Bioelectromagnetics: Principles and Applications

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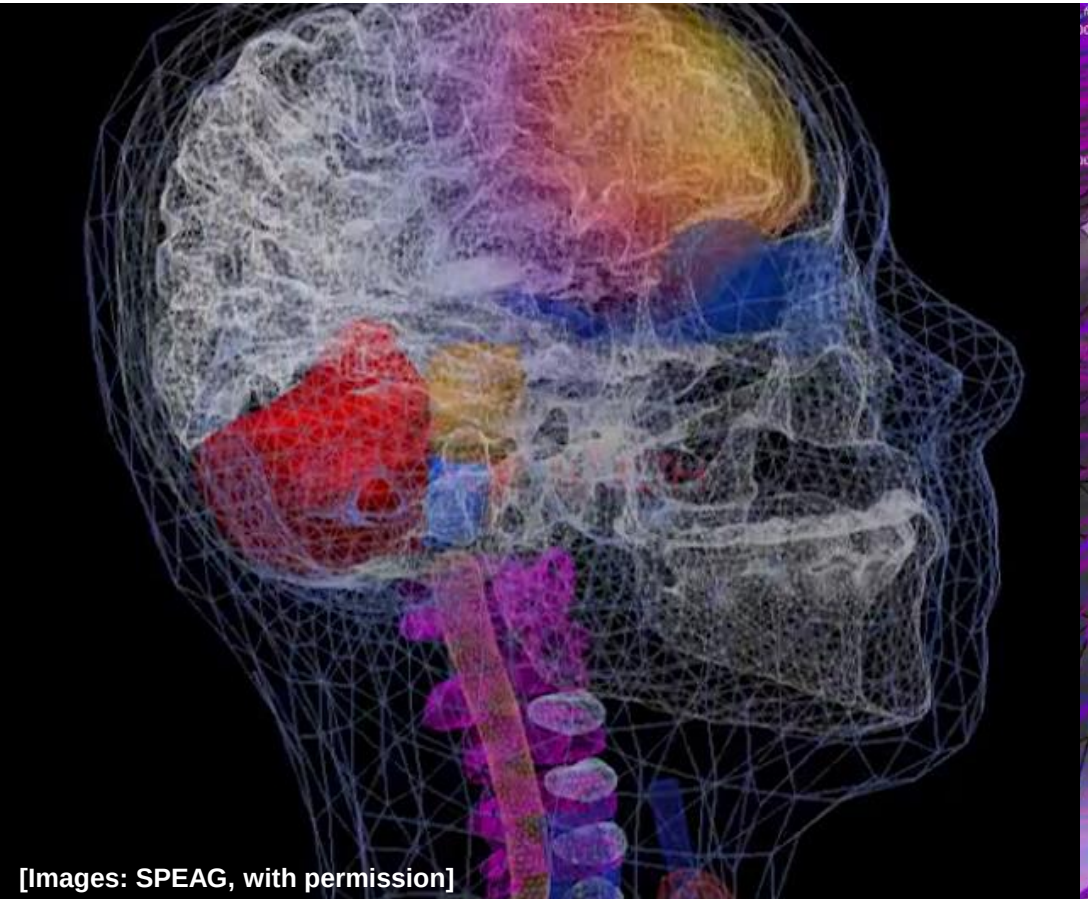
Course Overview, Summer Term 2018



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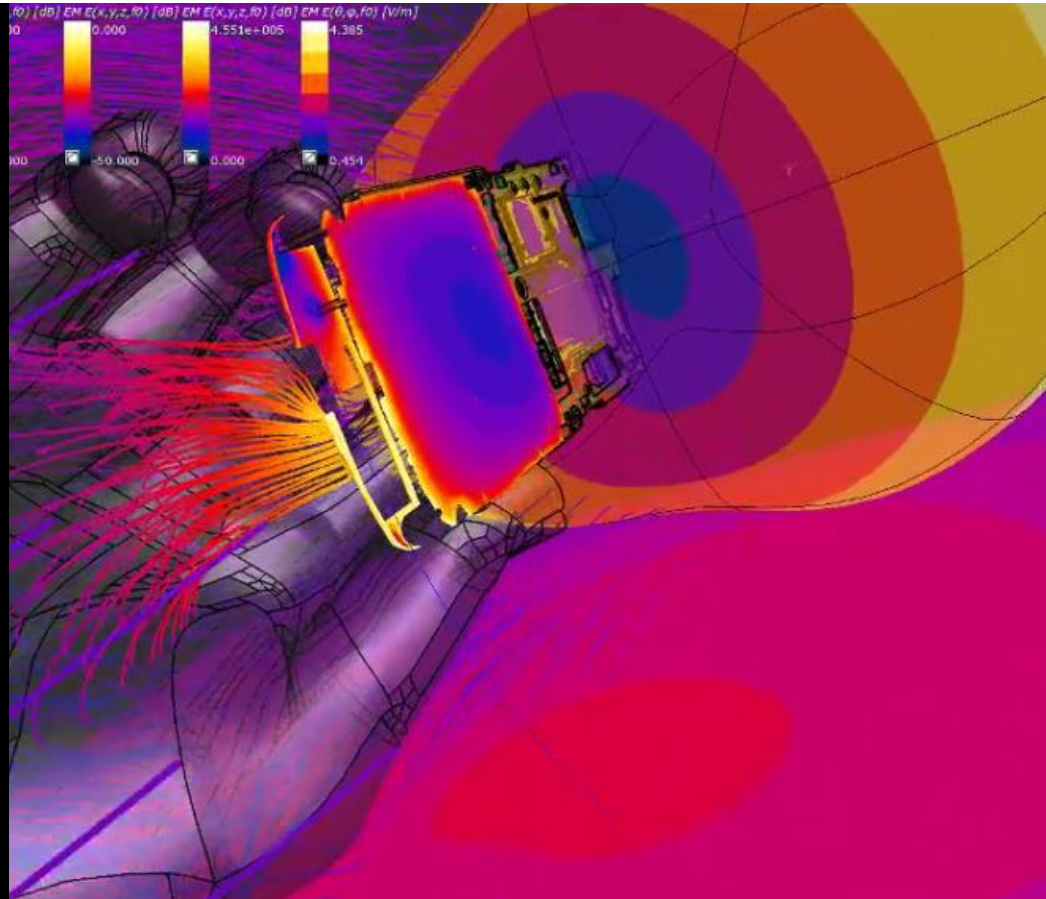


What this is About

The field of biolectromagnetics can be loosely defined as:

The science of electromagnetic field interaction with biological tissue

It is a subdicipline of biomedical engineering and has many connections to e.g. medical / biological imaging, electrotherapy, electrophysiology, biophysics, bioelectronics, electromagnetic compatibility / safety, and electrochemistry.

In the following the main goals, contents, and resources for this course are shortly outlined.

Goals of this Course

Students will be able to explain the basic principles, relationships, and methods of bioelectromagnetics, i.e. the science of electromagnetic field interaction with biological tissue. They can define and give examples for the most important physical phenomena and classify them corresponding to wavelength and frequency of the fields. They can give an overview over measurement and numerical techniques for characterization of electromagnetic fields in practical applications. They can give examples for therapeutic and diagnostic utilization of electromagnetic fields in medical technology.

In addition students will learn how to apply various methods to characterize the behavior of electromagnetic fields in biological tissue. In order to do this they can relate to and make use of the elementary solutions of Maxwell's Equations. They are able to assess the most important effects that these models predict for biological tissue, they can order the effects corresponding to wavelength and frequency, respectively, and they can analyze them in a quantitative way. They are able to evaluate the effects of electromagnetic fields for therapeutic and diagnostic applications and make an appropriate choice.

Curriculum

- Fundamental properties and phenomena of electromagnetic fields
- Mathematical description of electromagnetic fields
- Electromagnetic properties of biological tissue (conduction, polarization, magnetization, ionization)
- Principles of energy absorption in biological tissue, dosimetry
- Overview of numerical methods for field computation in biological tissue
- Measurement techniques for characterization of electromagnetic fields
- Classification of field interaction with biological tissue from DC to daylight
- Diagnostic applications of electromagnetic fields in medical technology
- Therapeutic applications of electromagnetic fields in medical technology
- The human body as a generator of electromagnetic fields
- The human body as a communication channel for electromagnetic signals

Literature

Course slides will be available for each lecture. In addition, the following books can be recommended:

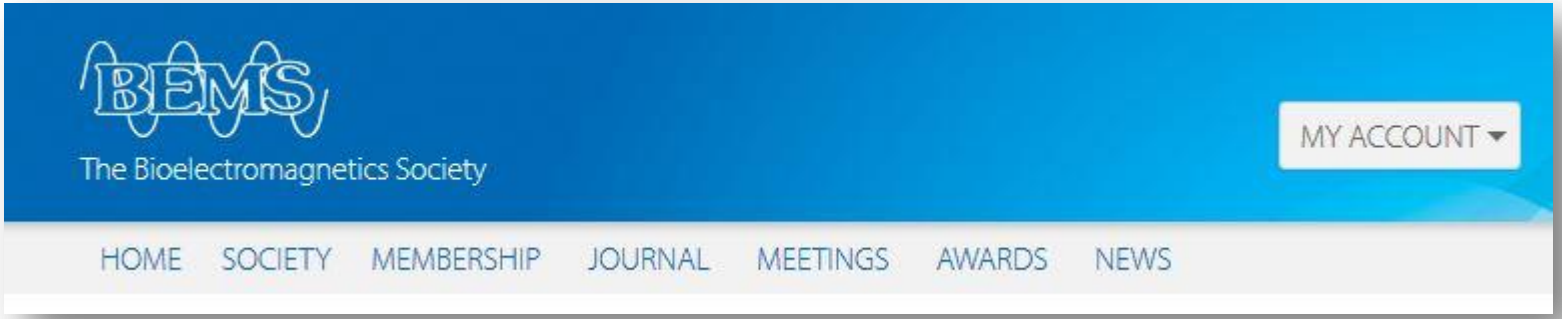
- C. Furse, D. A. Christensen, C. H. Durney, "**Basic Introduction to Biolelectromagnetics**", CRC Press
- S. Grimnes, O. G. Martinsen, "**Bioimpedance & Bioelectricity Basics**", Academic Publishers (E-Book TUHH)
- R. Plonsey, R. C. Barrr, "**Bioelectricity – A Quantitative Approach**", Springer (E-Book TUHH)
- J. C. Lin (Ed.), "**Electromagnetic Fields in Biological Systems**", CRC Press
- J. Malmivuo, R. Plonsey, " **Bioelectromagnetism**", available online at http://www.bem.fi/book/

All books can be made availabe by request.

Internet Resources

The Bioelectromagnetic Society (BEMS) offers lots of information at:

www.bems.org



[Source: www.bems.org]

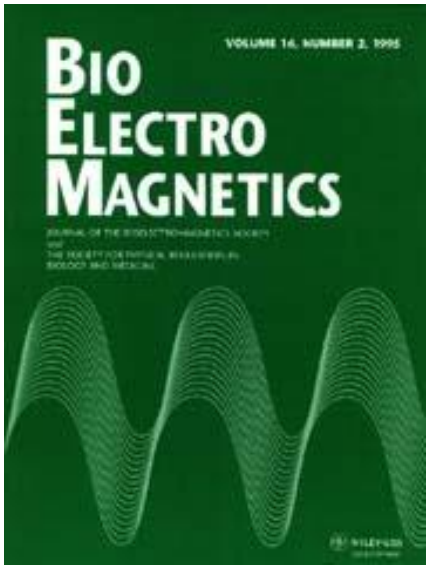
The European Virtual Campus for Biomedical Engineering can be found at:

www.evicab.eu

Among others it offers video lectures, slides, and exercises.

Scientific Publications

Studying scientific publications will be an important part of this course. Mostly the following sources will be used:



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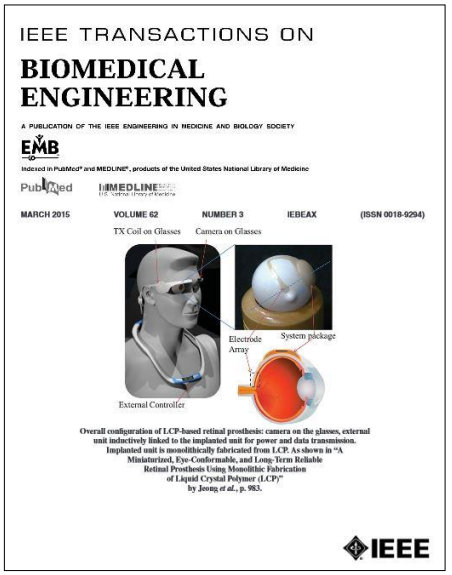

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Course Materials

The following course materials have been studied in previous lectures. Most of them are accessible via the TUHH online library:

- “THE ELECTROCARDIOGRAM CENTENNIAL: WILLEM EINTHOVEN (1860–1927)”, Proceedings of the IEEE, 2006
- “Your Personal Virtual Heart”, IEEE Spectrum, 2014
- “Magnetic Field Exposure Assessment in Electric Vehicles”, IEEE Transactions on EMC, February 2015
- “Catching Brain Waves in a Net”, IEEE Spectrum, 2014
- “Boundary Element Modeling of the Realistic Human Body Exposed to Extremely-Low-Frequency (ELF) Electric Fields: Computational and Geometrical Aspects”, IEEE Transactions on EMC, 2007
- “RF-Field Interactions with Biological Systems: Electrical Properties and Biophysical Mechanisms”, Proceedings of the IEEE, 1980
- “Bioelectricity: A Quantitative Approach” , Springer, 2007 (chapter 3)
- “Theoretical Evaluation of the Distributed Power Dissipation in Biological Cells Exposed to Electric Fields”, Bioelectromagnetics, 2000
- “A THEORY OF THE LOW-FREQUENCY DIELECTRIC DISPERSION OF COLLOIDAL PARTICLES IN ELECTROLYTE SOLU TION”, Journal of Physical Chemistry, 1962
- “Bioimpedance and Bioelectricity Basics”, Academic Press, 2008 (chapter 5)
- “A QUANTITATIVE DESCRIPTION OF MEMBRANE CURRENT AND ITS APPLICATION TO CONDUCTION AND EXCITATION IN NERVE”, Journal of Physiology, 1952
- “The Electrocardiographic Inverse Problem”, Science & Medicine, 1996

Course Materials – Continued

- ”How a Taser Works”, IEEE Spectrum, 2007
- “RF Head Coil Design With Improved RF Magnetic Near-Fields Uniformity for Magnetic Resonance Imaging (MRI) Systems”, IEEE Transactions on Microwave Theory and Techniques, 2014
- “Tracking Optimal Efficiency of Magnetic Resonance Wireless Power Transfer System for Biomedical Capsule Endoscopy”, IEEE Transactions on Microwave Theory and Techniques, 2014
- “Too Much Pressure”, IEEE Microwave Magazine, 2015
- “Current Activities on Exposure Limits for Humans in the Radio-Frequency Region”, IEEE Antennas and Propagation Magazine, 2014
- “Artificial Human Phantoms”, IEEE Microwave Magazine, 2015
- “Solid Phantom for Body-Centric Propagation Measurements at 60 GHz”, IEEE Transactions on Microwave Theory and Techniques, 2014
- “Computation of the Electromagnetic Fields and Induced Temperatures within a Microwave-Irradiated Model of the Human Eye”, IEEE Transactions on Microwave Theory and Techniques, 1975
- “3-D High-Resolution Imaging Radar at 300 GHz With Enhanced FoV”, IEEE Transactions on Microwave Theory and Techniques, 2015
- “Imaging with Terahertz Waves”, Optics Letters, 1995
- “Representation of a Function by Its Line Integrals, with Some Radiological Applications”, Journal of Applied Physics, 1963
- “Representation of a Function by Its Line Integrals, with Some Radiological Applications. II”, Journal of Applied Physics, 1964