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IEEE Wireless Power Week Technical Program June 2 2021

Keynote 1, Chairs: Chris Mi, Jenshan Lin

Shaping the Future of RF Wireless Power Transmission

Cesar Johnston, Chief Operating Officer and Executive Vice President of Engineering, Energous

The proliferation of handheld devices across our daily lives means we are often tethered via wires to power outlets. New, inductive-based technologies are enabling us to remove wires from the equation and eliminate the frustration of having to periodically plug in our gadgets. But, as wireless charging evolves and customers' requirements increase, a second-generation technology is needed to support multiple device charging, freedom of placement, and most important wireless power delivery at-a- distance from the wireless charger—not just at contact. Cesar Johnston, COO and EVP of Engineering at Energous and a leading authority on wireless power, will share his vision for the future of Wireless Power Transmission and the five big breakthroughs that are enabling this emerging technology to transform the way consumers and industries wirelessly charge and power electronic devices at home, in the office, in the car and beyond.

Technical Session TS1: Coil and Inductive Coupler

Chairs: Jenshan Lin, Zhizhang David Chen

TS1.1 Design of Reactive Shield Coil for Wireless Charger With Multiple Coils.....N/A

WPTC Sungryul Huh (Korea Advanced Institute of Science and Technology (KAIST), Korea (South)); Jaehyoung Park (Samsung Electronics, Korea (South)); Seonghun Lee and Kyunghwan Kim (LG Electronics, Korea (South)); Seongho Woo, Changmin Lee, Jaewon Rhee, Seokhyeon Son and Seungyoung Ahn (Korea Advanced Institute of Science and Technology, Korea (South))

Keynote 2, Chairs: Alessandra Costanzo, Simon Hemour

To Get A Grip on The Earth and Shake It: Nikola Tesla's Scheme for Wireless Power Transmission

W. Bernard Carlson, Vaughan Professor of Humanities, University of Virginia

Along with developing a practical AC motor, Nikola Tesla [1856-1943] contributed to electrical engineering by working for fifteen years on a scheme to transmit power wirelessly around the world. Inspired by the experiments of Heinrich Hertz and spurred on by a rivalry with Guglielmo Marconi, Tesla built two broadcasting stations, first in Colorado Springs [1899-1900] and then at Wardenclyffe on Long Island [1901-1905]. At these locations, Tesla pumped energy into the earth's crust in order to set up a stationary electromagnetic wave at the earth's resonant frequency. Tesla believed that people would tap into this wave for power and messages by simply grounding a receiver that "would be no bigger than a pocket watch." In this talk, I will outline the evolution of Tesla's thinking about wireless power in the 1890s and 1900s as well as his unsuccessful efforts to launch a business around this technology with funding from J.P. Morgan and others. Overall, I will suggest that Tesla was motivated to provide messages and power to millions of people and hence was among the first to recognize that the Information Revolution of the twentieth century would be about empowering individual users.

Technical Session TS2: Rectifiers and Rectennas

Chairs: Simon Hemour, Alessandra Costanzo

TS2-1 Joint Impact of Input Power, PAPR, and Load Resistance on the Receiver Efficiency of Multisine Waveforms in RF Energy Harvesting.....N/A

WPTC Nachiket Ayir and Taneli Riihonen (Tampere University, Finland)

TS2-2 On the Analytical Optimal Load Resistance of RF Energy Rectifier.....N/A

WPTC Lichen Yao (Eindhoven University of Technology & Holst Centre / IMEC-NL, The Netherlands); Guido Dolmans (Holst Centre / IMEC-NL, The Netherlands); Jac Romme (IMEC / Holst Centre, The Netherlands)

TS2-3 Dispenser Printed Flexible Rectenna for Dual-ISM Band High-Efficiency Supercapacitor Charging.....N/A

WPTC Mahmoud Wagih, Alex S Weddell and Stephen Beeby (University of Southampton, United Kingdom (Great Britain))

TS2-4 The 2.4 GHz Band SOI-CMOS High Power Bridge Rectifier IC With the Cross Coupled CMOS Pair.....N/A

WPTC Atsuya Hirono, Yuki Muramoto, Shunya Tsuchimoto, Naoki Sakai and Kenji Itoh (Kanazawa Institute of Technology, Japan)

TS2-5 A 2.45 GHz Shielded, Miniature Power and Data Receiver.....N/A

WPTC Hubregt J. Visser (imec The Netherlands, The Netherlands); Khodr Hammoud (Eindhoven University of Technology, The Netherlands)

TS2-6 Analysis of mmWave Rectifiers With an Accurate Rectification Model.....N/A

WPTC Si-Ping Gao (National University of Singapore, Singapore); Hao Zhang (Northwestern Polytechnical University, China); Yong-Xin Guo (National University of Singapore, Singapore)

TS2-7 Development of Class-R Rectifier for Microwave Wireless Power Transmission to EV Trucks.....N/A

WPTC Koki Miwatashi and Naoki Shinohara (Kyoto University, Japan)

TS2-8 A Nano-Power Self-Clocked D-LDO for RF Energy Harvesting.....N/A
WPTC Christos Konstantopoulos (University Of Innsbruck, Austria); Thomas Ussmueller (Universität Innsbruck, Austria)

TS2-9 Transparent and Flexible Self-Dual Antennas for Hybrid Inductive/Capacitive and Radiative Power Transfer.....N/A
WPTC Liang Zhu, Xuecong Nie and Pai-Yen Chen (University of Illinois at Chicago, USA); L. Jay Guo (University of Michigan, USA)

Keynote 3, Chairs: Khurram Afridi, Zhichao Luo

Wireless Charging for Electrified Roadways

Burak Ozpineci, Distinguished R&D Staff Head | Vehicle and Mobility Systems Research Section, Oakridge National Laboratory (ORNL), USA

With the demonstrations of high power static wireless charging systems, high power dynamic wireless charging is a possibility for future electrified roadways. Dynamic wireless charging feasibility has been studied at Oak Ridge National Laboratory (ORNL) where it was shown that with higher than 200kW wireless power transfer, less than 10% of each mile could be electrified for charge sustaining operation. The idea is not necessarily charging the electric vehicle batteries to full state of charge but to provide enough energy to the vehicles so that the charge they use during a mile of roadway can be recovered. This potentially opens up opportunities for unlimited range for electric vehicles. A recent update on ORNL's work in this area will be covered in this presentation as well as challenges observed. Possible comparisons to extreme fast charging systems will also be discussed.

Technical Session TS3: Stationary and Dynamic EV Charging

Chairs: Zhichao Luo, Seungyoung Ahn

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Keynote 4, Chairs: Don Tan, Al-Thaddeus Avestruz

Wireless Charging For Electric Vehicles: Moving To Mainstream

Morris Kesler, Chief Technical Officer, WiTricity

The desire for wireless charging of electric vehicles has been around for at least a decade and is now poised to move onto mainstream electric vehicles (EVs). Interest in EVs and in electric mobility, in general, has never been greater, and automakers and other E-mobility companies are investing heavily in new platform development. Wireless charging technology is ready to make charging these platforms a simple, hassle-free experience and even enable new opportunities for mobility and autonomy. The first standard development activity for EV wireless charging recently (October 2020) culminated with the publication of the SAE J2954 standard for wireless charging of light-duty vehicles. This opens the door for broad deployment, providing a means for creating systems that are interoperable across different manufacturers and vehicle types and makes public wireless charging infrastructure possible. However, a wireless power product involves much more than just power transfer. In this presentation, we will review requirements for a practical EV wireless charging system, explore key system considerations and solutions, and look at where the technology is headed as we move into the age of E-mobility.

Technical Session TS4: IoT, Industrial, Safety, and Sensors

Chairs: Al-Thaddeus Avestruz, Don Tan

Keynote 5, Chairs: Grant Covic, Rod Kim

Wireless Power 2.0: What Will It Take to Get There and When Will It Happen?

Alex Lidow, CEO and Co-Founder, Efficient Power Conversion

There are hundreds of millions of people who have experienced the first generation of wireless power transfer technology based on inductive coupling and the Qi format. The promise of convenience has only partially

been realized as the limitations of precise positioning and slow charging speeds have become more acute as fast charging of cell phones has become more important to the consumer. Magnetic resonance has long promised to overcome the limitations of Qi with its ability to (a) safely transfer much higher power, (b) enable spatial freedom stemming from large surfaces that can produce uniform magnetic fields, and (c) the ability to have one transmitter couple to a multitude of receivers. In this talk we will discuss the technological, financial, and emotional barriers that need to be broached before widespread consumer adoption of this next generation wireless power technology will gain traction.

Technical Session TS5: Inductive WPT Circuits and Systems

Chairs: Rod Kim, Grant Covic

Language and nomenclature affect the way we think. In recent years, the taxonomy of wireless power has grown to include technologies and modalities across a wide range. Whether it refers to short- range energy

transmission between systems without connectors or long-range delivery of energy over distances far exceeding a meter, there is value in defining the different classifications of wireless power transmission. In this keynote, Dr. Jaffe will give a summary overview of different approaches to one such classification scheme, in which power beaming will be distinguished as a clear subset of wireless power transmission. He will review recent progress for microwave, millimeter-wave, and optical power beaming, and discuss near-term plans and next steps. The discussion will be framed by the contexts of emerging applications and of longer-term visions of future possibilities.

Technical Session TS6: Far Field WPT

Chairs: Mohamed Abouzied, Christopher Rodenbeck

TS6-1 Range Selective Power Focusing With Time-Controlled Bi-Dimensional Frequency Diverse Arrays.....N/A

WPTC Enrico Fazzini (Università di Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Diego Masotti (University of Bologna, Italy)

TS6-2 28 GHz Microwave Power Beaming to a Free-Flight Drone.....N/A

WPTC Ryoma Moro, Naoki Keicho, Kota Motozuka, Maho Matsukura and Kohei Shimamura (University of Tsukuba, Japan); Masafumi Fukunari (University of Fukui, Japan); Koichi Mori (Nagoya University, Japan)

TS6-3 Electric Field Resonant Antenna for Wireless Power Transfer Based on Infinitesimal Dipole.....N/A

WPTC Takanori Washiro (Nippon Telegraph and Telephone Corporation, Japan)

TS6-4 Theoretical Analysis of Retro-Reflective Beamforming Schemes for Wireless Power Transmission to Multiple Mobile Targets.....N/A

WPTC Min Liu, Xin Wang and Songpeng Zhang (Nanjing University of Aeronautics and Astronautics, China); Mingyu Lu (West Virginia University Institute of Technology, USA)

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Keynote 7, Chairs: Chris Mi, Amir Mortazawi

Addressing the Charging Problem for Every Vehicle Type: Universal Wireless Power

Andrew Daga, CEO and Co-founder, Momentum Dynamics

As the world moves forward toward electrified transportation and logistics, it has become increasingly clear that charging infrastructure is critical to the rate of adoption, and even the rate of production of electric vehicles. We recognize that not all-electric vehicles are passenger cars – in fact, they necessarily include every type of vehicle – including all classes of trucks, buses, industrial equipment, logistics handling, and even rail and marine vehicles. Each of these use cases has a set of technical, operational, and economic requirements. The common challenges in the deployment and operation of EV charging infrastructure that can meet the needs of all of these types of vehicles are: maximizing utilization of the vehicles and charging equipment; minimizing the capital expense of the infrastructure and determining who will bear it; minimizing overall operating expense (including charging costs) and simplifying operations; operating within spatially constrained areas; minimizing changes to efficient operations; and determining how operators of charging equipment can build sustainable, profitable economic models. To date, these challenges have not been adequately addressed by manually operated conductive (or plug-in) charging. The presentation will provide a status update on the commercialization of automatically operated inductive charging, and how inductive charging has proven its capacity to solve each of these problems. The case for a common automatic charging system composed of inductive charging modules that can be scaled to any type of vehicle and any power level will be made.

Technical Session TS7: Capacitive Power Transfer

Chairs: Amir Mortazawi, Aiguo Patrick Hu

Keynote 8, Chairs: J.-C. Chiao, Souvik Dubey

Safety of RF Wireless Power Transfer Technology

James Lin, Professor Emeritus, University of Illinois at Chicago

Wireless power transfer (WPT) systems are being deployed to provide needed electric power either directly or via battery-charging services using a very wide spectrum. The optimism on WPT technology is clearly driven by the ubiquity of cell phones, laptops, and other mobile communication devices. Aside from not having to plug in the mobile phone or laptop, an fascinating cause for the interest in battery charging through WPT comes from the potential for mobile communication devices to get their electrical power the same way they get their data through harvesting ambient electromagnetic radiation. The dream is a truly wireless mobility scenario with completely tether-free electric power supply for mobile phones, laptops, electric appliances, and various transportation systems. Beyond wireless communication uses, the level of transmitted electromagnetic power required for large-scale or commercial implementation of WPT would be substantial. A key facet of the system design and research effort should include consideration of biological effects and human safety, especially in the RF region of the electromagnetic spectrum. This talk will feature my perspectives

on RF safety of WPT technologies.

Technical Session TS8: Biomedical Applications

Chairs: Souvik Dubey, Aasrith Ganti

TS8-1 A Smart Health Tracking Ring Powered by Wireless Power Transfer.....N/A

WPTC Son Nguyen (University of California Davis, USA); Connie Duong (University of California, Davis, USA); Rajeevan Amirtharajah (University of California Davis, USA)

TS8-2 Wireless Power Supply System for Left Ventricular Assist Device and Implanted Cardiac Defibrillator.....N/A

WPTC Tommaso Campi and Silvano Cruciani (University of L'Aquila, Italy); Francescaromana Maradei (University of Rome La Sapienza, Italy); Mauro Feliziani (University of L'Aquila, Italy)

TS8-3 Wireless Torque Transfer Using Multiple Coils With Different Phases.....N/A

WPTC Jaewon Rhee, Yujun Shin and Haerim Kim (Korea Advanced Institute of Science and Technology, Korea (South)); Jongwook Kim (KAIST(Korea Advanced Institute of Science and Technology), Korea (South)); Changmin Lee (Korea Advanced Institute of Science and Technology, Korea (South)); Sungryul Huh (Korea Advanced Institute of Science and Technology(KAIST), Korea (South)); Seongho Woo, Seokhyeon Son and Seungyoung Ahn (Korea Advanced Institute of Science and Technology, Korea (South))

TS8-4 Physical Bounds on Implant Powering Efficiency Using Body-Conformal WPT Systems.....N/A

WPTC Icaro V Soares (Institut do Électronique et des Technologies du Numérique & Université de Rennes 1, France); Mingxiang Gao (Swiss Federal Institute of Technology in Lausanne, Switzerland); Anja K. Skrivervik (EPFL, Switzerland); Zvonimir Sipus (University of Zagreb, Croatia); Maxim Zhadobov (University of RENNES 1, France); Ronan Sauleau (University of Rennes 1, France); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France)

TS8-5 Resonant Coupler Designs for Subcutaneous Implants.....N/A

WPTC Sen Bing, Khengdauliu Chawang and Jung-chih Chiao (Southern Methodist University, USA)

TS8-6 An Implantable Wireless Charger System With ×8.91 Increased Charging Power Using Smartphone and Relay Coil.....N/A

WPTC Hankyu Lee, Seungchul Jung, Yeunhee Huh and Jaechun Lee (Samsung Advanced Institute of Technology, Korea (South)); ChiSung Bae (Samsung Electronics, Korea (South)); Sang Joon Kim (Samsung Advanced Institute of Technology, Korea (South))

TS8-7 Design of a Wireless Power and Data Transfer System for pH Sensing Inside a Small Tube.....N/A

WPTC Fatemeh Mohseni, Paul Marsh and Filippo Capolino (University of California, Irvine, USA); Jung-chih Chiao (Southern Methodist University, USA); Hung Cao (University of California, Irvine, USA)

TS8-8 Magnetoelectric Versus Inductive Power Delivery for Sub-mm Receivers.....N/A

WPTC Adam Khalifa (Massachusetts General Hospital & Harvard Medical School, USA); Mehdi Nasrollahpour, Neville Sun, Mohsen Zaeimbashi, Huaihao Chen and Xianfeng Liang (Northeastern University, USA); Milad Alemohammad Alemohammad (Johns Hopkins University, USA); Ralph Etienne-Cummings (John Hopkins University, USA); Nian Sun (Northeastern University, USA); Sydney Cash (Massachusetts General Hospital, USA)

TS8-9 Demonstration of Healthcare-Specific Li-Ion Battery Charging Using Ultrasound Power Delivery.....N/A

WPTC Inder Raj S Makin (A. T. Still University, USA); Harry Jabs (Piezo Energy Technologies, USA); T. Douglas Mast (University of Cincinnati, USA); Leon Radziemski (Piezo Energy Technologies, USA)

Keynote 9, Chairs: Chris Mi, Naoki Shinohara

Worldwide Standardization of Wireless Power Transfer for EVs, SAE J2954

Jesse Schneider, Chair; CEO/ CTO, SAE Wireless Power Transfer Taskforce, J2954; ZEV Station

Electric and Plug-in Electric vehicles are just beginning to be commercialized in large scale production which are charged through conductive charging with multiple plug types. There are numerous advantages which wireless power transfer (WPT) offers, effectively charging without cables, related to improved customer acceptance of the charging and automatic charging of autonomous electric vehicles. In order to establish a worldwide standard, to ensure a smooth implementation of the WPT to 11kW related to safety, performance, interoperability vehicle alignment SAE published the J2954 standard. The standard establishes a specification for the vehicle & infrastructure EVSE coils, EMC/EMF limits and a common methodology for validation and testing WPT. An overview of the newly published Standard, SAE J2954 will be given including some background for the testing with automaker and supplier systems to validate. In addition, plans for the next phase of standardization for both light and heavy-duty electric vehicles will be given.

Technical Session TS9: Low Power Inductive and Ultrasound Methods

Chairs: Naoki Shinohara, Jenshan Lin

TS9-1 Pre-Charged Collapse-Mode Capacitive Micromachined Ultrasonic Transducer (CMUT) for Broadband Ultrasound Power Transfer.....N/A

WPTC Shinnosuke Kawasaki, Youri Westhoek, Indulakshmi Subramaniam and Marta Saccher (Delft University of Technology, The Netherlands); Ronald Dekker (Philips Research, The Netherlands)

TS9-2 A Novel Magnetically Coupled Resonant Wireless Power Transfer Technique Used in Rotary Ultrasonic Machining Process.....N/A

WPTC Xianpeng Qiao and Wu Yongbo (Southern University of Science and