4 MEASUREMENT OF STATIC ELECTRIC AND MAGNETIC FIELDS

Measurements of static electric and magnetic fields are used to characterize emissions from sources and exposure of persons or experimental subjects. Early epidemiological and laboratory studies used simple survey instruments that displayed the maximum static electric or magnetic field measured along a single axis. Most fields that are encountered will have a linear polarization vector whose direction is unknown. This requires the measurement of three orthogonal components of the electric or magnetic field, at each location of interest. This can be done with either a single sensor or with a multiple sensor instrument. If a single sensor is used, then each of the three orthogonal components must be measured sequentially. The preferred method is the use of an instrument with three mutually orthogonal sensors housed in a common, small volume. This allows the simultaneous measurement of each component of a field. Irrespective of whether a single or three sensor instrument is used, the total field vector must be obtained by squaring the magnitude of each field component, summing the three squared values, and then taking the square root of the sum as indicated in Eq. 4.1 for magnetic flux density.

$$B_{total} = \sqrt{B_x^2 + B_y^2 + B_z^2} \tag{4.1}$$

where:

B_{total} is the magnitude of the magnetic flux density
B_x, B_y, B_z are the magnitudes of the components of the magnetic flux density along the axes in a rectangular coordinate system.

It is not necessary to measure each of the components of the field if its polarization is linear and the orientation of the field vector is known. For example, the electric field orientation is known near the boundary of a conducting object, such as the ground (if it is highly conductive). The electric field vector here must be perpendicular to the conducting object. Therefore, only a vertical component of the electric field need be measured near a highly conducting surface (ICNIRP, 2003).

4.1 Electric fields

Static electric-field-strength sensors that are commercially available include the electric field mill, the vibrating plate, and the vibrating probe sensors. All are used to measure static fields with respect to a reference object (usually electrical ground). All of these instruments interrupt or ‘chop’ the static voltage detected by the sensor. This provides a time-varying (AC) voltage that is easier to process and calibrate than a static (DC) voltage. The field strengths that are measured by field mill, vibrating plate, and vibrating probe sensors involve the quantification of the AC current across known, high impedance between the sensing electrode and the ground (ICNIRP, 2003).

The electric field mill can determine the static electric field strength by measuring modulated, capacitively induced charges sensed by metal electrodes. The time-varying charge and the current are proportional to the electric field strength (*E*). Sensitivity of the electric field mill is on the order of a few hundred V m^{-1}, with a maximum measurement capability of up to 100 kV m^{-1} or more.

The vibrating plate sensor consists of a faceplate with an aperture and a central vibrating plate or probe. The faceplate is placed parallel to, and in contact with, the ground plane. A mechanical driver moves the vibrating plate or probe up and down in the direction normal to the faceplate. The position of the vibrating electrode oscillates from one extreme position that is flush with the faceplate aperture to the other extreme position where it is separated a fixed distance below the ground plane (usually, the ground plane is the earth beneath a HVDC power line). Sensitivity of the vibrating plate sensor is on the order of a few hundred V m^{-1}.

During the measurement procedure, other objects and persons operating the equipment must be removed from any area that will perturb the field at the location of the measurement instrument. E-field meters that operate in contact with the ground plane need only measure the vector component that exists close to ground (the component that is perpendicular to the ground plane). Fields mills and vibrating plate/probe sensors are intended to be placed on a ‘ground plane’, but can be elevated above the physical source of the earth if electrical connection to the earth is provided by a grounding wire (ICNIRP, 2003).

4.2 Magnetic fields

Magnetic flux densities that are of interest range from approximately 20 μT (the Earth's magnetic flux) to more than 20 T (high field NMR and MRI devices). The instrument for measuring the magnitude and direction of a magnetic field is called a magnetometer. Two types of magnetometers (Fluxgate and Hall effect) are practical for the measurement of static magnetic fields. Both are capable of determining a single vector component of the magnetic field. The Fluxgate magnetometer is a sensitive device based on the magnetic saturation effect in ferromagnetic materials. It is constructed of two parallel cores of a ferromagnetic material placed closely together. It measures an alternating current that is induced in a secondary coil wrapped around the cores. The secondary coil signal is proportional to the strength of any external magnetic field that is aligned in the proper orientation with respect to the cores. Current (AC) is passed through coils that are wrapped separately around each core. AC voltage Fluxgate magnetometers are capable of measuring the strength of the magnetic field from 1.0 nT to 0.01 T. They can be used in a mode that subtracts the constant value of the Earth's static field so that other static fields weaker that this field can be measured.

Hall effect devices consist of a thin square or rectangular plate or film of gallium arsenide and indium arsenide to which four electrical contacts are made. An electrical current is passed through the length of the semiconductor and the voltage across the width of the semiconductor is measured. The Hall voltage, V_h, is directly proportional to the number of flux lines passing through the foil, the cosine of the angle at which they pass through it (i.e. they are polarization dependent), and the amount of current passing through the device. Hall effect instruments can measure flux density from 100 μT to up to 100 T.