Wireless Power Transfer School

Nov 15, 2020
Sejong University
Seoul, Korea

WPT School 2020 Chairs:
Nuno Borges Carvalho
Alessandra Costanzo
Grant Anthony Covic

IEEE
pels IEEE POWER ELECTRONICS SOCIETY Powering a Sustainable Future
MTT-S MHz to THz Community
KIEES Korean Institute of Electromagnetic Engineering and Science
KIPE
IEIE
KIEE Wireless Power Transfer Society
KICS
연세대학교 YONSEI UNIVERSITY
KOREA TOURISM ORGANIZATION www.visitkorea.or.kr
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Wireless Power Transfer School
Nov 15, 2020, Seoul, Korea

Welcome to the WPT School 2020

We are pleased to welcome you to the second Wireless Power Transfer School held in Seoul, Korea, in conjunction with the Wireless Power Week 2020. In this one-day school we will cover near field and the far field WPT addressing from basic concepts up to advanced applications of WPT. Lecturers come from all over the world and will bring together in Seoul a nice variety of different approaches to WPT, these include a wide range of wireless powering topics, starting with "Fundamentals of Inductive Power Transfer" ending with "Co-Design of Far-field energy sources and battery-less sensor for the Industrial IoT". These lecturers will present their talks every 50 minutes on Sunday, Nov 15th. We are proud to present a team of eight world leading experts to give the invited lectures on the topics of the school. With the selection of excellent lectures, we believe that the school provides the first introduction to newcomers in the near field and the far field WPT. Additionally, its wide coverage will provide the valuable lectures to those who have already studied in this field but want to broaden their knowledge. In all, we wish you an intellectually challenging, inspiring and rewarding day here at Sejong campus, Seoul, Korea. We would like to thank the WPW 2020 organizers and the speakers who are happy to accept this school.

Sincerely yours,

WPT School 2020 Chairs;

Nuno Borges Carvalho
University of Aveiro
Portugal

Alessandra Costanzo
University of Bologna
Italy

Grant Anthony Covic
University of Auckland
New Zealand

Wireless Power Transfer School
Nov 15, 2020, Seoul, Korea

WPT School 2020 Program

Sunday, Nov 15, 2020

Conference Room 1 & 2, GwangGaeTo Bldg., Sejong University

Time	WPT School Program Details
08:30	Registration
08:40-09:00	Welcome remarks by WPT School Chair (*Nuno Borges Carvalho)*
Session 1	**Near Field WPT**
09:00-09:50	**Fundamentals of Inductive Power Transfer** *Duleepa Thrimawithana, University of Auckland, New Zealand*
09:50-10:40	**An introduction to MHz IPT** *Paul Mitcheson, Imperial College, UK*
10:40-11:00	Break
11:00-11:50	**Analysis of proximity and skin effects and optimal design of effective coils in magnetic coupled wireless power transfer** *Young-Jin Park, KERI, Korea*
11:50-12:40	**EMC and EMF Issues in Near Field Wireless Power Transfer System** *Mauro Feliziani, University of Aquila, Italy*
12:40-14:00	Lunch
Session 2	**Far Field WPT**
14:00-14:50	**WPB systems** *Hooman Kazemi, Raytheon, USA*
14:50-15:40	**Far Field WPT Theory and Techniques - Antennas, Beam Forming, and Target Detecting** *Naoki Shinohara, Kyoto University, Japan*
15:40-16:00	Break
16:00-16:50	**RF-DC converter design and Waveform design for efficiency increase** *Nuno Borges Carvalho, University of Aveiro, Portugal*
16:50-17:40	**Co-Design of Far-field energy sources and battery-less sensor for the Industrial IoT** *Alessandra Costanzo, University of Bologna, Italy*
17:40-18:00	Closing remarks by WPT School Chair (*Nuno Borges Carvalho)*

Fundamentals of Inductive Power Transfer

Duleepa J. Thrimawithana
The University of Auckland, Auckland New Zealand

Abstract: Currently, there is a strong drive to electrify the transportation sector as a solution to the environmental and economic impacts of vehicles using internal combustion engines. However, to-date, limitations of battery technologies have hindered the uptake of electric vehicles (EVs). For example, the main drawbacks commonly associated with EVs are the limited range and long charging times, both of which are a direct result of the low energy and power densities of current battery technologies. These issues are further aggravated due to the fact that the EVs need to be plugged-in to refuel, as it can take many hours to fully-charge a depleted EV battery. Although, fast and extreme fast charging systems have been developed and deployed to help EV users refuel in a fraction of an hour, this is achieved at the expense of battery life and user safety. In contrast, wireless charging of stationary and in-motion electric vehicles promises a future where EVs are replenished organically, thus avoiding long charging times, range anxiety and battery degradation. An ubiquitous wireless charging infrastructure, especially one that is bi-directional, can be used to provide grid services, thus not only drastically improving the uptake of EVs, but also supporting grids with high penetration of renewable electricity.

This workshop will start with a brief discussion on the history of wireless power transfer (WPT) technology. Subsequently, the fundamental operating principles of a wireless EV charger will be presented, and commonly used wireless charging solutions will be reviewed. This will be followed by a discussion on some of the unique technologies developed by the WPT research group at the University of Auckland, highlighting their key features and benefits. To conclude the presentation, our vision for a ubiquitous wireless charging infrastructure will presented along with key research questions that needs to be addressed to make this vision a reality.

Biography: Duleepa J. Thrimawithana, received his BE in Electrical Engineering (with First Class Honors) in 2005 and his Ph.D. in power electronics in 2009 from The University of Auckland, Auckland, New Zealand. From 2005 to 2008, he worked in collaboration with Tru-Test Ltd. in Auckland as a Research Engineer in the areas of power converters and high-voltage pulse generator design. He joined the Department of Electrical and Computer Engineering at The University of Auckland in 2009 where he currently works as a Senior Lecturer. He has co-authored over 100 international journal and conference publications and holds 18 patent families on wireless power transfer technologies. In recognition of his outstanding contributions to engineering as an early carrier researcher, Dr. Thrimawithana received the Jim and Hazel D. Lord Fellowship in 2014. His main research areas include wireless power transfer, power electronics and renewable energy.

An Introduction to MHz IPT

Paul Mitcheson
Imperial College London
UK

Abstract: This tutorial will address the motivation for using higher frequencies for IPT, and investigate the properties and design of the magnetic link at such frequencies. We will then look at circuit topologies (both inversion and rectification) that are suitable for high frequency operation and provide some examples of systems and applications for which MHz IPT has a role to play.

Biography: Paul Mitcheson received the MEng degree in Electrical and Electronic Engineering in 2001 and the PhD degree in 2005 both from Imperial College London. He is currently Professor of Electrical Energy Conversion in the Control and Power Research Group in the Electrical Engineering Department at Imperial and has research interests in energy harvesting systems, wireless power transfer and power electronics. He is a fellow of the higher education academy and senior member of the IEEE. He was general co-chair of PowerMEMS 2013, held in the Royal Society, London and of Wireless Power Week 2019, held at the IET Savoy Place, London. He sits on the Executive Committee of the UK Power Electronics Centre.

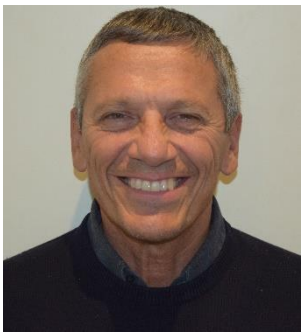
Analysis of proximity and skin effects and optimal design of effective coils in magnetic coupled wireless power transfer

Young-Jin Park
Korea Electrotechnology Research Institute (KERI), Korea

Abstract: Coil optimization is very important to improve coupling efficiency in a magnetic coupled wireless power transfer system. Coupling efficiency between two coils is related to AC resistance and self inductance of each coil and mutual inductance mainly. The resistance is related to turn number, coil size, thickness of wire, frequency, and so on. Also, it will be noted that the resistance of a coil is influenced mainly by skin effect and proximity effect caused by eddy current in metal wires. In the lecture, skin and proximity effects caused by eddy current in metal wires will be introduced. For calculation of resistance and analysis of skin and proximity effects, volume filament model is used. At first, resistance and self inductance of multi parallel straight round and rectangular wires are calculated and analyzed. Second, multi round loop coils and PCB loop coils are considered. It will be shown that by calculating AC resistance and self inductance, an optimal coil with maximum Q-factor can be designed with a physical dimension. Also, an optimization method for a compact effective WPT system design is displayed by the proposed method.

Biography: Young-Jin Park (S'99, M'03), received the B.S. degree from Chung-Ang University, Seoul, Korea, in 1997 and the M.S. degree in electrical engineering from the Korea Advanced Institute of Science and Technology, Taejon, Korea, in 1999. He received Dr.-Ing. in Electrical engineering and information technology from the Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany in 2002. From Mar. 2002 to Oct. 2002, he was a Research Associate at the Institute of High frequency technology and Electronics (IHE) in the KIT, Karlsruhe, Germany. From Nov. 2002, he has been with the Korea Electrotechnology Research Institute (KERI), where he is currently a Principal Researcher and the Director of the Electric-Medical Device Research Center. Since 2005, he has been an Adjunct Professor at University of Science and Technology (UST). His current research interests include wireless power transfer based on magnetic coupling and microwave and mm-wave antennas and propagation. Dr. Park was the recipient of Best Paper Awards at the IEEE MTT-S IMWS-IWPT 2011.

EMC and EMF Issues in Near Field Wireless Power Transfer System



Mauro Feliziani
University of L'Aquila
Italy

Abstract: The focus of this talk is on the analysis of electromagnetic compatibility (EMC) and electromagnetic field (EMF) safety aspects of Near Field Wireless Power Transfer Systems. Particularly, next generation of electric vehicles (EVs) equipped with WPT systems are considered. The WPT systems used to wirelessly recharge the internal batteries of EVs are intentional sources of time-varying magnetic fields inside and beside the EVs. A big concern is on the compliance of the emitted magnetic fields with the EMC and EMF safety standards and regulations also because the use of traditional technique for magnetic field mitigation is not efficient or can reduce the WPT performance. Furthermore, the use of EV bodyshell made by carbon fiber reinforced polymer (CFRP) increases the public health concern since CFRP is quite transparent to the magnetic field. The talk is mainly addressed to advanced models and methods for shielding, field mitigation, coil design and human exposure. Electromagnetic interference (EMI) assessment of active implantable medical devices (AIMDs) in patients inside and outside EVs is also presented.

Biography: Mauro Feliziani (M'91-SM'00) received the Laurea Degree in Electrical Engineering from Sapienza University of Rome, Rome, Italy, in 1983. From 1987 to 1994 he was with Sapienza University as a Researcher (1987-1992), and Associate Professor (1992-1994). In 1994 he joined the University of L'Aquila, Italy, as Full Professor of Electrical Engineering. He is the author or coauthor of more than 200 peer reviewed papers published in the fields of electromagnetic compatibility (EMC) and in electromagnetic field numerical computation. His current research interests include wireless power transfer and bioelectromagnetics. Prof. Feliziani was the recipient of the Best Paper Award of the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS - Electrostatics Process Committee - in 1995, the and the EMC Europe Symposium, in 2000. He was also co-author of: Best Student Paper at the IEEE International Symposium on EMC, Honolulu, USA, 2007; Second Best Student Paper at the BEMS Annual Meeting, Cancun, Mexico, 2006; Best Poster Presentation at the IEEE CEFC 2014, Annecy, France, and Best Conference Paper at WIRELESS POWER WEEK, London, UK, 2019. From 1995 to 2000, he was Associate Editor of the IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY. In March 2003, he was the Guest Editor of a special issue of the IEEE TRANSACTIONS ON MAGNETICS. In 2008, he was the Guest Editor of a Special Section of COMPEL. In 1994 he was co-founder of EMC Europe Symposium. He was the General Chair of the EMC Europe Symposium, Sorrento, Italy, in 2002, and of the EMC Europe Workshop, Rome, in 2005. He was the Technical Program Committee Chair of EMC Europe 2012, Rome, Italy. He was the President of the International Steering Committee of the EMC Europe Symposium in 2012-2015. He is the General Chair of the EMC Europe Symposium 2020, Rome, Italy.

WPB systems

Hooman Kazemi
Space and Airborne Systems
Raytheon Westlake Village-RVS
USA

Abstract: Wireless power transmission has been researched in the scientific and engineering community throughout the years for delivery of power to remote sites. In recent years, the near-field applications such as inductive and capacitive charging have provided key application need for the research and development within the WPT community. Far-field applications however have been discussed and demonstrated since 1950s with Bill Brown highlighting the modern era power beaming techniques and with record power levels delivered with associated high efficiencies. Far-field WPT demonstration since the 1950s have shown limited progress towards increased capability of such systems mainly due to the required power and size of the transmitter and rectenna receiver subsystems. The presentation focuses on the development of a new class of transmitters for far-field WPT demonstrated at millimeter wave frequency range together with rectenna receiver concepts for high efficiency power transfer.

The 92 GHz transmitter is capable of > 7kW of radiated power which can be focused on a rectenna receiver at distances of 300m to a kilometer. The presentation discusses the component technologies such as the transmitter power modules and its power source and overall mobility for various concepts of operation. The rectenna receiver technologies will also be discussed showcasing GaAs, GaN semiconductor technology circuits and new trends in the device technologies that will allow improved Overall performance. The presentation will also review far-field WPT applications for unmanned aerial and ground vehicles and major improvements that can result from the millimeter wave WPT technology compared to other state of the art WPT technologies.

Biography: Dr. Hooman Kazemi is an Engineering Fellow at Raytheon Space and Airborne System. He has been developing advanced Microwave, millimeter wave technologies for over 20 years. He received his Masters and PhD from University of Leeds, UK in 1996 and has been involved in advanced research and development of next generation systems and components. These include advanced Solid state power amplifiers, novel sensors, see thru clothing imaging systems, high data rate communication links and directed energy sources and receivers. His recent focus is on developing millimeter wave wireless power systems including high power sources and high efficiency receivers delivering power at long range for a variety of applications. He currently developing high power Rectenna circuits and systems together with a variety of sources to enable stand-off wireless power beaming in various modalities of ground, air and space.

Far Field WPT Theory and Techniques - Antennas, Beam Forming, and Target Detecting

Naoki Shinohara
Kyoto University
Japan

Biography: Naoki Shinohara received the B.E. degree in electronic engineering, the M.E. and Ph.D (Eng.) degrees in electrical engineering from Kyoto University, Japan, in 1991, 1993 and 1996, respectively. He was a research associate in Kyoto University from 1996. From 2010, he has been a professor in Kyoto University. He has been engaged in research on Solar Power Station/Satellite and Microwave Power Transmission system. He was IEEE MTT-S Distinguish Microwave Lecturer (2016-18), and is IEEE MTT-S Technical Committee 26 (Wireless Power Transfer and Conversion) former chair, IEEE MTT-S Kansai Chapter TPC member, IEEE Wireless Power Transfer Conference founder and advisory committee member, URSI commission D vice chair, international journal of Wireless Power Transfer (Cambridge Press) executive editor, the first chair and technical committee member on IEICE Wireless Power Transfer, Japan Society of Electromagnetic Wave Energy Applications president, Space Solar Power Systems Society vice chair, Wireless Power Transfer Consortium for Practical Applications (WiPoT) chair, and Wireless Power Management Consortium (WPMc) chair. His books are “Wireless Power Transfer via Radiowaves” (ISTE Ltd. and John Wiley & Sons, Inc., “Recent Wireless Power Transfer Technologies Via Radio Waves (ed.)” (River Publishers), and “Wireless Power Transfer: Theory, Technology, and Applications (ed.)” (IET), and some Japanese text books of WPT.

RF-DC converter design and Waveform design for efficiency increase

Nuno Borges Carvalho
University of Aveiro
Portugal

Abstract: RF-DC converters is one of the main bottlenecks when designing Wireless Power Transmission Links, its design and analysis is fundamental to increase the overall DC-DC efficiency of wireless power transmission solutions. In this talk we will discuss how to use large signal S parameters to optimize RF-DC converters, when signals vary over frequency and power, the issues for low power densities will also be discussed from a device point of view. On top of this a discussion on the signal shape to increase RF-DC conversion efficiency will also be explored and explained, the use of multi-sine waveforms, modulated and chaotic pulse shapes will be explored as a way to increase overall efficiency.

Biography: Nuno Borges Carvalho (S'97–M'00–SM'05-F'15) was born in Luanda, Angola, in 1972. He received the Diploma and Doctoral degrees in electronics and telecommunications engineering from the University of Aveiro, Aveiro, Portugal, in 1995 and 2000, respectively. He is currently a Full Professor and a Senior Research Scientist with the Institute of Telecommunications, University of Aveiro and an IEEE Fellow. He coauthored Intermodulation in Microwave and Wireless Circuits (Artech House, 2003), Microwave and Wireless Measurement Techniques (Cambridge University Press, 2013) and White Space Communication Technologies (Cambridge University Press, 2014). He has been a reviewer and author of over 200 papers in magazines and conferences. He is the Editor in Chief of the Cambridge Wireless Power Transfer Journal, an associate editor of the IEEE Microwave Magazine and former associate editor of the IEEE Transactions on Microwave Theory and Techniques and IET Microwaves Antennas and Propagation Journal. He is the co-inventor of six patents. His main research interests include software-defined radio front-ends, wireless power transmission, nonlinear distortion analysis in microwave/wireless circuits and systems, and measurement of nonlinear phenomena. He has recently been involved in the design of dedicated radios and systems for newly emerging wireless technologies. Dr. Borges Carvalho is a member of the IEEE MTT ADCOM, the chair of the IEEE MTT-20 Technical Committee and the past-chair of the IEEE Portuguese Section and MTT-11 and also belong to the technical committees, MTT-24 and MTT-26. He is also the vice-chair of the URSI Commission A (Metrology Group). He was the recipient of the 1995 University of Aveiro and the Portuguese Engineering Association Prize for the best 1995 student at the University of Aveiro, the 1998 Student Paper Competition (Third Place) of the IEEE Microwave Theory and Techniques Society (IEEE MTT-S) International Microwave Symposium (IMS), and the 2000 IEE Measurement Prize. He is a Distinguished Microwave Lecturer for the IEEE Microwave Theory and Techniques Society.

Co-Design of Far-field energy sources and battery-less sensor for the Industrial IoT

Alessandra Costanzo
University of Bologna
Italy

Abstract: This lecture will illustrate the design approach to implement battery-less wireless sensor network in harsh environments by adopting ultra-low power radios and dedicated RF sources at 2.45 GHz. The procedure is suitable for many use cases, such as industrial plants or automotive environments for predictive maintenance and components diagnosis. A co-designing method is illustrated to develop a system of independent RF sources for easy integration into the environment and for providing energy wirelessly in a pervasive way. The procedure proposed in this lecture demonstrates the successful deployment of battery-less sensors remotely powered by the designed RF sources and their simultaneous communication with a gateway in order to monitor vital parameters. The design of multi-layered energy harvesting nodes, for miniaturization purposes is also described.

Biography: Alessandra Costanzo is full professor at the University of Bologna, Italy since 2018. She is currently involved in research activities dedicated to design of entire wireless power transmission systems, based on the combination of EM and nonlinear numerical techniques, adopting both far-field and near-field solutions, for several power levels and operating frequencies. She has authored more than 200 scientific publications on peer reviewed international journals and conferences and several chapter books. She owns four international patents. She is co-founder the EU COST action IC1301 WiPE “Wireless power transfer for sustainable electronics”, just ended where she chaired WG1: “far-field wireless power transfer”. She was workshop chair of the EuMW2014. In 2018 she is ExCom chair of the WPTC2018 and TPC co-chair of the IEEE IMARC 2018. and of WPTC2019. She is the past-chair (2016-2017) of the MTT-26 committee on wireless energy transfer and conversion and member of the MTT-24 committee on RFID. She has served as associate editor of the IEEE Transaction on MTT, of the Cambridge International Journal of Microwave and Wireless Technologies and of the Cambridge International Journal of WPT. Since 2016 she is steering committee chair of the new IEEE Journal of RFID. She is MTT-S representative and Distinguished Lecturer of the CRFID, where she also serves as MTT-S representative. She is IEEE senior member.