of mobile phones/ terminals may be restricted by the hospital authorities in such areas of the hospitals that have sensitive medical equipments like in Intensive Care Unit, in order to minimize the risk of interference, if they so desire.

iv) The ICNIRP guidelines are protective of all persons (WHO Fact Sheet No. 193) and therefore, if individuals are concerned, they might choose to limit their own or their children's RF exposure by limiting the length of calls, or by using "hands-free" devices to keep mobile phones away from the head and body

8. Health Information and Communication

An effective system of health information and communications among scientists, government, industry and the public is needed to raise the level of general understanding about mobile phone technology and reduce any mistrust and fears, both real and perceived. This information should be accurate, and at the same time be appropriate in its level of discussion and understandable to the intended audience.

9. References

1. **ICNIRP Guidelines (1998):** "Limiting exposure to time- varying electrical, magnetic, and electromagnetic fields (up to 300 GHz)".

2. **Safety Code 6 (1999) Health Canada Guidelines:** "Limits of human exposure to radiofrequency electromagnetic fields in the frequency range from 3 kHz to 300 GHz".

3. **ITU-T Recommendation K.52 (2004):** "Guidance on complying with limits for human exposure to electromagnetic fields".

4. **ITU-T Recommendation K.61 (2003):** "Guidance to measurement and numerical prediction of electromagnetic fields for compliance with Human exposure limits for telecommunication installations"

5. **IEC 61566 (1997):** "Measurement of exposure to radio-frequency electromagnetic fields- Field strength in the frequency range 100 kHz to 1 GHz".

6. **IEC 62209-1 (2005):** "Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices-human models, instrumentation, and procedures – Part 1: procedure to determine the specific absorption rate (SAR) for hand-held devices used in closed proximity to the ear (frequency range of 300 MHz to 3 GHz)".

7. **IEC 62226-1 (2004):** "Exposure to electric or magnetic fields in the low and intermediate frequency range Methods for calculating the current density and internal electric field induced in the human body-part 1: General"

8. **IEC 62226-2-1 (2004):** “Exposure to electric or magnetic fields in the low and intermediate frequency range Methods for calculating the current density and internal electric field induced in the human body-part 2-1: Exposure to magnetic fields -2D models”

9. **WHO Fact Sheet No.304 (2006):** “Electromagnetic fields and public health: Base station and wireless technologies”.

10. **WHO Fact Sheet No.193 (2000):** “Electromagnetic fields and public health: mobile telephones and their base stations”.

Annex-1

Table 1.1/ K.52 – ICNIRP basic limits

Type of exposure	Frequency range	Current density For head and trunk (mA/m^2) (rms)	Whole – body average SAR (W/kg)	Localized SAR (head and trunk) (W/kg)	Localized SAR (limbs) (W/kg)
Occupational	Up to 1 Hz	40			
	1-4 Hz	40/f			
	4 Hz-1 kHz	10			
	1-100 kHz	f/100			
	100 kHz-10 MHz	f/100	0.4	10	20
	10 MHz-10 GHz		0.4	10	20
General public	Up to 1 Hz	8			
	1-4 Hz	8/f			
	4 Hz-1 kHz	2			
	1-100 kHz	f/500			
	100 kHz-10 MHz	f/500	0.08	2	4
	10 MHz-10 GHz		0.08	2	4

NOTE 1- f is the frequency in Hertz.
NOTE 2- Because of electrical in-homogeneity of the body, current densities should be averaged over a cross-section of 1 cm^2 perpendicular to the current direction.
NOTE 3- All SAR values are to be averaged over any 6- minute period
NOTE 4- The localized SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.

Table 1.2/ K.52 – ICNIRP reference levels (unperturbed rms values)

Type of exposure	Frequency range	Electric field Strength (V/m)	Magnetic field Strength (A/m)	Equivalent Plane Wave power Density S_{eq} (W/m^2)
Occupational exposure	Up to 1 Hz	-	$2x10^5$	-
	1-8 Hz	20 000	$2x10^5/f^2$	-
	8-25 Hz	20 000	$2x10^4/f$	-
	0.025-0.82 kHz	500/f	20/f	-
	0.82-65 kHz	610	24.4	-
	0.065-1 MHz	610	1.6/f	-
	1-10 MHz	610/f	1.6/f	-
	10-400 MHz	61	0.16	10
	400-2000 MHz	$3f^{½}$	$0.008f^{½}$	f/40
	2-300 GHz	137	0.36	50
General public	Up to 1 Hz	-	$2x10^4$	-
	1-8 Hz	10 000	$2x10^4/f^2$	-
	8-25 Hz	10 000	5 000/f	-
	0.025-0.8 kHz	250/f	4/f	-
	0.8-3 kHz	250/f	5	-
	3-150 kHz	87	5	-
	0.15-1 MHz	87	0.73/f	-
	1-10 MHz	$87/f^{½}$	0.73/f	-
	10-400 MHz	28	0.073	2
	400-2000 MHz	$1.375f^{½}$	$0.0037f^{½}$	f/200
	2-300 GHz	61	0.16	10

NOTE 1 - f is as indicated in the frequency range column.
NOTE 2- For frequencies between 100 kHz and 10 GHz, the averaging time is 6 minutes.
NOTE 3- For frequencies up to 100 kHz, the peak values can be obtained by multiplying the rms value by √2 (=1.414). For pulses of duration t_p, the equivalent frequency to apply should be calculated as $f = 1/(2\ t_p)$.
NOTE 4 -Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 MHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz, it is suggested that the peak equivalent plane-wave power density, as averaged over the pulse width, does not exceed 1000 times the S_{eq} limits, or that the field strength does not exceed the field strength exposure levels given in the table.
NOTE 5- For frequencies exceeding 10 GHz, the averaging time is $68/f^{1.05}$ minutes (f in GHz).

Annex-2

Best Practices for Base Stations Siting (Informative)

The following measures may observed voluntarily, as directive principles, by the service providers in the siting of the base stations for ensuring transparency in building networks, providing more information to the public & local planners and boosting the community's role in the siting of radio base stations:

a) Improved consultations with communities

Develop, with other stakeholders, clear standards and procedures to deliver significantly improved consultation with local communities.

b)Detailed consultation with planners

Participate in obligatory pre-application consultation with local planning authorities.

c) Site sharing

Publish clear, transparent and accountable criteria and cross-industry agreement in site sharing, against which progress will be published regularly.

d) Holding of Work shops

Established professional development workshops on technological developments within telecommunications for local authority officers and elected members.

See that the mobile phone briefings section for details of briefings are held across the country for councilors and planners – For any local authority interested in a presentation, the section also contains contact details.

e) Database of the base station sites

Deliver, with the Government, a database of information available to the public on radio base stations.

f) Compliance with ICNIRP& ITU-T Rec. K.52 public exposure levels guidance

Assess all radio base stations for international ICNIPR &ITU-T Rec. K.52 compliance for public exposure, and undertake a program for ICNIPR compliance for all radio base stations.

g) ICNIRP & ITU-T Rec. K.52 certification

Provide, as part of planning applications for radio base stations, a certification of compliance with ICNIRP public exposure guidelines & ITU-T Rec. K.52.

h) Prompt responses to enquiries

Provide specific staff resources to respond to complaints and enquires about radio base stations, within ten working days.

i) Support research into health and mobile phones

Being financially supporting the government's or other independent scientific research programme on mobile communications health issues.

j) Standard documentation for planning submissions

Develop standards supporting the documentation for all planning submissions whether for full planning or prior approval.

(**Source**: MOA, UK)

Annex-3

To be inserted: In pursuance of clause 6 i.e. "**Health information and communication",** relevant information, as per international "Best Practices", for safe use of mobile phones in different operating environments, may be included for the awareness of the consumers.

Appendix A

Illustrative Examples

Example A.1:

After time spatially averaged measurements, the electric fields to which an RF worker is exposed are found to be 30 V/m, 40 V/m and 50 V/m at 20 MHz, 90 MHz, 150 MHz, respectively. The relative value with respect to the exposure limits in the frequency bands of concern are given as follows:

- $R_1 = (30/61)^2 = 0.25$ for 20 MHz (in the frequency band 10-400 MHz)
- $R_2 = (40/61)^2 = 0.43$ for 90 MHz (in the frequency band 10-400MHz)
- $R_3 = (50/61)^2 = 0.67$ for 150 MHz)(in the frequency band 10-400 MHz)

From which $R_1 + R_2 + R_3 = 1.35$, which exceeds unity and therefore the combined filed strength does not conform with the Safe Limit.

Example A.2:

Assume that a worker is exposed to RF fields at three different frequencies. Exposure measurements were performed, which were time and spatially averaged, producing the following condition:

- 0.1 A/m at 27 MHz
- 70 V/m at 915 MHz
- 25 w/sqr. m at 10 000 MHz

The relative values with respect to the exposure limits in the frequency bands of concern are given as follows:

- $R_1 = (0.1/0.16)^2 = 0.39$ for 27 MHz (in the frequency band 10-40MHz)
- $R_2 = (70/90.75)^2 = 0.59$ for 915 MHz (in the frequency band 400-2000 MHz)
- $R_3 = (25/50) = 0.5$ for 10000 MHz (in the frequency band 2-300 GHz)

Form which $R_1 + R_2 + R_3 = 1.48$, which is more than unity and therefore the combined field strengths and power density does not conform with the Safe limit.

Appendix B

Basic criteria for determining the installation class

B.1 The classification of the installation is made on the basis of the ICNIRP limits whereas the criteria are based on a conservative estimate of the likely EMF exposure in the various situations.

B 2.1 Accessibility categories for normally compliant installations

These categories, which depend on the installation circumstances, assess the likelihood that a person can access the exceedance zone of the emitter. See Table B.1.

Table B.1/K.52 – Accessibility categories

Accessibility category	Relevant installation circumstances	Figure reference
1	Antenna is installed on an inaccessible tower – the centre of radiation is at a height *h* above ground level. There is a constraint $h > 3$ m. Antenna is installed on a publicly accessible structure (such as a rooftop) – the centre of radiation is at a height *h* above the structure.	Figure B.1
2	Antenna is installed at ground level – the centre of radiation is at a height *h* above ground level. There is an adjacent building or structure accessible to the general public and of approximately height *h* located a distance *d* from the antenna along the direction of propagation. There is a constraint $h > 3$ m.	Figure B.2
3	Antenna is installed at ground level – the centre of radiation is at a height *h* ($h > 3$ m) above ground level. There is an adjacent building or structure accessible to the general public and of approximately height *h'* located at a distance *d* from the antenna along the direction of propagation.	Figure B.3
4	Antenna is installed on a structure at a height *h* ($h > 3$ m). There is an exclusion area associated with the antenna. Two geometries for the exclusion area are defined: – A circular area with radius *a* surrounding the antenna; or – A rectangular area of size $a \times b$ in front of the antenna.	Figure B.4 Figure B.5

Figure B.1/K.52 – Illustration of the accessibility category 1

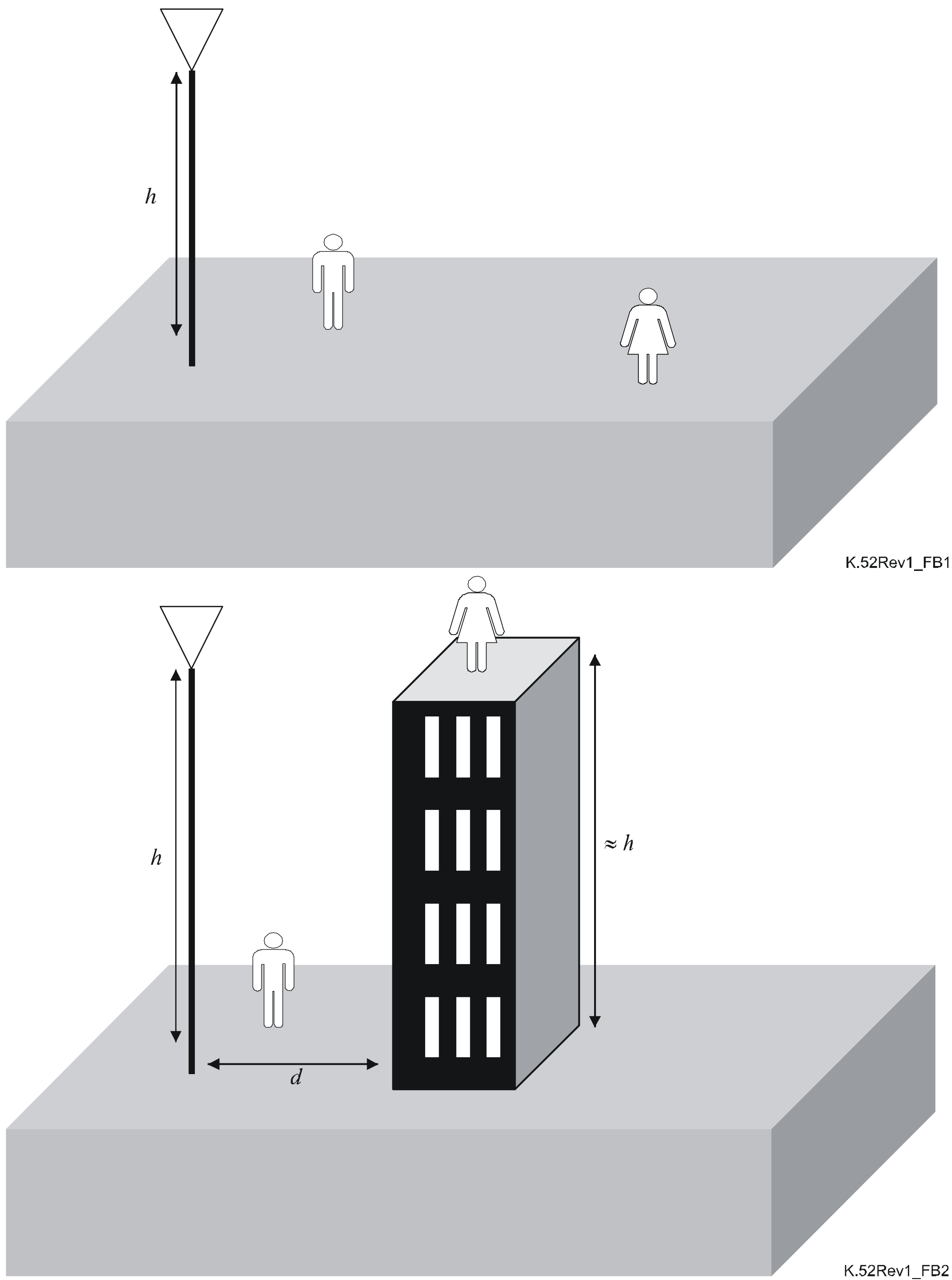


Figure B.2/K.52 – Illustration of the accessibility category 2

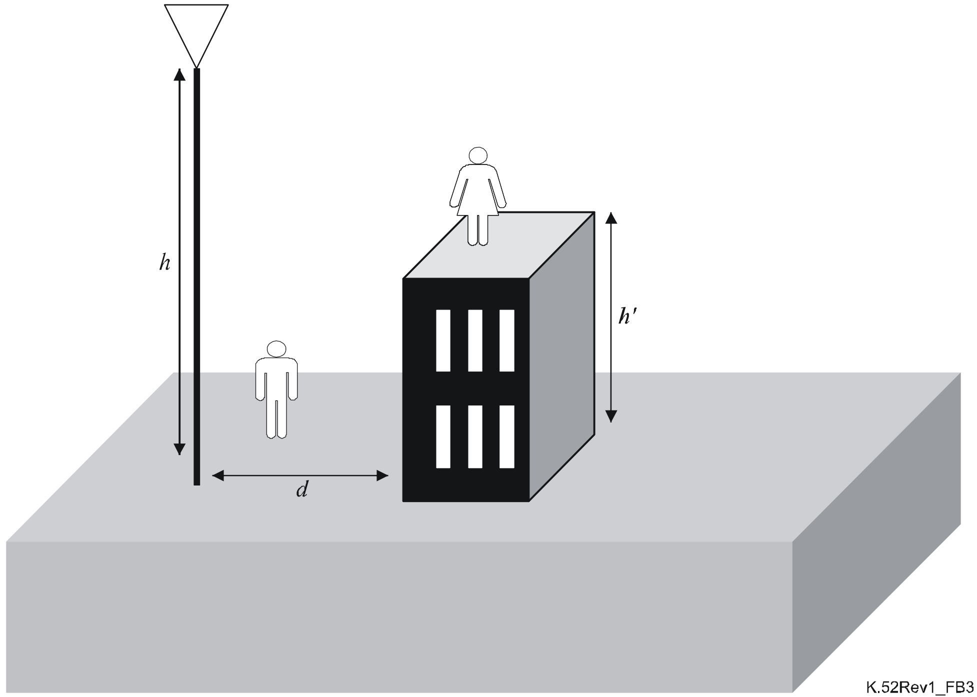


Figure B.3/K.52 – Illustration of the accessibility category 3

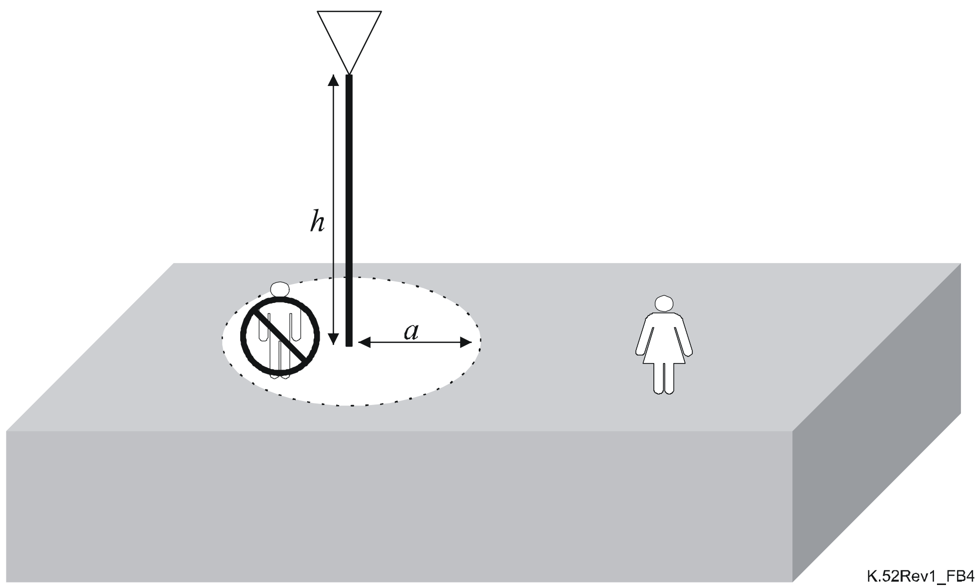


Figure B.4/K.52 – Illustration of the accessibility category 4, circular exclusion area

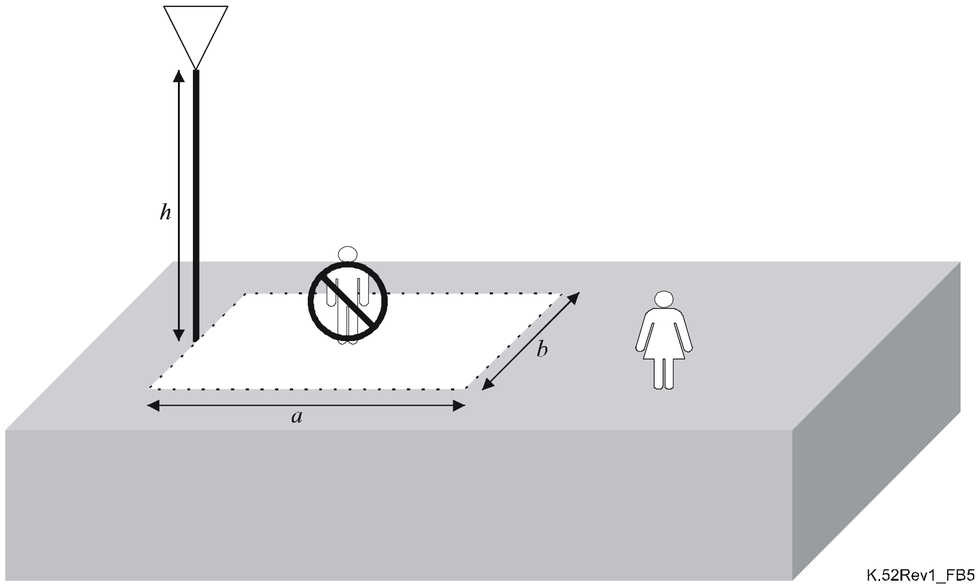


Figure B.5/K.52 – Illustration of the accessibility category 4, rectangular exclusion area

B.2.2 Frequency ranges

The carrier frequency determines the exposure limit for the radiated power density, $S_{lim}(f)$ as reported in the electromagnetic fields exposure standards.

B.2.3 Antenna directivity categories

Antenna directivity is important because it determines the pattern of potential exposure. High directivity means that most of the radiated power is concentrated in a narrow beam which may allow good control of the location of the exposure zones.

The antenna pattern is a major determinant and a frequently varying factor in determining the field. The most important parameter for determining the exposure due to elevated antennas is the vertical (elevation) antenna pattern. The horizontal (azimuth) pattern is not relevant because the exposure assessment assumes exposure along the direction of maximum radiation in the horizontal plane.

Note, however, that the vertical and horizontal patterns determine the antenna gain, and that horizontal pattern determines the exclusion area for accessibility category 4.

B.2.4 The exclusion area

This clause describes the exclusion areas for accessibility category 4. The exclusion area depends on the horizontal pattern of the antenna. The relevant parameter is the horizontal coverage of the antenna. Table B.3 presents the exclusion areas for a few typical values of the horizontal coverage of omnidirectional, sectional or narrow-beam antennas.

Table B.3/K.52 – Exclusion area as function of horizontal coverage

Horizontal coverage	Exclusion area
Omnidirectional	Circular area (Figure B.4)
120º	Rectangular area (Figure B.5) $b = 0.866a$
90º	Rectangular area (Figure B.5) $b = 0.707a$
60º	Rectangular area (Figure B.5) $b = 0.5a$
30º	Rectangular area (Figure B.5) $b = 0.259a$
Less than 5º	Rectangular area (Figure B.5) $b = 0.09a$