Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC

ANNEX I

PHYSICAL QUANTITIES REGARDING THE EXPOSURE TO ELECTROMAGNETIC FIELDS

The following physical quantities are used to describe the exposure to electromagnetic fields:

Electric field strength (E) is a vector quantity that corresponds to the force exerted on a charged particle regardless of its motion in space. It is expressed in volt per metre (Vm^{-1}). A distinction has to be made between the environmental electric field and the electric field present in the body (in situ) as a result of exposure to the environmental electric field.

Limb current (I_L) is the current in the limbs of a person exposed to electromagnetic fields in the frequency range from 10 MHz to 110 MHz as a result of contact with an object in an electromagnetic field or the flow of capacitive currents induced in the exposed body. It is expressed in ampere (A).

Contact current (I_C) is a current that appears when a person comes into contact with an object in an electromagnetic field. It is expressed in ampere (A). A steady state contact current occurs when a person is in continuous contact with an object in an electromagnetic field. In the process of making such contact, a spark discharge may occur with associated transient currents.

Electric charge (Q) is an appropriate quantity used for spark discharge and is expressed in coulomb (C).

Magnetic field strength (H) is a vector quantity that, together with the magnetic flux density, specifies a magnetic field at any point in space. It is expressed in ampere per metre (Am^{-1}).

Magnetic flux density (B) is a vector quantity resulting in a force that acts on moving charges, expressed in tesla (T). In free space and in biological materials, magnetic flux density and magnetic field strength can be interchanged using the magnetic field strength of H = 1 Am^{-1} equivalence to magnetic flux density of

$$B = 4\pi\ 10^{-7}$$

T (approximately 1,25 microtesla).

Power density (S) is an appropriate quantity used for very high frequencies, where the depth of penetration in the body is low. It is the radiant power incident perpendicular to a surface, divided by the area of the surface. It is expressed in watt per square metre (Wm^{-2}).

Specific energy absorption (SA) is an energy absorbed per unit mass of biological tissue, expressed in joule per kilogram (Jkg^{-1}). In this Directive, it is used for establishing limits for effects from pulsed microwave radiation.

Specific energy absorption rate (SAR), averaged over the whole body or over parts of the body, is the rate at which energy is absorbed per unit mass of body tissue and is expressed in watt per kilogram (Wkg^{-1}). Whole-body SAR is a widely accepted quantity for relating adverse thermal effects to radio frequency (RF) exposure. Besides the whole-body average SAR, local SAR values are necessary to evaluate and limit excessive energy deposition in small parts of the body resulting from special exposure conditions. Examples of such conditions include: an individual exposed to RF in the low MHz range (e.g. from dielectric heaters) and individuals exposed in the near field of an antenna.

Of these quantities, magnetic flux density (B), contact current (I_C), limb current (I_L), electric field strength (E), magnetic field strength (H), and power density (S) can be measured directly.

ANNEX II

NON-THERMAL EFFECTSEXPOSURE LIMIT VALUES AND ACTION LEVELS IN THE FREQUENCY RANGE FROM 0 Hz TO 10 MHz

A. EXPOSURE LIMIT VALUES (ELVs)

ELVs below 1 Hz (Table A1) are limits for static magnetic field which is not affected by the tissue of the body.

ELVs for frequencies from 1 Hz to 10 MHz (Table A2) are limits for electric fields induced in the body from exposure to time-varying electric and magnetic fields.

ELVs for external magnetic flux density from 0 to 1 Hz

The sensory effects ELV is the ELV for normal working conditions (Table A1) and is related to vertigo and other physiological effects related to disturbance of the human balance organ resulting mainly from moving in a static magnetic field

The health effects ELV for controlled working conditions (Table A1) is applicable on a temporary basis during the shift when justified by the practice or process, provided that preventive measures, such as controlling movements and providing information to workers, have been adopted.

TABLE A1

ELVs for external magnetic flux density (B_0) from 0 to 1 Hz

	Sensory effects ELVs
Normal working conditions	2 T
Localised limbs exposure	8 T
	Health effects ELVs
Controlled working conditions	8 T

Health effects ELVs for internal electric field strength from 1 Hz to 10 MHz

Health effects ELVs (Table A2) are related to electric stimulation of all peripheral and central nervous system tissues in the body, including the head.

TABLE A2

Health effects ELVs for internal electric field strength from 1 Hz to 10 MHz

Frequency range	**Health effects ELVs**
$1\ \text{Hz} \leq f < 3\ \text{kHz}$	$1{,}1\ \text{Vm}^{-1}$ (peak)
$3\ \text{kHz} \leq f \leq 10\ \text{MHz}$	$3{,}8 \times 10^{-4}\ f\ \text{Vm}^{-1}$ (peak)

Note A2-1: f is the frequency expressed in hertz (Hz).

Note A2-2: The health effects ELVs for internal electric field are spatial peak values in the entire body of the exposed subject.

Note A2-3: The ELVs are peak values in time which are equal to the Root-Mean-Square (RMS) values multiplied by √2 for sinusoidal fields. In the case of non-sinusoidal fields, exposure evaluation carried out in accordance with Article 4 shall be based on the weighted peak method (filtering in time domain), explained in the practical guides referred to in Article 14 but other scientifically proven and validated exposure evaluation procedures can be applied, provided that they lead to approximately equivalent and comparable results.

Sensory effects ELVs for internal electric field strength from 1 Hz to 400 Hz

The sensory effects ELVs (Table A3) are related to electric field effects on the central nervous system in the head, i.e. retinal phosphenes and minor transient changes in some brain functions.

TABLE A3

Sensory effects ELVs for internal electric field strength from 1 to 400 Hz

Frequency range	Sensory effects ELVs
$1 \leq f < 10$ Hz	$0{,}7/f$ Vm^{-1} (peak)
$10 \leq f < 25$ Hz	$0{,}07$ Vm^{-1} (peak)
$25 \leq f \leq 400$ Hz	$0{,}0028\ f$ Vm^{-1} (peak)

Note A3-1: f is the frequency expressed in hertz (Hz).

Note A3-2: The sensory effects ELVs for internal electric field are spatial peak values in the head of the exposed subject.

Note A3-3: The ELVs are peak values in time which are equal to the Root-Mean-Square (RMS) values multiplied by √2 for sinusoidal fields. In the case of non-sinusoidal fields, the exposure evaluation carried out in accordance with Article 4 shall be based on the weighted peak method (filtering in time domain), explained in the practical guides referred to in Article 14, but other scientifically proven and validated exposure evaluation procedures can be applied, provided that they lead to approximately equivalent and comparable results.

B. ACTION LEVELS (ALs)

The following physical quantities and values are used to specify the action levels (ALs), the magnitude of which are established to ensure by simplified assessment the compliance with relevant ELVs or at which relevant protection or prevention measures specified in Article 5 must be taken:

— Low ALs(E) and high ALs(E) for electric field strength E of time varying electric fields as specified in Table B1;

— Low ALs(B) and high ALs(B) for magnetic flux density B of time varying magnetic fields as specified in Table B2;

— ALs(I_C) for contact current as specified in Table B3;

— ALs(B_0) for magnetic flux density of static magnetic fields as specified in Table B4.

ALs correspond to calculated or measured electric and magnetic field values at the workplace in the absence of the worker.

Action levels (ALs) for exposure to electric fields

Low ALs (Table B1) for external electric field are based on limiting the internal electric field below the ELVs (Tables A2 and A3) and limiting spark discharges in the working environment.

Below high ALs, the internal electric field does not exceed the ELVs (Tables A2 and A3) and annoying spark discharges are prevented, provided that the protection measures referred to in Article 5(6) are taken.

TABLE B1

ALs for exposure to electric fields from 1 Hz to 10 MHz

Frequency range	**Electric field strength Low ALs (E)[Vm^{-1}] (RMS)**	**Electric field strength High ALs (E) [Vm^{-1}] (RMS)**
$1 \leq f < 25$ Hz	$2{,}0 \times 10^4$	$2{,}0 \times 10^4$
$25 \leq f < 50$ Hz	$5{,}0 \times 10^5/f$	$2{,}0 \times 10^4$
50 Hz $\leq f <$ 1,64 kHz	$5{,}0 \times 10^5/f$	$1{,}0 \times 10^6/f$
$1{,}64 \leq f <$ 3 kHz	$5{,}0 \times 10^5/f$	$6{,}1 \times 10^2$
3 kHz $\leq f \leq$ 10 MHz	$1{,}7 \times 10^2$	$6{,}1 \times 10^2$

Note B1-1: f is the frequency expressed in hertz (Hz).

Note B1-2: The low ALs (E) and high ALs (E) are the Root-Mean-Square (RMS) values of the electric field strength which are equal to the peak values divided by √2 for sinusoidal fields. In the case of non-sinusoidal fields, the exposure evaluation carried out in accordance with Article 4 shall be based on the weighted peak method (filtering in time domain), explained in the practical guides referred to in Article 14, but other scientifically proven and validated exposure evaluation procedures can be applied, provided that they lead to approximately equivalent and comparable results.

Note B1-3: ALs represent maximum calculated or measured values at the workers' body position. This results in a conservative exposure assessment and automatic compliance with ELVs in all non-uniform exposure conditions. In order to simplify the assessment of compliance with ELVs, carried out in accordance with Article 4, in specific non-uniform conditions, criteria for the spatial averaging of measured fields based on established dosimetry will be laid down in the practical guides referred to in Article 14. In the case of a very localised source within a distance of a few centimetres from the body, the induced electric field shall be determined dosimetrically, case by case.

Action levels (ALs) for exposure to magnetic fields

Low ALs (Table B2) are, for frequencies below 400 Hz, derived from the sensory effects ELVs (Table A3) and, for frequencies above 400 Hz, from the health effects ELVs for internal electric field (Table A2).

High ALs (Table B2) are derived from the health effects ELVs for internal electric field related to electric stimulation of peripheral and autonomous nerve tissues in head and trunk (Table A2). Compliance with the high ALs ensures that health effects ELVs are not exceeded, but the effects related to retinal phosphenes and minor transient changes in brain activity are possible, if the exposure of the head exceeds the low ALs for exposures up to 400 Hz. In such a case, Article 5(6) applies.

ALs for exposure of limbs are derived from the health effects ELVs for internal electric field related to electric stimulation of the tissues in limbs by taking into account that the magnetic field is coupled more weakly to the limbs than to the whole body.

TABLE B2

ALs for exposure to magnetic fields from 1 Hz to 10 MHz

Frequency range	Magnetic flux density Low ALs(B)[μT] (RMS)	Magnetic flux density High ALs(B) [μT] (RMS)	Magnetic flux density ALs for exposure of limbs to a localised magnetic field [μT] (RMS)
$1 \leq f < 8$ Hz	$2{,}0 \times 10^5/f^2$	$3{,}0 \times 10^5/f$	$9{,}0 \times 10^5/f$
$8 \leq f < 25$ Hz	$2{,}5 \times 10^4/f$	$3{,}0 \times 10^5/f$	$9{,}0 \times 10^5/f$
$25 \leq f < 300$ Hz	$1{,}0 \times 10^3$	$3{,}0 \times 10^5/f$	$9{,}0 \times 10^5/f$
300 Hz $\leq f < 3$ kHz	$3{,}0 \times 10^5/f$	$3{,}0 \times 10^5/f$	$9{,}0 \times 10^5/f$
3 kHz $\leq f \leq 10$ MHz	$1{,}0 \times 10^2$	$1{,}0 \times 10^2$	$3{,}0 \times 10^2$

Note B2-1: f is the frequency expressed in hertz (Hz).

Note B2-2: The low ALs and the high ALs are the Root-Mean-Square (RMS) values which are equal to the peak values divided by √2 for sinusoidal fields. In the case of non-sinusoidal fields the exposure evaluation carried out in accordance with Article 4 shall be based on the weighted peak method (filtering in time domain), explained in practical guides referred to in Article 14, but other scientifically proven and validated exposure evaluation procedures can be applied, provided that they lead to approximately equivalent and comparable results.

Note B2-3: ALs for exposure to magnetic fields represent maximum values at the workers' body position. This results in a conservative exposure assessment and automatic compliance with ELVs in all non-uniform exposure conditions. In order to simplify the assessment of compliance with ELVs, carried out in accordance with Article 4, in specific non-uniform conditions, criteria for the spatial averaging of measured fields based on established dosimetry will be laid down in the practical guides referred to in Article 14. In the case of a very localised source within a distance of a few centimetres from the body, the induced electric field shall be determined dosimetrically, case by case.

TABLE B3

ALs for contact current I_C

Frequency	ALs (I_C) steady state contact current [mA] (RMS)
up to 2,5 kHz	1,0
$2{,}5 \leq f < 100$ kHz	0,4 f
$100 \leq f \leq 10\,000$ kHz	40

Note B3-1: f is the frequency expressed in kilohertz (kHz).

Action levels (ALs) for magnetic flux density of static magnetic fields

TABLE B4

ALs for magnetic flux density of static magnetic fields

Hazards	**ALs(B_0)**
Interference with active implanted devices, e.g. cardiac pacemakers	0,5 mT
Attraction and projectile risk in the fringe field of high field strength sources (> 100 mT)	3 mT

ANNEX III

THERMAL EFFECTSEXPOSURE LIMIT VALUES AND ACTION LEVELS IN THE FREQUENCY RANGE FROM 100 kHz TO 300 GHz

A. EXPOSURE LIMIT VALUES (ELVs)

Health effects ELVs for frequencies from 100 kHz to 6 GHz (Table A1) are limits for energy and power absorbed per unit mass of body tissue generated from exposure to electric and magnetic fields.

Sensory effects ELVs for frequencies from 0,3 to 6 GHz (Table A2) are limits on absorbed energy in a small mass of tissue in the head from exposure to electromagnetic fields.

Health effects ELVs for frequencies above 6 GHz (Table A3) are limits for power density of an electromagnetic wave incident on the body surface.

TABLE A1

Health effects ELVs for exposure to electromagnetic fields from 100 kHz to 6 GHz

Health effects ELVs	**SAR values averaged over any six-minute period**
ELVs related to whole body heat stress expressed as averaged SAR in the body	0,4 Wkg^{-1}
ELVs related to localised heat stress in head and trunk expressed as localised SAR in the body	10 Wkg^{-1}
ELVs related to localised heat stress in the limbs expressed as localised SAR in the limbs	20 Wkg^{-1}

Note A1-1: Localised SAR averaging mass is any 10 g of contiguous tissue; the maximum SAR so obtained should be the value used for estimating exposure. This 10 g of tissue is intended to be a mass of contiguous tissue with roughly homogeneous electrical

properties. In specifying a contiguous mass of tissue, it is recognised that this concept may be used in computational dosimetry but may present difficulties for direct physical measurements. A simple geometry, such as cubic or spheric tissue mass, can be used.

Sensory effects ELVs from 0,3 GHz to 6 GHz

This sensory effects ELVs (Table A2) is related to avoiding auditory effects caused by exposures of the head to pulsed microwave radiation.

TABLE A2

Sensory effects ELVs for exposure to electromagnetic fields from 0,3 to 6 GHz

Frequency range	Localised specific energy absorption (SA)
$0,3 \leq f \leq 6$ GHz	10 $mJkg^{-1}$

Note A2-1: Localised SA averaging mass is 10 g of tissue.

TABLE A3

Health effects ELVs for exposure to electromagnetic fields from 6 to 300 GHz

Frequency range	Health effects ELVs related to power density
$6 \leq f \leq 300$ GHz	50 Wm^{-2}

Note A3-1: The power density shall be averaged over any 20 cm^2 of exposed area. Spatial maximum power densities averaged over 1 cm^2 should not exceed 20 times the value of 50 Wm^{-2}. Power densities from 6 to 10 GHz are to be averaged over any six-minute period. Above 10 GHz, the power density shall be averaged over any $68/f^{1,05}$-minute period (where f is the frequency in GHz) to compensate for progressively shorter penetration depth, as the frequency increases.

B. ACTION LEVELS (ALs)

The following physical quantities and values are used to specify the action levels (ALs), the magnitude of which are established to ensure by simplified assessment the compliance with the relevant ELVs or at which relevant protection or prevention measures specified in Article 5 must be taken:

— ALs(E) for electric field strength E of time varying electric field, as specified in Table B1;

— ALs(B) for magnetic flux density B of time varying magnetic field, as specified in Table B1;

— ALs(S) for power density of electromagnetic waves, as specified in Table B1;

— ALs(I_C) for contact current, as specified in Table B2;

— ALs(I_L) for limb current, as specified in Table B2;

ALs correspond to calculated or measured field values at the workplace in the absence of the worker, as maximum value at the position of the body or specified part of the body.

Action levels (ALs) for exposure to electric and magnetic fields

ALs(E) and ALs(B) are derived from the SAR or power density ELVs (Tables A1 and A3) based on the thresholds related to internal thermal effects caused by exposure to (external) electric and magnetic fields.

TABLE B1

ALs for exposure to electric and magnetic fields from 100 kHz to 300 GHz

Frequency range	Electric field strength ALs(E) [Vm^{-1}] (RMS)	Magnetic flux density ALs(B) [μT] (RMS)	Power density ALs(S) [Wm^{-2}]
100 kHz ≤ f < 1 MHz	$6{,}1 \times 10^2$	$2{,}0 \times 10^6/f$	—
1≤ f < 10 MHz	$6{,}1 \times 10^8/f$	$2{,}0 \times 10^6/f$	—
10 ≤ f < 400 MHz	61	0,2	—
400 MHz ≤ f < 2 GHz	$3 \times 10^{-3}\ f^{½}$	$1{,}0 \times 10^{-5}\ f^{½}$	—
2 ≤ f < 6 GHz	$1{,}4 \times 10^2$	$4{,}5 \times 10^{-1}$	—
6 ≤ f ≤ 300 GHz	$1{,}4 \times 10^2$	$4{,}5 \times 10^{-1}$	50

Note B1-1: f is the frequency expressed in hertz (Hz).

Note B1-2: $[ALs(E)]^2$ and $[ALs(B)]^2$ are to be averaged over a six-minute period. For RF pulses, the peak power density averaged over the pulse width shall not exceed 1 000 times the respective ALs(S) value. For multi-frequency fields, the analysis shall be based on summation, as explained in the practical guides referred to in Article 14.

Note B1-3: ALs(E) and ALs(B) represent maximum calculated or measured values at the workers' body position. This results in a conservative exposure assessment and automatic compliance with ELVs in all non-uniform exposure conditions. In order to simplify the assessment of compliance with ELVs, carried out in accordance with Article 4, in specific non-uniform conditions, criteria for the spatial averaging of measured fields based on established dosimetry will be laid down in the practical guides referred to in Article 14. In the case of a very localised source within a distance of a few centimetres from the body, compliance with ELVs shall be determined dosimetrically, case by case.

Note B1-4: The power density shall be averaged over any 20 cm^2 of exposed area. Spatial maximum power densities averaged over 1 cm^2 should not exceed 20 times the value of 50 Wm^{-2}. Power densities from 6 to 10 GHz are to be averaged over any six-minute period. Above 10 GHz, the power density shall be averaged over any $68/f^{1,05}$-minute period (where f is the frequency in GHz) to compensate for progressively shorter penetration depth as the frequency increases.

TABLE B2

ALs for steady state contact currents and induced limb currents

Frequency range	Steady state contact current, ALs(I_C) [mA] (RMS)	Induced limb current in any limb, ALs(I_L) [mA] (RMS)

100 kHz ≤ f < 10 MHz	40	—
10 ≤ f ≤ 110 MHz	40	100

Note B2-1: $[ALs(I_L)]^2$ is to be averaged over a six-minute period.

ANNEX IV

CORRELATION TABLE

Directive 2004/40/EC	**This Directive**
Article 1(1)	Article 1(1)
Article 1(2)	Article 1(2) and (3)
Article 1(3)	Article 1(4)
Article 1(4)	Article 1(5)
Article 1(5)	Article 1(6)
Article 2(a)	Article 2(a)
—	Article 2(b)
—	Article 2(c)
Article 2(b)	Article 2(d), (e) and (f)
Article 2(c)	Article 2(g)
Article 3(1)	Article 3(1)
Article 3(2)	Article 3(1)
—	Article 3(2)
Article 3(3)	Article 3(2) and (3)
—	Article 3(4)
Article 4(1)	Article 4(1)
Article 4(2)	Article 4(2) and (3)
Article 4(3)	Article 4(3)
Article 4(4)	Article 4(4)
Article 4(5)(a)	Article 4(5)(b)
Article 4(5)(b)	Article 4(5)(a)
—	Article 4(5)(c)
Article 4(5)(c)	Article 4(5)(d)
Article 4(5)(d)	Article 4(5)(e)
Article 4(5)(d)(i)	—

Article 4(5)(d)(ii)	—
Article 4(5)(d)(iii)	—
Article 4(5)(d)(iv)	—
Article 4(5)(e)	Article 4(5)(f)
Article 4(5)(f)	Article 4(5)(g)
—	Article 4(5)(h)
—	Article 4(5)(i)
Article 4(5)(g)	Article 4(5)(j)
Article 4(5)(h)	Article 4(5)(k)
—	Article 4(6)
Article 4(6)	Article 4(7)
Article 5(1)	Article 5(1)
Article 5(2), introductory wording	Article 5(2), introductory wording
Article 5(2)(a) to (c)	Article 5(2)(a) to (c)
—	Article 5(2)(d)
—	Article 5(2)(e)
Article 5(2)(d) to (g)	Article 5(2)(f) to (i)
—	Article 5(4)
Article 5(3)	Article 5(5)
—	Article 5(6)
—	Article 5(7)
Article 5(4)	Article 5(8)
—	Article 5(9)
Article 5(5)	Article 5(3)
Article 6, introductory wording	Article 6, introductory wording
Article 6(a)	Article 6(a)
Article 6(b)	Article 6(b)
—	Article 6(c)
Article 6(c)	Article 6(d)
Article 6(d)	Article 6(e)
—	Article 6(f)
Article 6(e)	Article 6(g)
Article 6(f)	Article 6(h)
—	Article 6(i)

Article 7	Article 7
Article 8(1)	Article 8(1)
Article 8(2)	—
Article 8(3)	Article 8(2)
Article 9	Article 9
—	Article 10
Article 10(1)	Article 11(1)(c)
Article 10(2)(a)	Article 11(1)(a)
Article 10(2)(b)	Article 11(1)(b)
Article 11	—
—	Article 12
—	Article 13
—	Article 14
—	Article 15
Article 13(1)	Article 16(1)
Article 13(2)	Article 16(2)
—	Article 17
Article 14	Article 18
Article 15	Article 19
Annex	Annex I, Annex II and Annex III
—	Annex IV