APPENDIX 2. SUMMARY OF EXPOSURE LIMIT VALUES, ACTION LEVELS AND REFERENCE LEVELS

Exposure limit values

The exposure limit values from the Schedule to the Control of Electromagnetic Fields at Work Regulations 2016 are given in tables 1 – 5. These are legal limits on exposure. However, exposure limit values are generally set in terms of quantities inside the body that are difficult to assess. Consequently, assessment will normally involve comparison of measured field strengths with the action levels reproduced later in this appendix.

Tables 1 and 2 are for non-thermal (low frequency) effects, whilst tables 3 – 5 are for thermal (high frequency) effects. For frequencies between 100 kHz and 10 MHz, it is necessary to assess compliance with the exposure limit values in **both** table 1 **and** table 3.

Throughout these tables, *f* is the frequency in Hz unless otherwise stated.

The exposure limit values given in table 1 are intended to prevent adverse health effects. Compliance with these limits is always mandatory.

Table 1 Health effects exposure limit values for non-thermal effects (1 Hz – 10 MHz)

Frequency range	Internal electric field strength (V/m)
1 Hz – 3 kHz	1.1
3 kHz – 10 MHz	$3.8 \times 10^{-4} f$

Notes

1. The ELVs are limits for electric fields induced in the body from exposure to time-varying external electric and external magnetic fields
2. The ELVs are spatial peak values in the entire body of an employee
3. The ELVs are peak values in time, which are equal to RMS values multiplied by √2 for sinusoidal fields. For non-sinusoidal fields the exposure assessment should be based on the weighted peak method in the time domain.

The exposure limit values given in table 2 are intended to prevent perception of the field. As this is annoying rather than hazardous, it is acceptable for exposures to temporarily exceed these values provided the conditions in the notes to the table are met.

Table 2 Sensory effects exposure limit values for non-thermal effects (1 Hz – 400 Hz)

Frequency range	Internal electric field strength (V/m)
1 Hz – 10 Hz	$0.7/f$
10 Hz – 25 Hz	0.07
25 Hz – 400 Hz	$0.0028 f$

Notes:

1. The ELVs are spatial peak values induced in the head of the exposed employee and can arise from exposure to either external electric or external magnetic fields
2. The ELVs may be exceeded during an employee's shift, providing the employer ensures that –
    a. they are exceeded only temporarily
    b. hazardous spark discharges and contact current in excess of those in table ?? are prevented through the provision of information and training and the use of suitable technical and personal protection measures
    c. adequate information is provided to the employee on the possibility of sensory effects related to time-varying magnetic fields, including retinal phosphenes
    d. where any of those sensory effects are reported to the employer, the risk assessment is updated where necessary
3. The ELVs are peak values in time, which are equal to RMS values multiplied by √2 for sinusoidal fields. The exposure assessment should be based on the weighted peak method in the time domain.

The exposure limit values given in table 3 are intended to prevent adverse health effects. Compliance with these limits is always mandatory.

Table 3 Health effects exposure limit values for thermal effects (100 kHz – 6 GHz)

Area of exposure	Specific energy absorption rate (W/kg)
Whole body	0.4 (averaged SAR in the body)
Head and trunk	10 (localised SAR in the head and trunk)
Limbs	20 (localised SAR in the limbs)

Notes:

1. The ELVs correspond to the SAR values averaged over any six minute period
2. Localised SAR in the body and limbs can be assessed by either computational dosimetry of physical measurement of 10 g of tissue. For computational dosimetry, 10 g of contiguous tissue with approximately homogeneous electrical properties must be used for the SAR average. For direct physical measurements a simple geometry, such as cubic or spherical tissue mass may be used. The maximum value obtained must be assessed against the ELVs

The exposure limit values given in table 4 are intended to prevent perception of the field. As this is annoying rather than hazardous, it is acceptable for exposures to temporarily exceed these values provided the conditions in the notes to the table are met.

Table 4 Sensory effects exposure limit values for thermal effects (300 MHz – 6 GHz)

Area of exposure	Specific energy absorption (mJ/kg)
Head	10

Notes:

1. Energy absorption must be averaged over 10 g of tissue
2. The ELV may be exceeded during an employee's shift provided the employer ensures that:
    a. it is only exceeded temporarily
    b. adequate information is provided to the employee on the possibility of sensory effects related to pulsed microwave radiation, including auditory sensations
    c. where any of those sensory effects are reported to the employer, the risk assessment is updated where necessary

The exposure limit values given in table 5 are intended to prevent adverse health effects. Compliance with these limits is always mandatory.

Table 5 Health effects exposure limit values for thermal effects (6 GHz – 300 GHz)

Frequency range	Power density (W/m^2)
6 GHz – 300 GHz	50

Notes:

1. The power density is the maximum level averaged over any 20 cm^2 of exposed area. Spatial maximum power densities averaged over any 1 cm^2 must not exceed 1000 W/m^2.
2. From 6 GHz to 10 GHz, power density must be averaged over any six minute period. Above 10 GHz, it must be averaged over any $68/f^{1.05}$ minute period, where f is the frequency in GHz.

Action levels

The action levels from the schedule to the Control of Electromagnetic Fields at Work Regulations 2016 are given in tables 6 – 10. Action levels are **not** legal limits. Instead they are a guide either to compliance with the exposure limit values or to the avoidance of indirect effects.

Those related to the exposure limit values (tables 6 – 9) have been derived by dosimetric modelling that assumes worst case exposure conditions. Hence provided the action levels are not exceeded, compliance with the exposure limit values is assured. However, in many realistic exposure scenarios it would be possible to exceed the action levels and still comply with the exposure limit values. In general, it is simplest to work to the action levels. Nevertheless, if this

is difficult or impossible, it is always acceptable to assess compliance with the exposure limit values directly.

Tables 6 and 7 relate to non-thermal effects, whilst tables 8 and 9 relate to thermal effects. For frequencies between 100 kHz and 10 MHz it is necessary to consider compliance with **both** non-thermal **and** thermal action levels.

Unless otherwise stated, *f* is the frequency in Hz.

The low action levels in table 6 relate to the avoidance of spark discharges, which may be annoying. It follows that it is acceptable to temporarily exceed the low action levels provided measures have been taken to limit spark discharges (see the notes to the table). The high action levels may only be exceeded where it is possible to demonstrate compliance with the health effects exposure limit value.

Table 6 Action levels for electric fields (1 Hz – 10 MHz)

Frequency range	**External electric field strength (V/m)**	
	Low action level	**High action level**
1 Hz – 25 Hz	2.0×10^4	2.0×10^4
25 Hz – 50 Hz	$5.0 \times 10^5/f$	2.0×10^4
50 Hz – 1.64 kHz	$5.0 \times 10^5/f$	$1.0 \times 10^6/f$
1.64 kHz – 3 kHz	$5.0 \times 10^5/f$	6.1×10^2
3 kHz – 10 MHz	1.7×10^2	6.1×10^2

Notes:

1. Between the low and high action levels exposures will be compliant with the exposure limit values, but spark discharges may occur. These should be managed through suitable technical and personal protection measures and through the provision of information and training.
2. The action levels are given as root mean square (RMS) values, which are equivalent to peak values divided by √2 for sinusoidal fields. For non-sinusoidal fields exposure assessment should be based on the weighted peak method (filtering in the time domain).
3. Action levels are defined as body-absent values and this must be considered when carrying out measurements.
4. Action levels are not applicable to situations where the source is in the immediate vicinity of the exposed person. In this situation assessment of compliance with the exposure limit values is necessary.

The low action levels in table 7 relate to compliance with the non-thermal sensory effects exposure limit values, which may result in perception of the field that could be annoying or distracting. It follows that it is acceptable to temporarily exceed the low action levels provided the conditions in the notes to the relevant table are met. Low action levels are applicable to localised exposure of the head.

The high action levels and the limb action levels relate to compliance with the non-thermal health effects exposure limit values. The high action levels apply to whole body exposure, whilst the limb action levels apply in the case of localised exposure in the immediate vicinity of a limb. It is not acceptable to exceed either the high or limb action levels unless it is possible to demonstrate compliance with the health effects exposure limit value.

Table 7 Action levels for magnetic fields (1 Hz – 10 MHz)

Frequency range	External magnetic flux density (μT)		
	Low action level	High action level	Limb action level
1 Hz – 8 Hz	$2.0 \times 10^5/f^2$	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
8 Hz – 25 Hz	$2.5\ 10^4/f$	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
25 Hz – 300 Hz	1.0×10^3	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
300 Hz – 3 kHz	$3.0 \times 10^5/f$	$3.0 \times 10^5/f$	$9.0 \times 10^5/f$
3 kHz – 10 MHz	1.0×10^2	1.0×10^2	3.0×10^2

Notes:

1. Between the low and high action levels, for frequencies up to 400 Hz, exposure in the head may exceed the sensory effects exposure limit value, but will be compliant with the health effects exposure limit value
2. The low action levels may be exceeded during an employee's shift, providing the employer ensures that –
    a. they are exceeded only temporarily
    b. adequate information is provided to the employee on the possibility of sensory effects related to time-varying magnetic fields, including retinal phosphenes
    c. where any of those sensory effects are reported to the employer, the risk assessment is updated where necessary
3. The action levels are given as root mean square (RMS) values, which are equivalent to peak values divided by √2 for sinusoidal fields. For non-sinusoidal fields exposure assessment should be based on the weighted peak method (filtering in the time domain).
4. Action levels are defined as body-absent values and this must be considered when carrying out measurements (not normally an issue when carrying out measurements of low frequency magnetic fields).
5. Action levels are not applicable to situations where the source is in the immediate vicinity of the exposed person. In this situation assessment of compliance with the exposure limit values is necessary.

The action levels in table 8 relate to compliance with the thermal health effects exposure limit values. They apply to whole body exposure. It is not acceptable to exceed the action levels unless it is possible to demonstrate compliance with the health effects exposure limit value.

Table 8 Action levels for exposure to electromagnetic fields (100 kHz – 300 GHz)

Frequency range	External electric field strength (V/m)	External magnetic flux density (μT)	Power density (W/m^2)
100 kHz – 1 MHz	6.1×10^2	$2.0 \times 10^6/f$	-
1 MHz – 10 MHz	$6.1 \times 10^8/f$	$2.0 \times 10^6/f$	-
10 MHz – 400 MHz	61	0.2	-
400 MHz – 2 GHz	$3.0 \times 10^{-3}\ f^{0.5}$	$1.0 \times 10^{-5}\ f^{0.5}$	-
2 GHz – 6 GHz	1.4×10^2	4.5×10^{-1}	-
6 GHz – 300 GHz	1.4×10^2	4.5×10^{-1}	50

Notes:

1. Action levels for electric field strength and magnetic flux density are RMS values
2. For pulsed sources the peak power density averaged over the pulse width must not exceed 50 kW/m^2.
3. Action levels are defined as body-absent values and this must be considered when carrying out measurements.
4. Action levels are not applicable to situations where the source is in the immediate vicinity of the exposed person. In this situation assessment of compliance with the exposure limit values is necessary.
5. The power density is the maximum level averaged over any 20 cm^2 of exposed area. Spatial maximum power densities averaged over any 1 cm^2 must not exceed 1000 W/m^2.
6. From 6 GHz to 10 GHz, power density must be averaged over any six minute period. Above 10 GHz, it must be averaged over any $68/f^{1.05}$ minute period, where f is the frequency in GHz.

The action level in table 9 relates to compliance with the thermal health effects exposure limit values for localised specific energy absorption rate in the limbs. It is not acceptable to exceed the action level unless it is possible to demonstrate compliance with the health effects exposure limit value.

Table 9 Action level for limb currents (10 MHz – 110 MHz)

Frequency range	Limb current (mA)
10 MHz – 110 MHz	100

Notes:

1. The action level is an RMS value

The action levels in table 10 relate to the avoidance of indirect effects such as shock and burn. Instrumentation to measure contact currents is not widely available at present.

Table 10 Action levels for contact currents (1 Hz – 110 MHz)

Frequency range	Contact current (mA)
1 Hz – 2.5 kHz	1.0
2.5 kHz – 100 kHz	0.4 f
100 kHz – 110 MHz	40

Notes:

1. Frequency relates to the frequency of the electromagnetic field in which a conducting object is present
2. f is the frequency in kHz
3. The action levels are RMS values
4. The action levels represent the maximum steady state current created during a continuous contact with an object in an electromagnetic field

Reference levels

Council Recommendation 1999/519/EC is intended to provide a framework for limiting public exposure to electric, magnetic and electromagnetic fields and radiations. As an internationally accepted limitation system, the reference levels specified in the Council Recommendation have also been used to define the conditions for electromagnetic compatibility testing of active implanted medical devices and more recently for medical devices (including body-worn active medical devices). Hence they provide a useful framework for the protection of employees who are reliant on active medical devices (whether implanted or body-worn).

In addition, it is currently believed that exposure up to the reference levels specified in the Council Recommendation will not present a risk to pregnant women or those fitted with passive implanted medical devices. It is possible that exposures above the reference levels may also be safe for these two latter groups of employees at particular risk, but at present it would be more difficult to demonstrate this.

Table 11 Reference levels for exposure to electric, magnetic and electromagnetic fields and radiations (1 Hz – 300 GHz)

Frequency range	Electric field strength (V/m)	Magnetic field strength (A/m)	Magnetic flux density (μT)	Power density (W/m^2)
1 Hz – 8 Hz	10 000	3.2×10^4	4.0×10^4	-
8 Hz – 25 Hz	10 000	$3.2 \times 10^4/f^2$	$4.0 \times 10^4/f^2$	-
0.025 kHz – 0.8 kHz	$250/f$	$4/f$	$5/f$	-
0.8 kHz – 3 kHz	$250/f$	5	6.25	-
3 kHz – 150 kHz	87	5	6.25	-
0.15 MHz – 1 MHz	87	$0.73/f$	$0.92/f$	-
1 MHz – 10 MHz	$87/f^{0.5}$	$0.73/f$	$0.92/f$	-
10 MHz – 400 MHz	28	0.073	0.092	2
400 MHz – 2000 MHz	$1.375f^{0.5}$	$0.0037f^{0.5}$	$0.0046f^{0.5}$	$f/200$
2 GHz – 300 GHz	61	0.16	0.20	10

Notes:

1. f is the frequency indicated in the frequency column
2. For frequencies between 100 kHz and 10 GHz, S, E^2, H^2 and B^2 are averaged over any 6 minute period
3. For frequencies greater than 10 GHz, S, E^2, H^2 and B^2 are averaged over any $68/f^{1.05}$ minute period
4. For pulsed sources the peak power density averaged over the pulse width should not exceed 10 kW/m^2.
5. The reference levels are specified as RMS values.

For peak values, the following reference levels apply to electric field strength, magnetic field strength and magnetic flux density:

- for frequencies up to 100 kHz, peak reference values are obtained by multiplying the corresponding RMS values by $\sqrt{2}$
- for pulses of duration t_p the equivalent frequency to apply should be calculated as $f = 1/(2\ t_p)$
- for frequencies between 100 kHz and 10 MHz, peak reference values are obtained by multiplying the corresponding RMS values by 10^{α}, where $\alpha = (0.665 \log(f/10^5) + 0.176)$, where f is the frequency in Hz
- for frequencies between 10 MHz and 300 GHz, peak reference values are obtained by multiplying the corresponding RMS values by 32.