

This is a preview - click here to buy the full publication



IEC TR 62905

Edition 1.0 2018-02

TECHNICAL REPORT



Exposure assessment methods for wireless power transfer systems

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 17.220.20

ISBN 978-2-8322-5350-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms and definitions	10
4 Symbols and abbreviations.....	12
4.1 Physical quantities	12
4.2 Constants	12
4.3 Abbreviations.....	12
5 Overview of WPT systems	13
5.1 General.....	13
5.2 WPT systems whose frequency range is less than 100 kHz	13
5.3 WPT systems whose frequency range is from 100 kHz to 10 MHz.....	17
6 Basic assessment methods	20
6.1 General.....	20
6.2 Basic assessment methods considering direct effect.....	20
6.2.1 General	20
6.2.2 Evaluation based on transmit power or current	21
6.2.3 Evaluation of incident fields against reference levels	21
6.2.4 Evaluation of incident fields against basic restrictions.....	21
6.2.5 Evaluation of induced E-field and SAR against basic restrictions	22
6.2.6 Assessment procedure	23
6.3 Basic assessment method considering indirect effect.....	23
Annex A (informative) WPT systems whose frequency range is over 10 MHz.....	25
Annex B (informative) International exposure guidelines	27
B.1 ICNIRP guidelines.....	27
B.2 IEEE standards.....	30
Annex C (informative) Assessment methods	33
C.1 Exclusion based on transmit power or current.....	33
C.2 Measurement of incident electromagnetic fields	34
C.2.1 Equipment for electric field measurement	34
C.2.2 Equipment for magnetic field measurement	34
C.2.3 Measurement method	35
C.3 Coupling factor	36
C.4 Generic gradient source model	37
C.5 Induced E-field or SAR	40
C.5.1 Measurement.....	40
C.5.2 Calculation	41
C.6 Contact current.....	43
C.6.1 Equipment	43
C.6.2 Measurements.....	45
Annex D (informative) Case studies	46
D.1 WPT system for EV.....	46
D.1.1 General	46
D.1.2 Assessment procedures for WPT system for EV	47
D.2 Experimental assessment results for EV	58

D.2.1	General	58
D.2.2	Electromagnetic field measurement results	58
D.2.3	Contact current measurement.....	60
D.3	WPT system for mobile devices	61
D.3.1	General	61
D.3.2	Assessment procedures for WPT system for mobile.....	62
Annex E (informative)	Numerical and experimental studies	64
E.1	Exposure evaluation of WPT for EV	64
E.1.1	Research in Japan.....	64
E.1.2	Research in Korea	68
E.2	Exposure evaluation of WPT for mobile device.....	72
E.2.1	WPT system in 140 kHz band	72
E.2.2	WPT systems in MHz band	74
E.3	Coupling factor	79
E.3.1	WPT system for EV	79
E.3.2	WPT system for mobile device.....	82
E.3.3	Evaluation example of CF and GGSM using a cylinder model	83
E.4	SAR measurement.....	87
E.5	Contact current	89
E.5.1	WPT system for EV	89
E.5.2	WPT systems for mobile (MHz).....	90
Annex F (informative)	Medical implants.....	92
F.1	Background.....	92
F.2	Medical implant enhancement factor	92
F.3	Numerical evaluation of medical implant enhancement factor.....	97
F.3.1	General	97
F.3.2	Numerical setup.....	97
Bibliography.....		99
Figure 1 – Wireless power kitchen appliances [1].....		13
(WPT kitchen island of apartment)		14
Figure 2 – Use cases of the LCD and semiconductor product lines and kitchen WPT systems [1]		14
Figure 3 – Example of a WPT system for EV/PHEV [1]		15
Figure 4 – Example of an online electric vehicle [1].....		16
Figure 5 – Technical characteristics of an online electric vehicle [1].....		16
Figure 6 – Example magnetic induction WPT system block diagram [1].....		18
Figure 7 – Example magnetic resonance WPT system block diagram [1]		18
Figure 8 – Capacitive coupling WPT system block diagram [1].....		19
Figure 9 – Typical structure of the capacitive coupling system [1]		19
Figure 10 – Flowchart of assessment procedure considering the direct effect		23
Figure 11 – Two exposure situations for ungrounded and grounded metal objects		24
Figure 12 – Flowchart of assessment procedures for indirect effects.....		24
Figure C.1 – Frequency characteristics of impedance of adult male and IEC equivalent circuit.....		44
Figure C.2 – IEC equivalent circuit.....		44
Figure C.3 – Example of contact current measurement equipment		44

Figure D.1 – Example for areas of protection, for ground mounted systems [37]	47
Figure D.2 – Area 3 measurement position [37]	48
Figure D.3 – Area 4 measurement position [37]	48
Figure D.4 – Assessment flow of Part 1	51
Figure D.5 – Assessment flow of Part 2	55
Figure D.6 – Assessment flow of Part 3	56
Figure D.7 – Example measurement layout for Area 3 surrounding area of vehicle	59
Figure D.8 – Example measurement layout for Area 4 car interior	60
Figure D.9 – Contact current meters used in the measurement	60
Figure D.10 – Measurement of contact current.....	61
Figure E.1 – Geometry of vehicle model	64
Figure E.2 – Measured and simulated magnetic field strength leaked from wireless power system in an electric vehicle [46].....	65
Figure E.3 – Distance dependence of peak induced electric field strength in human body model	65
Figure E.4 – Analysis of induced electric field strength in the human body for different human positions relative to the vehicle [41].....	66
Figure E.5 – Relationship between the maximum induced electric field in the human body and the magnetic field strength [41].....	67
Figure E.6 – The induced electric field distributions in a human body model lying on the ground with his right arm stretched [48]	68
Figure E.7 – EMF human exposure condition from the power line and pickup coils of OLEV system.....	69
Figure E.8 – The model in the field generated by OLEV	70
Figure E.9 – The calculated magnetic field distributions at each distance from OLEV	71
Figure E.10 – Photograph of magnetic field measurement for transmitting and receiving pads of wireless charging system.....	72
Figure E.11 – Measurement results of magnetic field value for two cases of low voltage output (case 1) and high voltage output (case 2).....	72
Figure E.12 – Transmitting and receiving coils, and magnetic sheet.....	73
Figure E.13 – Simulated magnetic field strength distribution (Charging (a) xy plane, (b) yz plane; Standby model (c) xy plane, (d) yz plane) and measured value (Charging (e) xy plane, (f) yz plane; Standby mode (g) xy plane, (h) yz plane)	73
Figure E.14 – Position of human body and coil (left), exposure point in chest (right)	74
Figure E.15 – Realistic human body model and system position.....	75
Figure E.16 – Position of the human body model: (a) the human body is moved in the horizontal direction, (b) the coils are moved in vertical direction.....	76
Figure E.17 – Peak of 10 g average SAR moved in (a) horizontal direction, (b) vertical direction.....	76
Figure E.18 – Peaks of 10 g average SAR	77
Figure E.19 – Wireless power transfer system configurations.....	78
Figure E.20 – Electric field and magnetic field distributions around the coil when an input power is 1 W	78
Figure E.21 – Exposure conditions for WPT system	78
Figure E.22 – Top and bird's-eye views of (a) solenoid type and (b) circular spiral type coupling coils, and (c) geometry of electric vehicle with a wireless power transfer system [13].....	81
Figure E.23 – A numerical model of dielectric cylinder used in the calculation.....	83

Figure E.24 – Distribution of induced electric field strength inside the cylinder in the vicinity of a one-turn loop with 1 A current	85
Figure E.25 – A two-line current model	85
Figure E.26 – Decay profile of incident magnetic field for each component	86
Figure E.27 – Profile of incident magnetic field for $G_n = 13$ (left) and 80 (right)	86
Figure E.28 – Distribution of induced electric field for x-, y-, and z-components of the incident magnetic field profiles generated by GGSM	86
Figure E.29 – Solenoid-type WPT system (left) and flat-spiral-type WPT system (right) used for SAR measurement	88
Figure E.30 – SAR distribution in a liquid phantom, calculated by MoM (above) and measured by the developed measurement system (below)	88
Figure E.31 – Two conditions of contact current measurement	89
Figure E.32 – Contact currents with ungrounded condition	90
Figure E.33 – Contact currents with grounded condition	90
Figure E.34 – Contact current with ungrounded metal	91
Figure E.35 – Contact current with grounded metal	91
Figure F.1 – Model of the insulated perfectly conducting wire with non-insulated bare tips used as generic implantable medical device	94
Figure F.2 – $pSAR_{0,1g}$ (W/kg) at the lead tip as a function of frequency in the range 100 kHz to 10 MHz for each lead length (100 mm, 200 mm, 500 mm and 800 mm)	96
Figure F.3 – Induced E-field tangential to the implant, embedded in the homogeneous tissue, in the absence of the implant, to reach ICNIRP2010 BRs in the frequency range 10 kHz to 10 MHz and as a function of the lead length, when the implant is present	97
Table 1 – Summary of application, technology and specification of WPT systems whose frequency range is less than 100 kHz	17
Table 2 – WPT systems whose frequency range is from 100 kHz to 10 MHz	20
Table A.1 – Classification of WPT applications	26
Table A.2 – Characteristics of beam WPT applications	26
Table B.1 – Basic restrictions up to 10 GHz of ICNIRP1998	27
Table B.2 – Basic restrictions of ICNIRP2010	28
Table B.3 – Reference levels for electric and magnetic fields (unperturbed rms values) of ICNIRP1998	29
Table B.4 – Reference levels for electric and magnetic fields (unperturbed rms values) of ICNIRP2010	29
Table B.5 – Reference levels for contact currents of ICNIRP1998 and ICNIRP2010	30
Table B.6 – Basic restrictions up to 5 MHz of IEEE C95.6 and IEEE C95.1	30
Table B.7 – Basic restrictions between 100 kHz and 3 GHz of IEEE C95.1	31
Table B.8 – Magnetic field MPE up to 5 MHz of IEEE C95.1 and IEEE C95.6	31
Table B.9 – Electric field MPE for whole-body exposure up to 100 kHz of IEEE C95.1 and IEEE C95.6	31
Table B.10 – MPE for electric and magnetic field over 100 kHz for whole-body exposure of IEEE C95.1 and IEEE C95.6	32
Table B.11 – Contact current MPE of IEEE C95.1 and IEEE C95.6	32
Table C.1 – Basic restrictions regarding SAR (unit is W/kg)	33
Table C.2 – Possible exclusion power level regarding local SAR	34

Table C.3 – Coupling transformation matrix to estimate induced E-field for compliance with ICNIRP 2010	38
Table C.4 – Coupling transformation matrix to estimate induced current density for compliance with ICNIRP 1998	38
Table C.5 – Coupling transformation matrix to estimate induced E-field for compliance with IEEE 2005	39
Table C.6 – Coupling transformation matrix to estimate SAR (pSAR _{10g} and wbSAR) for compliance with ICNIRP 1998 and IEEE 2005	39
Table C.7 – Dielectric properties of the tissue equivalent liquid defined in IEC 62209-2	40
Table C.8 – Dielectric properties of the tissue equivalent NaCl solution	40
Table C.9 – Human models and source models	42
Table C.10 – Computational methods	43
Table C.11 – SAR evaluation method based on numerical simulation.....	43
Table D.1 – Uncertainty of H-field measurements for WPT systems in Area 3	52
Table D.2 – Numerical uncertainty of the exposure of anatomical human models to WPT systems for EV	53
Table D.3 – Uncertainty of EMF measurements for WPT systems in Area 4	54
Table D.4 – Uncertainty of contact current measurements	57
Table D.5 – ICNIRP2010 guideline at 85 kHz.....	58
Table D.6 – Specification of DUT	58
Table D.7 – Measured incident H-fields and E-fields of Area 3	59
Table D.8 – Measured incident H-fields and E-fields of Area 4	59
Table D.9 – Measurement results of contact current [mA]	61
Table E.1 – Estimated permissible power for WPT system for EV	68
Table E.2 – Local SAR and induced electric field in a human body on the chest surface ...	74
Table E.3 – Simulated result of local SAR and whole-body average SAR by Nagoya Institute of Technology (NITech) / NTT DOCOMO and NICT (input power is 40 W)	79
Table E.4 – Dimensions of WPT systems for electric vehicles considered by different groups [13]	81
Table E.5 – Coupling factor for internal electric field of WPT systems for EV [13]	82
Table E.6 – Coupling factor for peak 10 g SAR for WPT systems at 6,78 MHz (implemented on the desk) [13].....	83
Table E.7 – Coupling factor for internal electric field for WPT systems at 6,78 MHz (implemented on the desk) [13].....	83
Table E.8 – NICT and IT'IS results of induced electric field and local peak 10 g average SAR in the dielectric cylinder using GGSM	87
Table E.9 – Experimental and numerical results of spatial peak 10 g average SAR (input power = 10 W)	88
Table F.1 – Preliminary medical implant enhancement factors for nerve stimulation up to 10 MHz	93
Table F.2 – Preliminary medical implant enhancement factors for tissue heating up to 10 MHz (ΔT).....	93
Table F.3 – Dielectric and thermal properties assigned to the muscle tissue and to the generic implants	94
Table F.4 – Induced E-field in the homogeneous tissue without the implant to reach J-BR of ICNIRP 1998	95
Table F.5 – Induced E-field in the homogeneous tissue without the implant to reach SAR-BR of ICNIRP 1998 and IEEE 2005 for $f \geq 100$ kHz.....	95

INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPOSURE ASSESSMENT METHODS FOR WIRELESS POWER TRANSFER SYSTEMS

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a Technical Report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 62905, which is a Technical Report, has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
106/416/DTR	106/424A/RVDTR

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

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

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC TC 106 has the scope to prepare International Standards on measurement and calculation methods used to assess human exposure to electric, magnetic and electromagnetic fields. Wireless power transfer (WPT) systems have been developed and gradually become popular over the world. WPT basically utilize similar wireless technologies to provide power to mobile phones, tablet PCs, electric vehicles (EVs) and so on without cables; but the used frequency range, i.e., tens of kHz to tens of MHz, has not been often used and paid attention to. Both stimulation-based effects (< 10 MHz, for example) and heat-based effects (> 100 kHz, for example) should be considered in this frequency range. ITU-R published a report (ITU-R SM. 2303-1) related to WPT in June 2015 which also mentions RF exposure assessment methodologies. However, no concrete assessment method has been introduced. Only IEC TC 69 has addressed exposure assessment method of WPT for EV in IEC 61980-1:2015. There is no product standard related to WPT other than that standard. Considering that WPT products might be spread in the near future, IEC TC 106 needs to be aware of this issue and established a working group to address methods for assessment of WPT related to human exposures to electric, magnetic and electromagnetic fields.

Based on these backgrounds IEC TC 106 prepared this document consisting of an overview of WPT, basic exposure assessment methods for direct and indirect effects by WPT, case studies, and relevant research. Frequency up to 10 MHz is mainly focused on because both stimulation and heat effects need to be considered but have not been addressed so far. This document also mentions enhancement of internal fields by medical implant devices.

It is hoped that this document will be useful and helpful to develop International Standards for WPT exposure assessment.

EXPOSURE ASSESSMENT METHODS FOR WIRELESS POWER TRANSFER SYSTEMS

1 Scope

This document describes general exposure assessment methods for wireless power transfer (WPT) at frequency up to 10 MHz considering thermal and stimulus effects. Exposure assessment procedures and experimental results are shown as examples such as electric vehicles (EVs) and mobile devices.

2 Normative references

There are no normative references in this document.