IEC 61786-2

Edition 1.0 2014-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

**Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings –
Part 2: Basic standard for measurements**

**Mesure de champs magnétiques continus et de champs magnétiques et électriques alternatifs dans la plage de fréquences de 1 Hz a 100 kHz dans leur rapport à l'exposition humaine –
Partie 2: Norme de base pour les mesures**

IEC 61786-2:2014-12(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX W

ICS 17.220.20
ISBN 978-2-8322-1970-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MEASUREMENT OF DC MAGNETIC, AC MAGNETIC AND AC ELECTRIC FIELDS FROM 1 Hz TO 100 kHz WITH REGARD TO EXPOSURE OF HUMAN BEINGS –

Part 2: Basic standard for measurements

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The text of this standard is based on the following documents:

FDIS	Report on voting
106/322/FDIS	106/326/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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MEASUREMENT OF DC MAGNETIC, AC MAGNETIC AND AC ELECTRIC FIELDS FROM 1 Hz TO 100 kHz WITH REGARD TO EXPOSURE OF HUMAN BEINGS –

Part 2: Basic standard for measurements

1 Scope

This part of IEC 61786 provides requirements for the measurement of quasi-static magnetic and electric fields that have a frequency content in the range 1 Hz to 100 kHz, and DC magnetic fields, to evaluate the exposure levels of the human body to these fields.

Specifically, this standard gives requirements for establishing measurement procedures that achieve defined goals pertaining to human exposure.

NOTE Requirements on field meters and calibration are described in IEC 61786-1

Because of differences in the characteristics of the fields from sources in the various environments, e.g. frequency content, temporal and spatial variations, polarization, and magnitude, and differences in the goals of the measurements, the specific measurement procedures will be different in the various environments.

Sources of fields include devices that operate at power frequencies and produce power frequency and power-frequency harmonic fields, as well as devices that produce fields independent of the power frequency, and DC power transmission, and the geomagnetic field. The magnitude ranges covered by this standard are 0,1 µT to 200 mT for AC (1 µT to 10 T for DC) for magnetic fields, and 1 V/m to 50 kV/m for electric fields.

When measurements outside this range are performed, most of the provisions of this standard will still apply, but special attention should be paid to the specified uncertainty and calibration procedures.

Examples of sources of fields that can be measured with this standard include:

– devices that operate at power frequencies (50/60 Hz) and produce power frequency and power-frequency harmonic fields (examples: power lines, electric appliances…)
– devices that produce fields that are independent of the power frequency. (Examples: electric railway (DC to 20 kHz), commercial aeroplanes (400 Hz), induction heaters (up to 100 kHz), and electric vehicles.)
– devices that produces static magnetic fields: MRI, DC power lines, DC welding, electrolysis, magnets, electric furnaces, etc. DC currents are often generated by converters, which also create AC components (power frequency harmonics), which should be assessed.

When EMF products standards are available, these products standards should be used.

With regard to electric field measurements, this standard considers only the measurement of the unperturbed electric field strength at a point in space (i.e. the electric field prior to the introduction of the field meter and operator) or on conducting surfaces.

Sources of uncertainty during measurements are also identified and guidance is provided on how they should be combined to determine total measurement uncertainty.

2 Normative references

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

IEC 61786-1:2013, *Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 1: Requirements for measuring instruments*

ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

NOTE Throughout this standard, the words "magnetic flux density" and "magnetic field" will be considered synonymous.

3.1
average exposure level
spatial average over the entire human body of fields to which the individual is exposed

3.2
correction factor
numerical factor by which the uncorrected result of a measurement is multiplied to compensate for a known error

Note 1 to entry: Since the known error cannot be determined perfectly, the compensation cannot be complete.

3.3
coverage factor
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: For a quantity z described by a normal distribution with expectation μ_z and standard deviation σ, the interval $\mu_z \pm k\sigma$ encompasses 68,27 %, 95,45 %, and 99,73 % of the distribution for a coverage factor k = 1, 2, and 3, respectively.

3.4
repeatability (of results of measurements)
closeness of agreement between the results of successive measurements of the same measurand, carried out under the same conditions of measurement, i.e.:

– by the same measurement procedure,
– by the same observer,
– with the same measuring instruments, used under the same conditions,
– in the same laboratory,
– at relatively short intervals of time.

[SOURCE: IEC 60050-311:2001, 311-06-06, modified –The note to entry has been deleted.]

3.5
reproducibility (of measurements)
closeness of agreement between the results of measurements of the same value of a quantity, when the individual measurements are made under different conditions of measurement:

- principle of measurement,
- method of measurement,
- observer,
- measuring instruments,
- reference standards,
- laboratory,
- under conditions of use of the instruments, different from those customarily used,
- after intervals of time relatively long compared with the duration of a single measurement

[SOURCE: IEC 60050-311:2001, 311-06-07, modified –The notes to entry have been deleted.]

3.6
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

3.7
uncertainty of measurement
parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: Uncertainty of measurement generally comprises many components. Some of these components may be estimated on the basis of the statistical distribution of the results of series of measurements, and can be characterised by experimental standard deviations. Estimates of other components can be based on experience or other information.

4 General considerations

4.1 Different goals of measurement

4.1.1 General

Magnetic and electric fields can be characterised according to a number of parameters, i.e. magnitude, frequency, polarization, etc. (see IEC 61786-1:2013, Annex C). Characterisation of one or more of these parameters and how they might relate to human exposure may serve as possible goals of a measurement programme. As an aid for readers interested in developing a field measurement protocol, this subclause provides a list of such possible measurement goals and possible methods for their accomplishment.

Except in the vicinity of high voltage sources, there is no need to measure the power frequency electric field, because the electric field will be, at most, a few tens of volts per metre [3; 22][1].

Annex A gives examples of typical field characteristics in different environments.

The goals of a measurement programme, such as those considered below, shall be clearly defined. A clear definition of goals is required for the determination of instrumentation and calibration requirements, e.g. instrumentation pass-band, magnitude range, frequency calibration points, etc. Once the goals have been identified and appropriate instrumentation has been acquired, a pilot study in the measurement environment of interest may be desirable

1 Numbers in square brackets refer to the Bibliography.

before decisions are made as to the final measurement methods and associated protocol. The protocol will describe the step-by-step procedure to follow, using the possible methods indicated, to accomplish the measurement goals. The protocol may explicitly indicate such things as instrument requirements (e.g. pass-band, probe size, magnitude range), location of measurements and duration of measurements. It should then be possible, using the same protocol, to compare with confidence measurement results obtained in similar electrical environments.

Possible measurement goals and possible methods for their accomplishment are given in 4.1.2 to 4.1.6.

4.1.2 Characterisation of field levels for compliance with safety standards

Limits on permissible electric or magnetic field levels expressed as resultant values and as a function of frequency have been indicated in a number of documents, such as [17-19; 21] necessitating the determination of field levels with the maximum value or spatial value in specified areas. The choice of measurement location shall be done in consideration of the possible location of people.

Method: Three-axis meters shall be used to make such measurements of the resultant magnetic and electric fields. Standards and guidance exist for such measurements near power lines [4; 9; 15] and electric appliances [10] .

Measurements of magnetic fields near power lines should be correlated with load currents. Load currents for appliances are either constant or, typically, periodic through a fixed range in a relatively short time, enabling the determination of the largest resultant magnetic field with relatively few measurements.

4.1.3 Characterisation of spatial variations

Magnetic and electric fields are not constant around sources. For example, variations of magnetic or electric fields below power lines are typical (Figures 1 and 2) and can be calculated.

In Figure 1, non-uniformity is defined by [4; 9] as the maximum value of

$$\left(\left|B_{\mathrm{h}} - B_{\mathrm{avg}}\right|\right) / B_{\mathrm{avg}} \times 100\ (\%)$$

Where

B_{h} is the magnetic field level at heights of 0,5 m, 1,0 m and 1,5 m above ground;

B_{avg} is the arithmetic mean of the three levels.

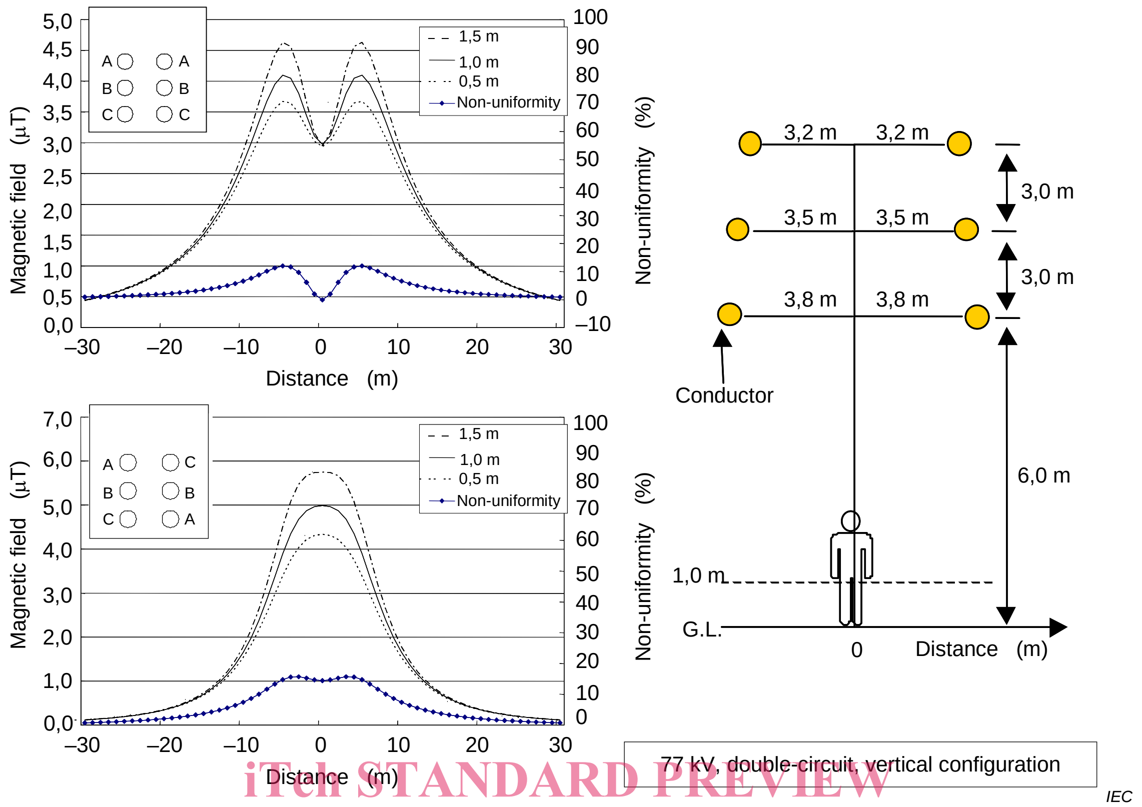


Figure 1 – Magnetic field levels under a 77 kV overhead transmission line (from [9])

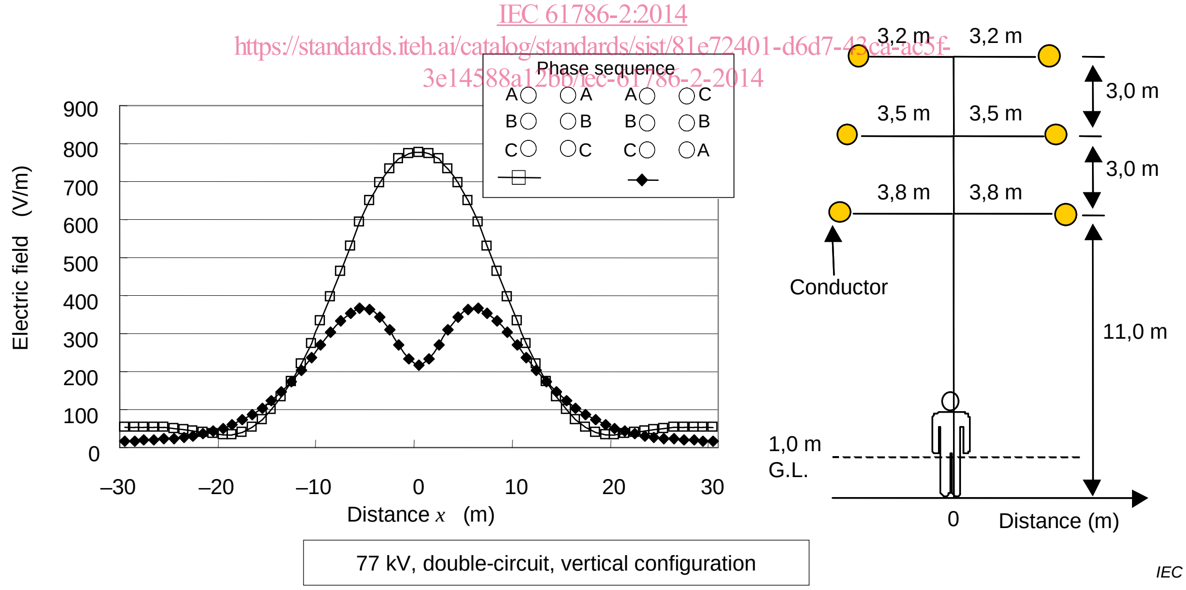


Figure 2 – Electric field levels under an overhead transmission line (from [9])

The spatial distribution of magnetic fields away from power lines or single identifiable sources is typically unknown.

Alternating magnetic fields in most environments will be non-uniform because of the spatial dependence of the fields from the source currents. It is noteworthy that static magnetic fields also show considerable spatial variability in residences [29].

Method: The magnetic field components shall be recorded as a function of coordinate position when characterising spatial variation. Standards exist for carrying out such measurements near power lines [4; 9; 15] and electric appliances [[9]]. While such measurements can be made with survey meters, instrumentation incorporating "measurement wheels" is available for characterising spatial distributions of magnetic fields in environments where physical obstructions do not hinder the movement of the wheel. As the wheel rotates, it periodically triggers a three-axis magnetic field meter to record the resultant magnetic field. Software provided with such instrumentation permits the generation of plots of magnetic field profiles, equifield contours, statistical analyses of the field levels, etc [2; 26]. As for characterisation of field levels for compliance with safety limits, such data will not take the temporal variations of the field profiles into account without repeated measurements.

4.1.4 Characterisation of temporal variation

Because magnetic fields are produced by load currents and ground return currents that can vary greatly with time, the temporal variations of magnetic fields can easily exceed a factor of 2.

Under a power line, the magnetic field depends on the load of the line. For single circuit lines or double circuit lines operated in parallel, the magnetic field is directly proportional to the load of the line. Figure 3 gives an example of the load of a 735 kV line and the outdoor temperature. In this case, the load is influenced by human activities (daily cycle) and by outdoor temperature (season cycle) and by the place of the line in the network. Moreover, the magnetic field level can vary with the sagging of the conductors because of heating due to large current loads and environmental conditions [16] .

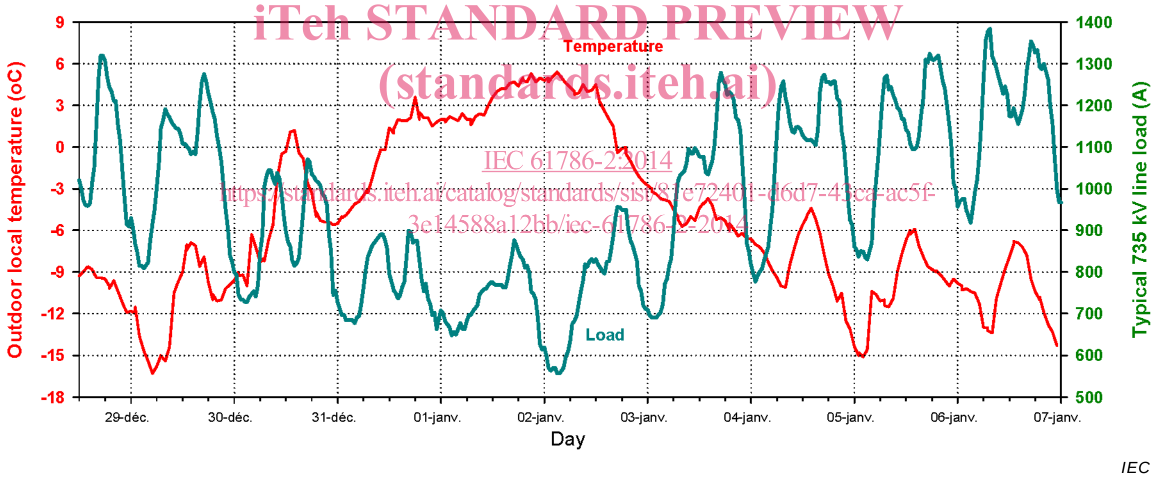
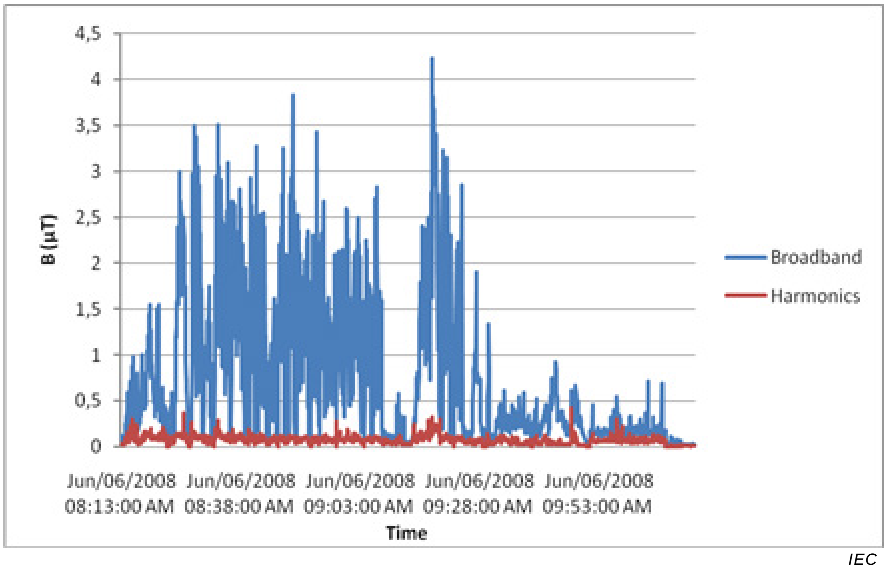


Figure 3 – Example of load variation of 735kV line due to the human activities (daily) and outdoor temperature (seasonal)

Method: Three-axis and single-axis magnetic field meters are available with output connections that can be used in combination with commercially available data loggers to record the variation of magnetic field levels at one or more locations, as a function of time. Three-axis exposure meters and magnetic field waveform capturing instrumentation can also be used to periodically record field levels. Because of the dependence of magnetic field levels on load currents, which can vary daily, weekly, seasonally (Figure 3), etc., the challenge is to determine a time interval for recording measurements that will capture enough variations of the field to obtain a valid statistical description. Conducting an initial pilot study in the measurement environment of interest can be useful for addressing the question of measurement sampling time.

Finding the temporal maximum of the magnetic field by measurement is not easy. For some simple situations, such as under single circuit power lines, this may be estimated by recording the current during the magnetic field measurement and extrapolation to the maximum load.

An additional consideration should be taken into account when measurements are performed in electric mass transportation systems or other areas where there are variable speed motors. For example, in trains, the magnetic field can be a function of the speed of the train (see Figure 4).



NOTE Broadband = 40 Hz – 800 Hz, harmonics = 100 Hz – 800 Hz.

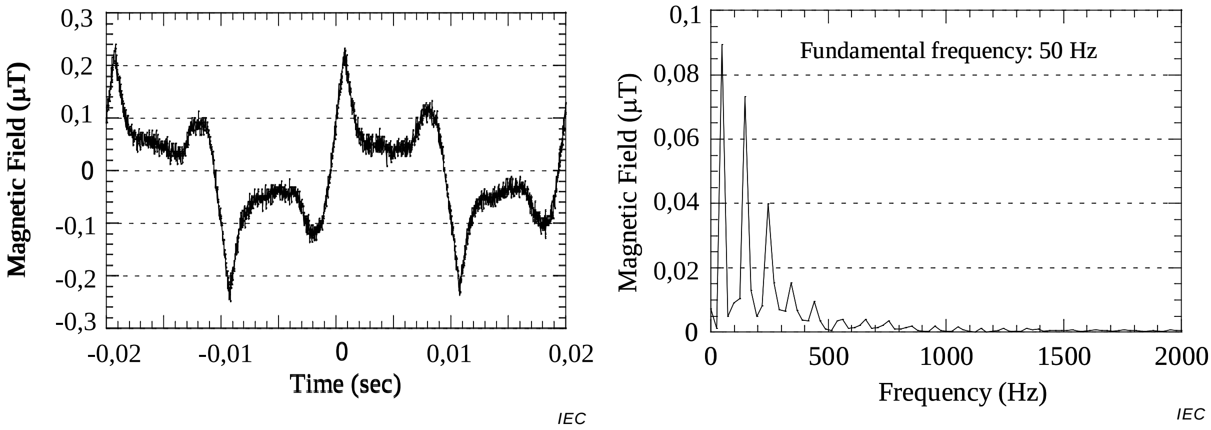
Figure 4 – 50 Hz magnetic field in a high speed train in France

For the electric fields, unlike spot measurements of magnetic fields from power lines, the measured values will not change greatly because the voltages remain nearly constant. However, the electric field level can vary with the sagging of the conductors because of heating due to large current loads [16] .

4.1.5 Characterisation of frequency content in magnetic field or electric field

Since (1) electric and magnetic fields from electrical equipment often contain power-frequency harmonics or frequencies unrelated to the power frequency, and (2) electric and magnetic field limits have been set as a function of frequency [17-19; 21], characterisation of the frequency content can be an important goal.

An example of a magnetic field that is rich in harmonics and that is produced by a common electrical appliance is shown in Figure 5. Figure 5a shows a waveform of the horizontal component of the magnetic field 10 cm away from the surface of the front-centre of an operating 66,04 cm (26 inches) flat-screen LCD television. The harmonic components in the field are indicated in Figure 5b, which shows a frequency spectrum for the waveform in Figure 5a. It is shown that the fundamental frequency is 50 Hz and significant levels of 3rd and 5th harmonics are included.



(a) (b)

Figure 5 – Waveform (a) and frequency spectrum (b) of magnetic field generated by a 66,04 cm (26 inches) flat-screen LCD television

Method: Commercially available single-axis and three-axis magnetic field meters are sometimes provided with output connections that give an output voltage proportional to the magnetic field strength.

Such instrumentation, in combination with commercially available spectrum analysers, can be used to characterise the frequency components in the magnetic field. Alternatively, wave-capturing instrumentation has software that enables the determination of the frequency content from the recorded data. Magnetic field meters which can be switched to indicate rms field values of the power frequency and one or more harmonic frequencies are also available. More modern electric and magnetic field meters include a spectrum analyser.

It should be noted that the frequency content of magnetic fields produced by variable speed electrical equipment, e.g. electric mass transportation systems, can change as a function of speed [5].

The electric field of AC power systems has low total harmonic distortion.Therefore the harmonics of power frequency electric field are negligible [9].

4.1.6 Characterisation of population exposure to magnetic field and definition of metric

A number of epidemiological studies on occupational or residential exposure, that have examined the possibility of health effects from exposure to power frequency magnetic fields, have been conducted. From the magnetic field measurements, different statistic indicators can be defined.

Method: A more precise assessment of exposure is determined by wearing a small three-axis exposure meter that periodically records the field at a location of interest on the body.

Estimates of human exposure shall be made from a combination of spatial and temporal variation measurements and information which describes patterns of human activity [31].

Commercially available three-axis exposure meters that can be worn on the body can be used. Such instrumentation periodically records the resultant magnetic field value for periods of time extending to several days, depending on the frequency of sampling of the magnetic field, memory storage capacity and battery life. The sampling rate will depend in part on the model assumed for the interaction between the field and subject. The data collected can be downloaded to a computer, and software provided with the instrumentation or specially developed, is used to determine exposure to the parameters such as TWA (time weighted average), geometric mean, and several percentile values.