TUTORIAL: ADVANCED TOPICS IN BIOELECTROMAGNETICS

Part A: Exposure of Humans to Electromagnetic Radiation, by Dragan Poljak

Abstract: The goal of the Tutorial is to review various aspects of undesired human exposure to non-ionizing radiation generated by artificial sources. The Tutorial includes the basic ideas of electrosmog, coupling mechanisms between humans and electromagnetic fields, biological effects of electromagnetic fields, electromagnetic-thermal dosimetry models and solution methods, international/national safety guidelines, relevant exposure limits and safety measures.
First, some theoretical and experimental methods of incident field dosimetry for the determination of external fields due to power lines, transformer substations, radio base station antennas and mobile phones are given.
Furthermore, the tutorial aims to review some electromagnetic-thermal dosimetry methods for the assessment of human exposure to low frequency (LF), high frequency (HF) and transient electromagnetic radiation. In particular, the approaches are based on certain integral/differential equation formulations and related numerical solution procedures (primarily based on the use of Boundary Element Method – BEM, and Finite Element method – FEM) for the calculation of induced current densities, internal fields and specific absorption rate (SAR). For HF exposures the related temperature increase in tissues is of interest, as well. Illustrative computational examples pertaining to various realistic exposure scenarios, such as; pregnant woman/foetus exposed to low frequency (LF) fields, the human eye, the human brain and the human head exposed to HF electromagnetic fields will be given.
The obtained numerical results for induced current densities, internal fields and SAR are compared against exposure limits proposed by ICNIRP (International Commission on Non Ionizing Radiation Protection).
Finally, the last part of the Tutorial deals with deterministic stochastic-modeling to account for the influence of the variability in the morphology and the tissue properties of the organs, (such as the brain and eye) to the electromagnetic-thermal response of the body.

Biography: Dragan Poljak was born on 10 October 1965. He received his BSc in 1990, his MSc in 1994 and PhD in electrical engineering in 1996 from the University of Split, Croatia. He is the Full Professor at Department of Electronics, Faculty of electrical engineering, mechanical engineering and naval architecture at the University of Split, and he is also Adjunct Professor at Wessex Institute of Technology. His research interests include frequency and time domain computational methods in electromagnetics, particularly in the numerical modelling of wire antenna structures, and numerical modelling applied to environmental aspects of electromagnetic fields. To date Professor Poljak has published nearly 200 journal and conference papers in the area of computational electromagnetics, seven authored books and one edited book, by WIT Press, Southampton-Boston, and one book by Wiley, New Jersey. Professor Poljak is a member of IEEE, a member of the Editorial Board of the journal Engineering Analysis with Boundary Elements, and co-chairman of many WIT International Conferences. He is also editor of the WIT Press Series Advances in Electrical Engineering and Electromagnetics. He was awarded by several prizes for his carrier achievements, such as National Prize for Science (2004), Croation section of IEEE annual Award (2016).
In 2011 professor Poljak became a member of WIT Bord of Directors. From 2011 to 2015 he was the Vice-dean for research at the Faculty of electrical engineering, mechanical engineering and naval architecture. In June 2013 professor Poljak became a member of the board of the Croatian Science Foundation.
He is currently involved in 3 COST projects, ITER physics EUROfusion collaboration and one national center for excellence in research for technical sciences.
He is a co-chair of Working Group 2 of IEEE/International Committee on Electromagnetic Safety (ICES) Technical Committee 95 SC6 EMF Dosimetry Modeling.

Part B: Modeling Aspects and Parameter Uncertainty in Computational Dosimetry, by Mario Cvetković

Abstract: The interaction between electromagnetic field (EMF) and humans could be observed in two ways – the first being the unwanted exposure due to various electrical equipment while the second is the biomedical application of EMF in nowadays various therapeutic and diagnostic techniques.
The former case is very important due to increased concern among the general population related to the possible harmful effects. As the established biological effect of high frequency (HF) electromagnetic fields is tissue heating, the assessment of this HF exposure is based on determining the specific absorption rate (SAR) that is related to the electric field induced in the tissue. The HF exposure assessment is particularly important in the case of human eye and brain since experimental measurement in healthy humans is very difficult to obtain or if at all possible.
On the other hand, the efficient medical treatments using electromagnetic radiation also require the knowledge of the accurate distribution of the EM fields inside the tissues. As measurement of these quantities is rather difficult, the use of computational methods has become necessary to determine internal field distributions, both in the case of unwanted exposure assessment or to assisst in the biomedical application of EMF.
The computational models employed for this particular type of assessment can be classified as realistic models of the human body or the simplified models, computationally much less demanding but failing to provide accurate results in most of the exposure scenarios. The detailed models of the complete human body are nowadays readily available; however, the detailed human body model puts the significant burden in the computational model preparation at the same time putting strain on the available computational resources. In addition to this, there are cases when only the particular organ or body parts are of research interest, as when the initial assessment is considered. This talk will review some results for the induced electric field, the specific absorption rate, and the temperature increase in the case of human eye and human head exposed to HF radiation when using single organ models and a more detailed anatomical models, respectively.
Another important aspect the computational dosimetry has to consider is related to the uncertainty of the various input parameters such as due to difference in organ size between the individuals, as well as the biological tissue parameters such as permittivity and the electrical conductivity, or the tissue thermal parameters, that will eventually affect the distribution of the induced fields.
To approach this problem, the so called stochastic dosimetry is used, combining the use of the deterministic techniques with the statistical methods such as Stochastic Collocation. This approach is demonstrated first on the case of the Transcranial Magnetic Stimulation, by examining the influence of the brain tissue parameters' uncertainty and the coil positioning variations on the induced electric field and the related electric current density in the human brain model. The same approach is also shown within the dosimetric assessment of human brain exposed to high frequency EM field, where the effects of the variability in the brain morphology and the tissue properties as well as in the sensitivity analysis of thermal parameters investigating their influence on the temperature rise is carried out.

Biography: Mario Cvetkovic received the B.S. degree in electrical engineering from the University of Split, Croatia in 2005. In 2009 he obtained M.Phil degree from the Wessex Institute of Technology, University of Wales, UK. In December 2013 he received Ph.D. from University of Split, Croatia. He is the assistant professor at the Department of Electrical Engineering, Faculty of electrical engineering, mechanical engineering and naval architecture (FESB), University of Split.
In December 2010, he held a seminar to graduate and postgraduate students at the Technical University of Ilmenau, Germany, and in September 2014 he held a seminar at the Mälardalen University, Västerås, Sweden. He is a recipient of the "Best Student Paper Award", awarded at the 16th edition of the international conference SoftCOM 2008. At the Scientific Novices Seminar held in 2012, he was awarded with the recognition for his previous scientific achievements. To date he has published more than 50 journal and conference papers and two book chapters (CRC Press and Springer. His research interests are numerical modeling including finite element and moment methods, computational bioelectromagnetics and heat transfer related phenomena.
He is a member and is also serving as a secretary of Working Group 2 of IEEE/International Committee on Electromagnetic Safety (ICES) Technical Committee 95 SC6 EMF Dosimetry Modeling.

Part C: Computational electromagnetic dosimetry in Magnetic Resonance Imaging, by Oriano Bottauscio

The studies related to the interaction between electromagnetic fields and human tissues are of increasing interest in biomedicine, both with the aim of extending diagnostic and therapeutic methodologies, such as Magnetic Resonance Imaging (MRI), Transcranial Magnetic Stimulation (TMS), electromagnetic hyperthermia, and as a support to verify the compliance with regulatory limits of exposure for patients and medical personnel.
Since direct dosimetric surveys are almost unfeasible in vivo, studies are developed properly combining experiments and advanced computations in order to correlate physical quantities induced within human body with external stimuli.
This tutorial will review some aspects related to computational dosimetry in biomedical applications. Namely, attention will be focused on the numerical modeling and the experimental evaluation of the electromagnetic and thermal quantities induced inside human body when exposed to the fields (static, low frequency and radio-frequency) produced by MRI scanners.
First, some preliminary concepts related to EM fields and human body coupling mechanisms will be briefly introduced, together with some aspects related to human body and tissue modelling.
A review of the main computational methodologies for EM dosimetry will be then given, discussing their main merits and drawbacks. This part will be specialized for the different exposure cases that are present in the MRI context: low frequency gradient coil fields, radiofrequency fields (RF), motion-induced fields and thermal effects. Examples of experimental validations of computational codes performed through a specific laboratory set-up will be given.
The second part of the tutorial will be focused on examples of results obtained in the field of MR-safety, considering relevant exposure scenarios. In particular: (a) the analysis of energy deposition in human tissues by RF field, estimation of local Specific Absorption Rate (SAR) and related temperature increase; (b) the evaluation of induced electric fields by Gradient Coil fields and estimation of Peripheral Nerve Stimulation (PNS).
Particular attention will be devoted to the case of patients with implanted medical devices, whose number is rapidly growing, in order to determine the conditions which determine the most critical localized energy deposition and the consequent heating.
The last part of the tutorial will present the results of an extensive exposure assessment of motion induced fields, i.e., the electric fields induced in a body moving through the stationary magnetic field of a MRI scanner. Results of the analysis will be given based on the last specific Guidelines provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Biography: Oriano Bottauscio (SM'15) was born in 1961. He received the M.S. degree in electrical engineering from the Politecnico di Torino, Turin, Italy, in 1985.
He is currently Research Director at the Istituto Nazionale di Ricerca Metrologica (INRIM) Torino. From 2001 to 2006 he was responsible of the Applied Electromagnetics Department, while since 2015 he is the Head of the Division of Metrology for Quality of Life.
From 1996 to 2001, he was a contract Professor in electrical engineering. From 2007 to 2015 he was member of the Board of Professors of the Ph.D. School of Politecnico di Torino in Electrical Engineering. Currently he is Vice-Coordinator of the Ph.D. School in Metrology organized in convention between Politecnico di Torino and INRIM.
He has authored or coauthored more than 200 scientific papers published in international peer-reviewed journals, with more than 2000 citations. He is also authors of national and international patents.
His research activity is devoted to computational electromagnetism, with main reference to bioelectromagnetics, electromagnetic dosimetry related to medical equipment, electromagnetic fields and human exposure, and magnetic field mitigation.
Dr. Bottauscio was an Associate Editor (in 2009 and 2011) and Chief Editor (in 2013) of the special issues of the IEEE TRANSACTIONS ON MAGNETICS related to the Soft Magnetic Materials Conference. He was responsible and participate to several national and European research projects.
From 2001 to 2005, he was a member of CENELEC TC 106X "Electromagnetic field in human environment"—WG3 "Measurement and calculation procedures in electric, magnetic and electromagnetic fields (0 Hz–300 GHz)" and from 2002 to 2009 a member of the CIGRE Task Force C4.204 "Magnetic Field Mitigation Techniques." Since 2016, he has been a member of the IEEE TC95, SC6 "EMF Dosimetry Modeling", Working Group 2.