# Ming Liu


Ph.D. Candidate (April 2014 - Present)

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## Research Interests:

High frequency power electronics circuits such as high frequency resonant converters and wireless power transfer (WPT) systems, general power electronics and applications, circuit- and system-level optimization.

## Education:

Univ. of Michigan-Shanghai Jiao Tong Univ. Joint Institute, Shanghai Jiao Tong University, Shanghai, P.R. China

- Ph.D., Electrical and Computer Engineering, 4/2014 - Present

University of Science and Technology Beijing, Beijing, P.R. China

- M.S., Mechatronic Engineering, 9/2009 - 4/2012

SiChuan University, Chengdu, SiChuan, P.R. China

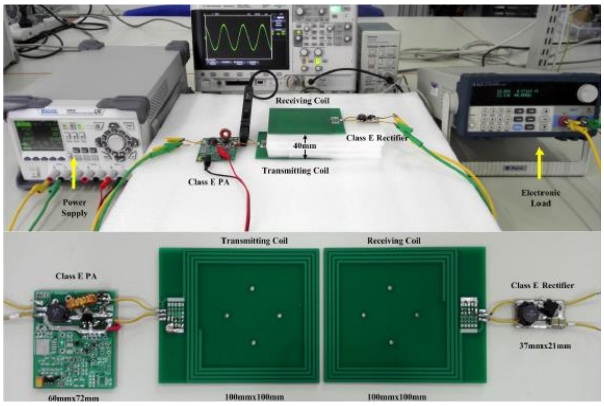
- B.S., Mechatronic Engineering, 9/2003 - 7/2007

## Work Experience:

- Assistant Research Fellow in Power Electronics, Chinese Academy of Sciences, 6/2012 - 3/2014
- Power Electronics Engineer, Beijing North Vehicle Group Corporation, 8/2007 - 7/2009

## Research Experiences:

**1. Optimized parameter design for 6.78MHz WPT systems using Class E rectifier**




Magnetic resonance coupling working at megahertz (MHz) is widely considered a promising technology for the midrange transfer of a medium amount of power. It is known that the soft-switching based Class E rectifiers are suitable for highfrequency rectification, and thus potentially improve the overall efficiency of MHz wireless power transfer (WPT) systems. In this research, the input impedance of the Class E rectifier is accurately derived, for the first time, considering the on-resistance of the diode and the equivalent series resistance of the filter inductor. This derived input impedance is then used to develop and guide design procedures that determine the optimal parameters of the rectifier, coupling coils, and a Class E PA in an example 6.78-MHz WPT system. Furthermore, the efficiencies of these three components and the overall WPT system are also analytically derived for design and evaluation purposes. In the final experiments, the analytical results are found to well match the experimental results. With loosely coupled coils (mutual inductance coefficient k=0.1327), the experimental 6.78- MHz WPT system can achieve 84% efficiency at a power level of 20 Watts. [Publication]

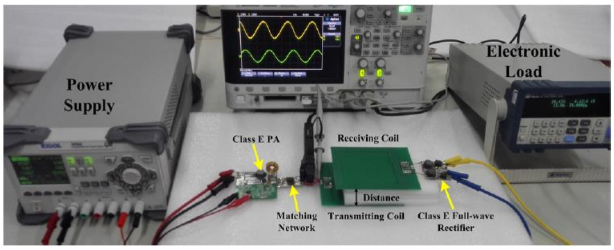
### 2. Low harmonics and high efficiency Class E full-wave rectifier for MHz WPT systems

Efforts have been made to build high-efficiency MHz WPT systems via both component- and system-level approaches. However, so far there have been few discussions on high frequency rectifier for MHz WPT applications. The soft-switching-based rectifiers, such as the Class E rectifiers, are one of promising candidates for MHz rectification. This research investigates the application of a Class E full-wave current-driven rectifier, for the first time, in WPT systems. A procedure is also developed to optimize the design of the rectifier and the MHz WPT system. For comparison purposes, the performances of both the Class E rectifier and the conventional full-bridge rectifier are investigated in terms of total harmonic distortion (THD), efficiency, power factor, voltage/current stresses, and voltage/current transfer functions, when being applied in an example 6.78 MHz WPT system. The simulation and experimental results show that the input voltage THD of the Class E full-wave rectifier is reduced to one fourth of the THD of the full-bridge rectifier. In the optimally designed MHz WPT system, efficiencies of both the rectification (over 91%) and the overall system (around 80%) are obviously improved compared to the system using the conventional full-bridge rectifier. [Publication]

### 3. Robust design of a Class E2 dc-dc Converters for MHz Wireless Power Transfer

For MHz WPT, the so-called Class $E^2$ dc-dc converter is attractive due to the soft-switching properties of Class E power amplifier (PA) and Class E rectifier. Using the existing design the Class $E^2$ dc-dc converter can only achieve an optimal performance such as a high efficiency under a fixed operating condition. Meanwhile, in real applications variations in the coil relative position and the final load are usually common. The purpose of this research is to analyze and develop a general design methodology for a robust Class E2 dc-dc converter in MHz WPT applications. Component and system efficiencies are analytically derived, which serve as the basis for the determination of the design parameters. The classical matching network of the Class E PA is also improved that provides the required impedance compression capability. Then the robust parameter design procedure is developed. Both the experimental and calculated results show that proposed design approach can significantly improve the robustness of the efficiency of the Class E2 dc-dc converter against variations in coil relative position and final load. [Paper has been submitted and is now under review]

### 4. A High Efficiency/Output and Low Noise MHz WPT over A Wide Range of mutual inductance




The soft-switching based Class E power amplifier (PA) and rectifier are known to be suitable for high frequency applications, which may potentially improve the performance of the MHz WPT systems. Meanwhile, the efficiency and output power of the Class E PA is sensitive to its loading condition, particularly when there is variation in the relative position of the coupling coils, namely a changed mutual inductance between the coils. Thus the purpose of this research is to propose and discuss circuit and design improvements that maintain a high efficiency and output power of the MHz WPT systems over a wide range of mutual inductance, when the Class E PA and rectifier are employed. Besides, the suppression of the harmonic contents, i.e., the electromagnetic interference problem, is also taken into account in the circuit design. Both the simulation and experimental results show that the newly added and optimally designed matching network obviously improves the drops of the efficiency and output power of the Class E PA and the overall WPT system when the mutual inductance varies. The reduction of the total harmonic distortion in the input voltage of the coupling coils is also significant, from the original 52.9% to 9.6%. The circuit and design improvements discussed in this research could serve as a general and practical solution for building high performance MHz WPT systems. [Paper has been submitted and is now under review]

## Project Experiences:

**UAES, Robert Bosch GmbH (China)** **Team leader** **3/2016 –present**

Design and implement a dual-band on-board WPT system (Qi and A4WP).

**Intel (USA)** **Team leader** **10/2015 -present**

Design and implement low-noise high efficiency rectifier for MHz WPT systems.

**Huawei (China)** **Team leader** **2/2016-present**

Design and implement a MHz wireless power transfer system for battery management.

**Intel (USA)** **Team member** **8/2014-1/2015**

Design and implement auto-tuning power amplifiers and high efficiency rectifiers for MHz WPT systems.

## Certificates & Skills:

- English: Fluent in speaking and writing (note: working language in UM-SJTU Joint Institute)
- Professional software skill: ADS, Cadence, HFSS, CCS, Matlab, C++, PSIM
- Professional hardware design experience: PMSM drive and control, embedded systems and programming, general power electronic circuits, etc.

## Publications:

- ***Journal*** **(**Accepted: 2; under review: 5; in preparation: 1**)**

1. **M. Liu**, M. Fu, and C. Ma, "Parameter Design for a 6.78-MHz Wireless Power Transfer System based on Analytical Derivation of Class E Current-Driven Rectifier," *IEEE Transactions on Power Electronics*, vol. 31, no. 6, pp. 4280–4291, June 2016. [PDF]
2. **M. Liu**, M. Fu, and C. Ma, "Low-Harmonic-Contents and High-Efficiency Class E Full-Wave Current-Drive Rectifier for Megahertz Wireless Power Transfer Systems," *IEEE Transactions on Power Electronics*, In press. [PDF]
3. **M. Liu**, Y. Qiao, S. Liu, and C. Ma, "Analysis and Design of A Robust Class $E^2$ DC-DC Converter for Megahertz Wireless Power Transfer", IEEE Transactions on Power Electronics, under review.
4. **M. Liu**, S. Liu, and C. Ma, "A High Efficiency/Output Power and Low Noise Megahertz Wireless Power Transfer System over A Wide Range of Mutual Inductance", IEEE Transactions on Microwave Theory and Techniques, under review.
5. **M. Liu**, C. Zhao, J. Song, and C. Ma, "Optimization Design of a 6.78-MHz Wireless Battery Charging System with respect to Average Power Loss", in preparation.
6. S. Liu, **M. Liu**, C. Ma, and X. Zhu, "A Novel Design Methodology for High-Efficiency Current-Mode and Voltage-Mode Class-E Power Amplifiers in Wireless Power Transfer systems", under review.
7. M. Fu, H. Yin, **M. Liu**, and C. Ma, "Analysis and Control for A 6.78 MHz Multiple-Receiver Wireless Power Transfer System Driven by Class E Power Amplifier", under review.
8. M. Fu, H. Yin, **M. Liu**, and C. Ma, "A 6.78 MHz Wireless Power Transfer System with High Efficiency over A Wide Load Power Range", under review.

- ***Conference***

1. **M. Liu**, M. Fu, Z. Tang, and C. Ma, "A Compact Class E Rectifier for Megahertz Wireless Power Transfer", IEEE PELS Workshop on Emerging Technologies: Wireless Power (2015 WoW), June 5-6, 2015, Daejeon, Korea. [PDF]
2. S. Liu, **M. Liu**, M. Fu, C. Ma，X. Zhu, "A High-Efficiency Class-E Power Amplifier with Wide-Range Load in WPT Systems", IEEE Wireless Power Transfer Conference, May 13-15, 2015, Boulder, Colorado，USA. [PDF]
3. Z. Tang, M. Fu, **M, Liu** and C. Ma, "Optimization of the Compensation Capacitors for Megahertz Wireless Power Transfer Systems", accepted by Annual Conference of the IEEE Industrial Electronics Society (IECON) 2015. [PDF]
4. M. Fu, Z. Tang, **M. Liu**, X. Zhu and C. Ma, "Full-Bridge Rectifier Input Reactance Compensation in Megahertz

Wireless Power Transfer Systems", IEEE PELS Workshop on Emerging Technologies: Wireless Power (2015 WoW), June 5-6, 2015, Daejeon, Korea. [PDF]

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