2017 Asian Wireless Power Transfer Workshop (AWPT 2017)

Final Technical Program

DECEMBER 9-11, 2017 | SINGAPORE

Organized by
National University of Singapore

Technically Co-Sponsored by
IEICE and IEEE Singapore Section

Conference Venue:

National University of Singapore
University Hall Auditorium
Level 2, Lee Kong Chian Wing
21 Lower Kent Ridge Road
Singapore 119077

http://www.ieice.org/~wpt/international/AWPT2017/

Welcome Message from the General Co-Chairs

On behalf of the organizing committee, and with great pleasure, we warmly welcome you to the 2017 Asian Wireless Power Transfer Workshop (AWPT 2017) to be held at the National University of Singapore, Singapore from December 09 to December 11, 2017. The organizing committee has put together a comprehensive technical program to facilitate the exchange of information on the progress and advancements of wireless power technologies for consumable, biomedical and industrial applications, along with a memorable and entertaining social program.

The AWPT 2017 is organized by National University of Singapore. This workshop is technically co-sponsored by IEICE and IEEE Singapore Section. The AWPT 2017 brings in a unique mix of high-quality keynote, invited and contributed papers. In particular, we urge you not to miss our keynote and invited talks, featuring innovative and enabling technologies on wireless power technologies by world-class speakers from the industry and academia.

The AWPT 2017 received a total submission of 62 submissions, including invited papers and regular papers. The technical program committee is very pleased with the quality of the submissions and we trust that you will find many papers interesting and informative. The technical session will be conducted in a single oral track over three days. In addition to the regular sessions, we are honoured to have two renowned experts as plenary speakers.

In addition to the comprehensive technical and scientific program and exciting social events, the AWPT 2017 also offers you ample opportunities to explore the most vibrant Singapore. You will be enthralled by the multitude of entertainment and leisure options available, not to mention the mouth-watering foods that you can sample in Singapore. We invite you to come and enjoy all these wonderful activities specially organized for you, see old friends and make new ones.

We look forward to welcoming you all in the Lion City!

Yongxin Guo (General Co-Chair)
National University of Singapore, Singapore
Qiang Chen (General Co-Chair)
Tohoku University, Japan

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Xiuyin Zhang, SCUT, China

Chunling Yang, NCKU, Taiwan, RoC

Jong-Gwan Yook, Yonsei Univ., Korea

Conference Venue

Venue Address
National University of Singapore
University Hall Auditorium, level 2
Lee Kong Chian Wing,
21 Lower Kent Ridge Road, Singapore 119077

How to get to the University Hall

- **By Cab**
  - Address: National University of Singapore, University Hall Auditorium, Lee Kong Chian Wing, 21 Lower Kent Ridge Road, Singapore, 119077.
  - From Changi International Airport – estimated travel time: 30 mins; Estimated charges: S$25.00 (subject to taxi type, traffic condition, routes taken, as well as peak/electronic road pricing (ERP) surcharges).

- **By MRT (Mass Rapid Transit)/Bus**
  - Nearest MRT station: Kent Ridge MRT (**Circle line – CC24**)
  - From Kent Ridge MRT station to University Hall
    - Option 1: Take internal shuttle bus A1 or D2 (free-of-charge) and alight at University Hall station
    - Option 2: Take public bus number 95 (use EZ-link card or make payment of S$1 by coin to the bus driver) and alight at University Hall station

Figure 1 – Bus stops between Kent Ridge MRT and University Hall (apply to both Internal Shuttle Bus A1, D2 and public bus number 95).

Location Map
Google Map link: https://goo.gl/maps/grwniucMLfm

Figure 2 – University Hall location

Useful Telephone Numbers

Police	999	Airport Flight Information	1800 542 4422
Fire/Ambulance	995	Directory Assistance	6777 7777
Non-Emergency Ambulance	1777	Singapore Tourism Board	1800 738 3778
Police Hotline	6225 0000	NTUC Comfort Taxi	6552 1111
Singapore General Hospital	6222 3322	Foreign Mission One Call Centre	1800 334 4800

Registration

Registration will be opened according to the following schedule:

December 09, 2017 (Saturday) 8:30–17:00, U Hall, Level 2
December 10, 2017 (Sunday) 8:30–17:00, U Hall, Level 2

The on-site registration fee is shown in the following table. If you have pre-registered, your name badge and Technical Program book will be ready for you to pick up during the above conference registration time. Please wear your name badge throughout the conference. Access will be prohibited to the exhibition, tea break, and technical sessions if a name badge is not present.

	Early-Bird (before 10 November 2017)	On-site (after 10 November 2017)
Regular	280	SGD350
Student	180	SGD230

Please remember to collect the hardcopy of the receipt from the registration desk if necessary.

AWPT 2017

Asian Wireless Power Transfer Workshop

December 9-11, 2017 | National University of Singapore, Singapore

DAY 1 Dec 9, 2017	DAY 2 Dec 10, 2017	DAY 3 Dec 11, 2017
08:30-17:00 Registration		
09:00-09:20 | Opening Address	09:00-09:45 | Session 1 **Keynote II** **Prof. Minoru Okada** NIST	09:00-10:20 | Session 1 **Systems III**
09:20-10:05 | Session 1 **Keynote I** **Prof. Baoyan Duan** Xidian University	09:45-10:25 | Session 2 **Circuits**	
10:05-10:30 | Coffee break	10:25-11:00 | Coffee break	
10:30-12:30 | Session 2 **Biomedical I**	11:00-12:30 | Session 3 **Biomedical II**	*End of conference
12:30-13:30 | Lunch break	12:30-13:30 | Lunch break	
13:30-15:30 | Session 3 **Rectifier**	13:30-15:30 | Session 4 **Antennas**	
15:30-15:50 | Coffee break	15:30-15:50 | Coffee break	
15:50-18:00 | Session 4 **Systems I**	15:50-17:40 | Session 5 **Systems II**	
Welcome Reception	Banquet	

Keynote 1

ON NEW DEVELOPMENTS OF SPACE SOLAR POWER SATELLITE (SSPS) OF CHINA

Baoyan Duan

Academician of Chinese Academy of Engineering

Full Prof of Electromechanical Engineering, Xidian University, China

Professor Duan received the B.S., M.S., and Ph.D. degrees in Mechanical Engineering from Xidian University, Xi'an, China, in 1981, 1984, and 1989 respectively. From 1991 to 1994, he studied as Postdoctoral Fellow at Liverpool University, U.K. He was a Visiting Scientist at Cornell University, Ithaca, NY, in 2000. He is currently a full Professor in the School of Electromechanical Engineering at Xidian University, where he founded the research institute on mechatronics about electronic equipment structural design. His current research interests include mechatronics, electromechanical coupling theory and application, engineering structural optimization, and CAD/CAE. He has published 5 books and authored or co-authored over 200 papers and invited presentations in international conferences and symposia.

He is a Fellow of IET and Chinese Institute of Electronics (CIE), Members of International Association for Computational Mechanics (IACM) and International Society for Structural and Multidisciplinary Optimization (ISSMO). He is Chairman of Electromechanical Engineering Society of China.

He has received the 2nd prize of national award for science and technology progress of China three times (2004, 2008 and 2013). In 2012, he was issued Hong Kang HLHL prize of science and technology progress.

CCTV (**C**hinese **C**entral **T**ele**V**ision station) produced and broadcasted a special video program titled with **DUAN Baoyan: Minor discipline and Great Vision** (http://eesd.xidian.edu.cn) in November, 2016.

Abstract

This presentation will give a comprehensive introduction about the development of Space Solar Power Satellite (SSPS) in China. Firstly, a novel design called OMEGA SSPS innovative design project is presented and its advantages over the existed projects of the world are given in details. Secondly, the corresponding theory and technologies such as the high efficiency solar power collection, new optic-electric transfer, overall thermal problem solution, wireless microwave energy transfer and the corresponding transferring antenna in space and rectenna in the earth, and so on. Thirdly, the numerical simulation results of the above points are shown to demonstrate the project. Forth, the practical experiment results and prototype are discussed. And finally, the next plan and road map of Chinese development of SSPS are given too.

Keynote 2

NON-BEAM WIRELESS POWER TRANSFER FOR GUIDED VEHICLE

Minoru Okada
Professor, Nara Institute of Science and Technology, Japan

Minoru Okada received the B.E. degree in communications engineering from the University of Electro-Communications, Tokyo, Japan, in 1990. He received the M.E and Ph.D. degrees in communications engineering from Osaka University, Osaka, Japan, in 1992 and 1998, respectively. From 1993 to 2000, he was a Research Associate at Osaka University. From 1999 to 2000, he was a Visiting Research Fellow at University of Southampton, U.K. In 2000, he joined the Graduate School of Information Science, Nara Institute of Science and Technology, Nara, Japan, as an Associate Professor and became a Professor in 2006. His research interest is wireless communications, including WLAN, digital broadcasting, and satellite communications. Dr. Okada is a member of the Institute of Image, Information, and Television Engineers of Japan (ITEJ), the Institute of Television Engineers of Japan, the Institute of Electrical, Information, and Communication Engineers of Japan (IEICE), and the Information Processing Society of Japan (IPSJ). He received the Young Engineer Award from IEICE in 1999.

Abstract
Automated Guided Vehicle (AGV) is an autonomously moving electric vehicle (EV) for carrying materials in a factory. AGV is capable of increasing the productivity, recharging the batteries is required after use, and it interrupts the production process in the plant. Therefore, AGV requires the battery charging during the motion for further improvement in the productivity and usability. This presentation introduces a non-beam wireless power transfer (WPT) system based on parallel feeder line. The proposed WPT is capable of sending power to the moving vehicles alongside the feeder line. The experimental results showed that the developed WPT could provide the electrical power to the moving vehicle in more than 100 meters of the feeding area. In this talk, we also show a WPT with multiple transmitters and receivers, or, a multiple-input-multiple-output (MIMO) WPT system. The proposed MIMO-WPT is capable of improving the transmission efficiency. Also, it is more robust in position misalignment of the couplers.

Day 1 | Saturday, December 9

Session 1 | Keynote I
Chair: Naoki Shinohara, Kyoto University, Japan

D1-S1-01	09:20-10:05	On new developments of Space Solar Power Satellite (SSPS) of China *Prof. Baoyan Duan (Xidian University)*

Coffee Break

Session 2 | Biomedical I
Co-Chairs: Kenjiro Nishikawa, Kagoshima University
Chin-Lung Yang, National Cheng Kung University

D1-S2-01	10:30-10:50	Inductive Coupling Wireless Power Transfer using Printed Spirals on Hydrocolloid Dressings **(Invited)** *Jerald Yoo (NUS)*
D1-S2-02	10:50-11:10	Mixed Helico-Spiral Coil Design Using Generic Algorithm for Biomedical Applications **(Invited)** *Chin-Lung Yang, Shao-Ping Cheng (NCKU)*
D1-S2-03	11:10-11:30	Enabling Technologies for Biomedical Applications: Antennas and Wireless Power *Yongxin Guo (NUS)*
D1-S2-04	11:30-11:50	Recent standardization activities of methods for assessment of wireless power transfer related to human exposure *Kanako Wake (NICT), Teruo Onishi (NTT DOCOMO, INC.)*
D1-S2-05	11:50-12:10	Dual-band Antenna for NFC Wireless Power Transfer and Bluetooth Communication *Yuji Tanabe, Ada S Y Poon (Stanford Univ.*)
D1-S2-06	12:10-12:30	Wireless technologies for bioelectronic therapies *John Ho (NUS)*

Lunch Break

Day 1 | Saturday, December 9

Session 3 | Rectifier
Co-Chairs: Qiaowei Yuan, National Institute of Technology, Sendai College
Raja Muthusamy Kumarasamy, IME, A*STAR

D1-S3-01	13:30-13:50	Magnetic tunnel junctions and their usage in energy harvesting **(Invited)** *Hyunsoo Yang (NUS)*
D1-S3-02	13:50-14:10	High-efficiency microwave rectifier with wide incident power range based on impedance/resistance compression network **(Invited)** *Xiu Yin Zhang, Jian Liu (SCUT)*
D1-S3-03	14:10-14:30	A Study on Influences of an Internal Resistance of a Power Supply on a Self-Biased RF-DC Conversion Circuit *Tsunayuki Yamamoto, Hiroshi Kubo, Kana Shiratsuchi (Yamaguchi Univ.)*
D1-S3-04	14:30-14:50	Microwave Rectifying Circuits with Extended Dynamic Range (**Invited**) *Pengde Wu, Kama Huang, Changjun Liu (Sichuan Univ.)*
D1-S3-05	14:50-15:00	Experimental Study on Microwave Rectifiers with Pulse Modulated Wave *Takashi Hirakawa, Naoki Shinohara (Kyoto Univ.)*
D1-S3-06	15:00-15:10	Harmonic-recycling Rectifier with Efficiency Improvement and DC Voltage Boost *Tung Ngo, Zaw Thet Aung, Yongxin Guo (NUS)*
D1-S3-07	15:10-15:20	Multiple Connection of Rectifiers for High Power RF-to-DC Conversion *Shogo Nishioka, Shinji Abe, Naoki Sakai, Takashi Ohira (TUT)*
D1-S3-08	15:20-15:30	S Band Compact Rectifiers With High Efficiency *Fei Cheng, Changjun Liu, Kama Huang (Sichuan Univ.)*

Coffee Break

Day 1 | Saturday, December 9

Session 4 | Systems I
Co-Chairs: Jong-Gwan Yook, Yonsei University
Hiroshi Hirayama, Nagoya Institute Technology

D1-S4-01	15:50-16:10	A High-Gain Multi-Beam Rectenna for RF Power Harvesting **(Invited)** *Sheng Sun (UESTC)*
D1-S4-02	16:10-16:30	Wireless Charging Coil Design for Mobile Applications **(Invited)** *Tae-Hyung Kim, Se-Hwa Yoon (Yonsei Univ.), Gi-Ho Yun (Sungkyul Univ.), Woong Yong Lee (Amotech), Jong-Gwan Yook (Yonsei Univ.)*
D1-S4-03	16:30-16:50	Efficiency Calculator for Arbitrary Transmitting/Receiving Elements *Qiaowei Yuan (NIT, Sendai College), Qiang Chen (Uni. Tohoku)*
D1-S4-04	16:50-17:10	Study on the Wireless Power Transfer System Using the 5G New Radio Access Technology *Yang-Han Lee, Yu-De Liao, Ting-Wei Lin, Yi-Lun Chen, Wen-Han Jhang, Ching-Chang Wong (Tamkang Univ.), Qiaowei Yuan (Advanced Course of Information and Electronic System Engineering), Naoki Shinohara (Research Institute for Sustainable Humanosphere (RISH) ,Yoshida-), Qiang Chen (Department of Communications Engineering, Graduate School of Eng)*
D1-S4-05	17:10-17:20	Performance Evaluation of 4x1 MISO Magnetic Resonance Beamforming Wireless Power Transfer System *Ayako Suzuki, Koshi Hamano, Keita Ohtsuka, Ryuya Tanaka, Kenjiro Nishikawa (Kagoshima Univ.)*
D1-S4-06	17:20-17:30	Methods of detecting vehicle's longitudinal and lateral position through wireless power transfer *Karam Hwang, Seungyoung Ahn (KAIST)*
D1-S4-07	17:30-17:40	Evanescent-wave Coupling for Highly Efficient Wireless Power Transfer *Daisuke Nakamichi, Hiroyasu Sato, Qiang Chen (Tohoku Univ.)*
D1-S4-08	17:40-17:50	The Relationship between the Class-F Charge Pump Rectenna Array and the DC Load *Ce Wang, Seishiro Kojima, Yang Bo, Daichi Nishio, Tomohiko Mitani, Naoki Shinohara (Kyoto Univ.)*
D1-S4-09	17:50-18:00	High-Efficiency Broadband Microwave Rectifier Based on RF Transmission-Line Transformer *Pengde Wu, Lei Zhang, Wan Jiang, Changjun Liu, Yingsheng Zhao (SiChuan Univ.)*

Day 2 | Sunday, December 10

Session 1: Keynote II
Chair: John Ho, National University of Singapore

D2-S1-01	09:00-09:45	Non-Beam Wireless Power Transfer for Guided Vehicle *Prof. Minoru Okada (NIST)*

Session 2 | Circuits
Chair: Sheng Sun, University of Electronic Science and Technology of China

D2-S2-01	09:45-10:05	Class-E^2 Converter Design for Wireless Power Transfer Application *Yen Hsiang Chang, Heng Ming Hsu (NCHU)*
D2-S2-02	10:05-10:15	Experimental Verification of Optimal Load to Achieve Maximum Efficiency in Capacitive Power Transfer with Resonance Coupling *Kenta Suzuki, Takehiro Imura, Yoichi Hori (The Univ. of Tokyo)*
D2-S2-03	10:15-10:25	Development of Power Receiving Control Circuit for Cavity Resonance Enabled Wireless Power Transfer *Ippei Takano, Daigo Furusu, Shinji Nimura, Masaya Tamura (Toyohashi Tech.)*

Coffee Break

Day 2 | Sunday, December 10

Session 3 | Biomedical II
Co-Chairs: Takehiro Imura, University of Tokyo
Shaoying Huang, Singapore University of Technology and Design

D2-S3-01	11:00-11:10	Capacitive Coupling for Wireless Power and Data Transmission to Flexible Bioelectronic Implants *Kush Agarwal, Yong-Xin Guo (NUS), Maysam Ghovanloo (Georgia Tech), Nitish Thakor (NUS)*
D2-S3-02	11:10-11:20	Reduction of SAR for Wireless Power Transfer of Visual Prosthesis Using Shielded Loop *Yuichi Yamawaki, Hiroshi Hirayama (NIT), Hideki Jonokuchi (Imra America Inc)*
D2-S3-03	11:20-11:30	Electromagnetic Bandgap Structure Enhanced Ellipsoidal Coils for Wireless Power Transfer for Ingestible Devices *Wenshen Zhou, Omkar, Shao Ying Huang (Singapore Univ. of Tech. and Design)*
D2-S3-04	11:30-11:40	Photodynamic Glioblastoma Therapy with A Wireless Light-Emitting Mesh *Lee Pui Mun, John S Ho (NUS)*
D2-S3-05	11:40-11:50	Numerical Simulations of Implantable Cardiac Pacemaker EMI Triggered by 85 kHz-band Wireless Power Transfer System *Tetsuya Sekiguchi, Takashi Hikage, Toshio Nojima (Hokkaido Univ.)*
D2-S3-06	11:50-12:00	Harmonic detection of wireless biomedical sensors *Tian Xi, John S. Ho (NUS)*
D2-S3-07	12:00-12:10	Novel Extended Non-Breakdown Rectifier Topologies for Power-Optimized Waveform based Wireless Power Transfer Systems *Hao Zhang (NUST), Zheng Zhong, Yong-Xin Guo (NUS), Wen Wu (NUST)*
D2-S3-08	12:10-12:20	Wireless Powering with Maximum Power for Biomedical Applications *Zengdi Bao, Yong-Xin Guo (NUS), Raj Mittra (UCF)*
D2-S3-09	12:20-12:30	In vivo wireless photonic photodynamic therapy *Fengyuan Yang, John Ho (NUS)*

Lunch Break

Day 2 | Sunday, December 10

Session 4 | Antennas
Co-Chairs: Akio Wakejima, Nagoya Institute Technology
Yujian Li, National University of Singapore

D2-S4-01	13:30-13:50	Implementation of High Efficiency Coupling Coil in Wireless Power Transfer System *Zhong Kai Chen, Heng Ming Hsu (NCHU)*
D2-S4-02	13:50-14:10	Design of S band Cylindrical Waveguide-slotted Omnidirectional Antenna *Fang Zhengxin, Zhang Lixin (Ecriee)*
D2-S4-03	14:10-14:30	A wideband antenna for RF energy harvesting and wireless communications *Yujian Li, Ngo Tung, Yong-Xin Guo (NUS)*
D2-S4-04	14:30-14:50	Low-loss planar SPP transmission line based on LCP technology in microwave frequencies *Liu Weihong, Qiao Kaige (Xi'an Univ. of Posts and Comm.)*
D2-S4-05	14:50-15:00	On a Transmission Efficiency of Shielded Spiral Antenna for Coupled-Resonant Wireless Power Transfer *Naoya Kajiura, Hiroshi Hirayama (Nagoya Inst.of Tech.)*
D2-S4-06	15:00-15:10	Enhanced Electromagnetic Energy Harvesting with Subwavelength Chiral Structures *Dong Zhenya, Yang Fengyuan, John Ho (NUS)*
D2-S4-07	15:10-15:20	900MHz band low power rectenna with the high-impedance folded dipole antenna *Takahiro Furuta, Kenji Itoh, Shigeru Makino, Tetsuo Hirota, Keisuke Noguchi (KIT)*
D2-S4-08	15:20-15:30	Basic Characteristics of a Folded Spiral Antenna for Coupled-resonant Wireless Power Transfer *Kohei Nimura, Hiroshi Hirayama (Nagoya Inst.of Tech.)*

Coffee Break

Day 2 | Sunday, December 10

Session 5 | Systems II
Co-Chairs: Masatoshi Suzuki, Tsukuba University
Jiafeng Zhou, University of Liverpool

D2-S5-01	15:50-16:10	High Power and Long Distance Microwave WPT using 300kW Gyrotron at 28GHz *Masatoshi Suzuki, Maho Matsukura, Kohei Shimamura, Shigeru Yokota, Tsuyoshi kariya, Ryutaro Minami, Shunsuke Minakawa, Satoru Suganuma, Sei Mizojiri (Tsukuba Univ.)*
D2-S5-02	16:10-16:30	Using Control Coil to Improve Magnetic Energy Extraction from AC Power Line Under Magnetic Saturation *Yuan Zhuang, Chen Xu, Chaoyun Song, Anqi Chen (Univ. of Liverpool), Wei Lee (Zhejiang Univ. of Tech.), Yi Huang, Jiafeng Zhou (Univ. of Liverpool)*
D2-S5-03	16:30-16:40	Identification of kQ Product for Wireless Power Transfer System with Open End Coils Based on Input Impedance Measurement *Katsuhiro Hata, Takehiro Imura, Yoichi Hori (The Univ. of Tokyo)*
D2-S5-04	16:40-16:50	Comparison of 85 kHz Self-resonant Open-end Coils with Different Types of Wire for Capacitor-less Wireless Power Transfer System *Yoshiaki Takahashi, Takehiro Imura, Yoichi Hori (The Univ. of Tokyo)*
D2-S5-05	16:50-17:00	Measurement of complex permittivity for fresh water under high electric field *Kousuke Murai, Yasumasa Naka, Takuma Nakata, Masaya Tamura (Toyohashi Tech)*
D2-S5-06	17:00-17:10	Design and Prototyping of Differential Power Receiver for Cavity Resonance enabled Wireless Power Transfer *Daigo Furusu, Ippei Takano, Shinji Nimura, Masaya Tamura (Toyohashi Univ. of Tech.)*
D2-S5-07	17:10-17:20	The Array Antenna for Solar Energy Harvesting from The Sun *Wenbo Liu, Yasuhiro Tsunemitsu (Takushoku Univ.)*
D2-S5-08	17:20-17:30	Development of a Multilayer Substrate Filter for a Compact Rectifier for Wireless Power Transfer *Kouta Okazaki (Kyoto Univ.), Shotaro Ishino (Furuno Electric Co, Ltd.), Naoki Shinohara (Kyoto Univ.)*
D2-S5-09	17:30-17:40	Design of Capacitive Coupler for High Efficiency Wireless Power Transfer Under Fresh Water *Yasumasa Naka, Kosuke Murai, Masaya Tamura (Toyohashi Tech.)*

Day 3 | Monday, December 11

Session 1 | Systems III
Co-Chairs: Karim Faeyz, Nanyang Technological University
Tung Ngo, National University of Singapore

D3-S1-01	09:00-09:20	Design of A Coil System for Electromagnetic Power Transfer and Distribution in Generation of Thermoacoustic Signals for Rail Inspection *Zilian Qu, Wensong Wang, Bonan Wayne Chen, Yongsen Dong, Zhongyuan Fang, Yuanjin Zheng (NTU)*
D3-S1-02	09:20-09:40	A Coil Array Design for Electromagnetic Field Focusing In Rail Detection *Wensong Wang, Zilian Qu, Bonan Wayne Chen, Yongsen Dong, Yuanjin Zheng (NTU)*
D3-S1-03	09:40-10:00	Design and Analysis of Data Transmission System using Magnetic Resonance Wireless Power Transfer *Kouki Nakanishi, Masaki Ishii, Masahiro Sasaki (SIT)*
D3-S1-04	10:00-10:10	Propagation Characteristics of Indoor Wireless Power Transfer Using MIMO Technology *Shingo Yamaji, Hiroshi Hirayama (Nagoya Inst. of Tech.)*
D3-S1-05	10:10-10:20	Study of Power management module for wireless energy harvesting applications *Zaw Thet Aung, Yongxin Guo (NUS)*