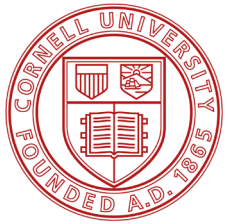
Dynamic Capacitive Wireless Charging of Electric Vehicles

Khurram Afridi

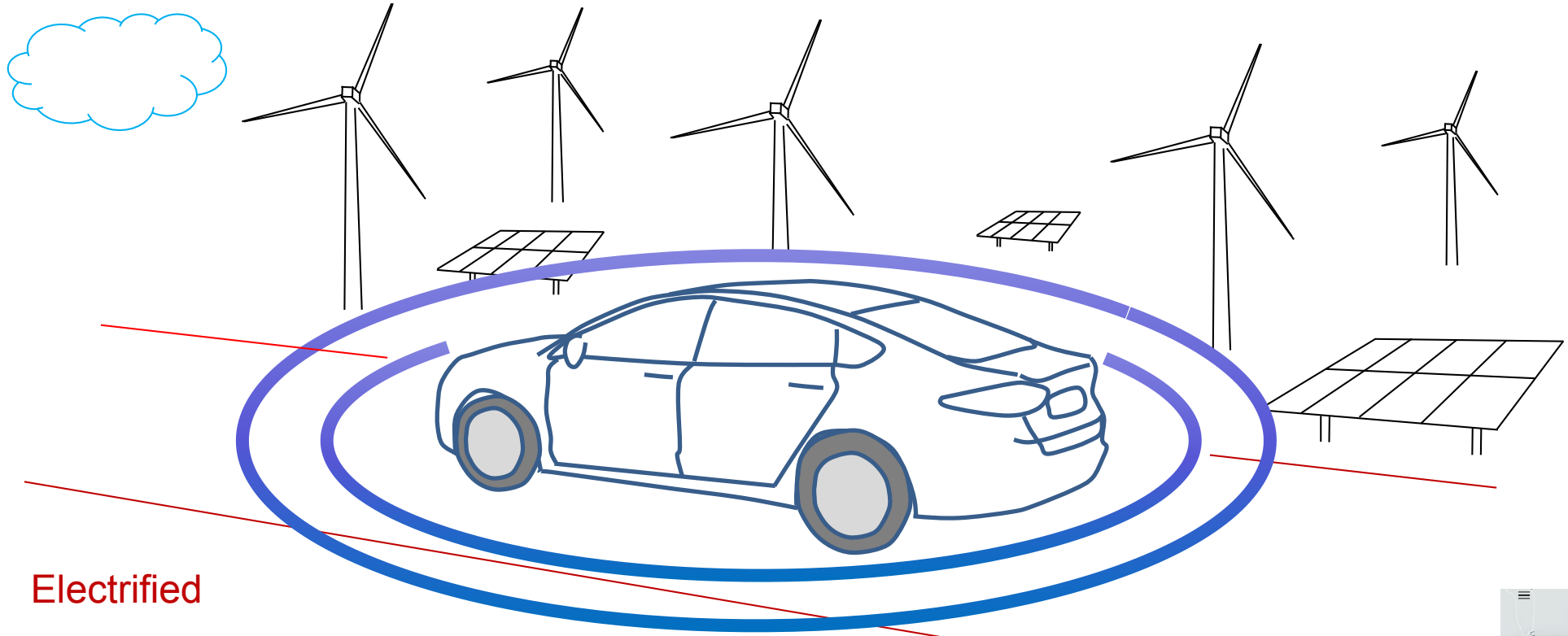
Cornell University



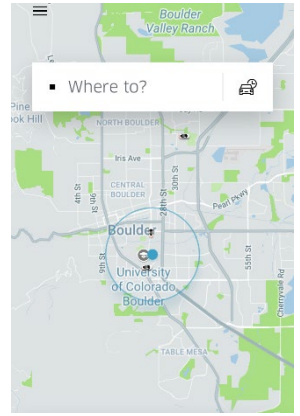
Conference on Electric Roads & Vehicles

February 11, 2020

The Future of Road Transportation

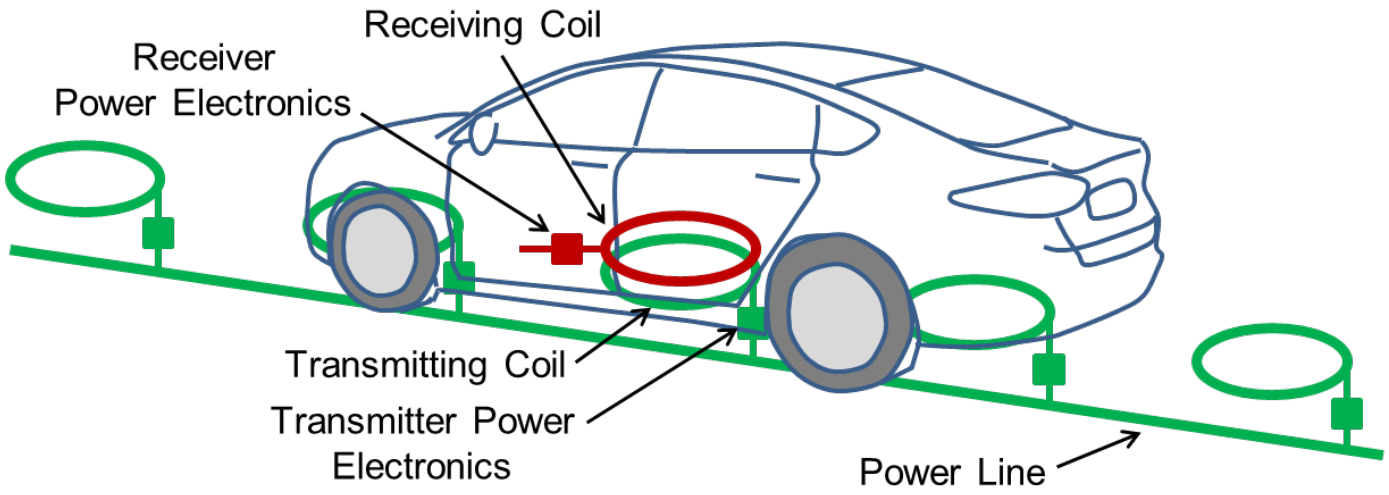


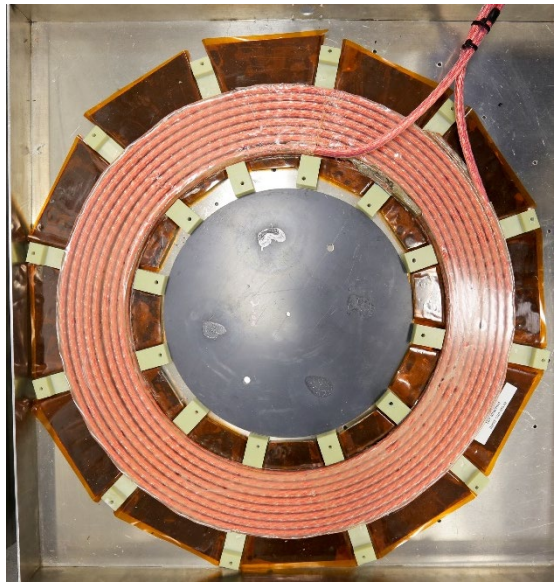
- Electrified
- Autonomous
- Shared



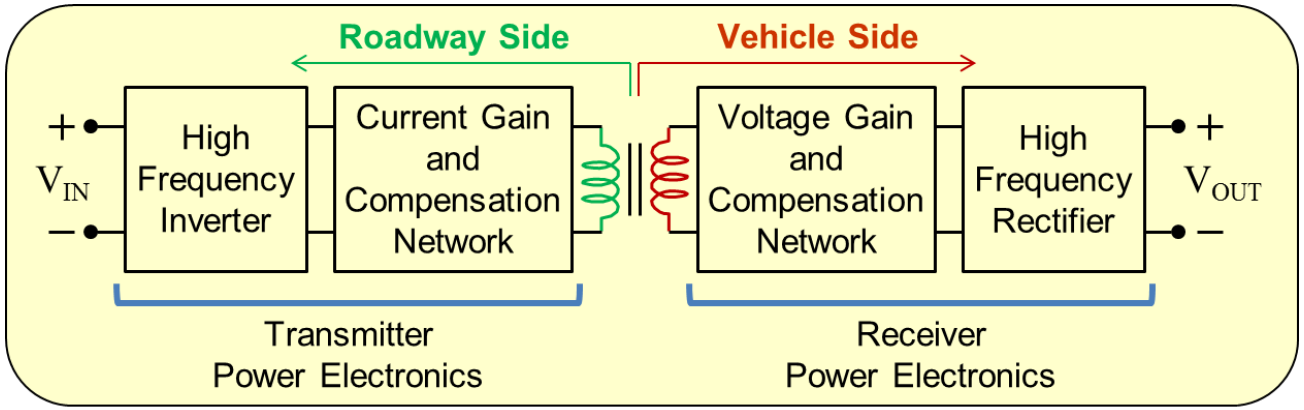
- Dynamic wireless charging can enable this future:
  - Increase penetration of electric vehicles (EVs)
  - Make EVs fully autonomous
  - Allow shared autonomous EVs to operate continuously

Inductive Wireless Charging



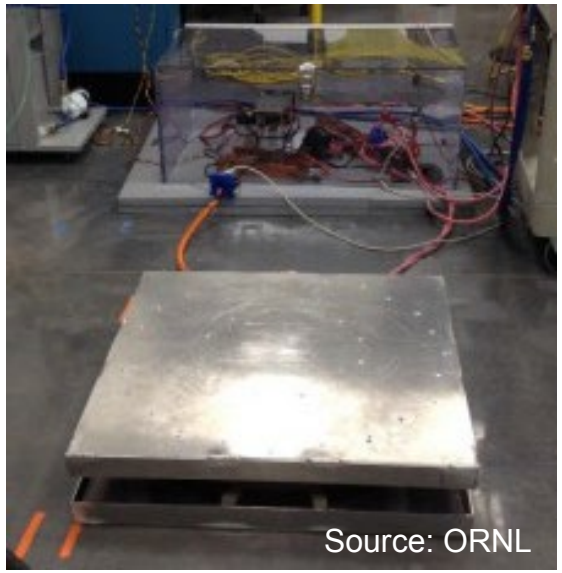


Source: ORNL



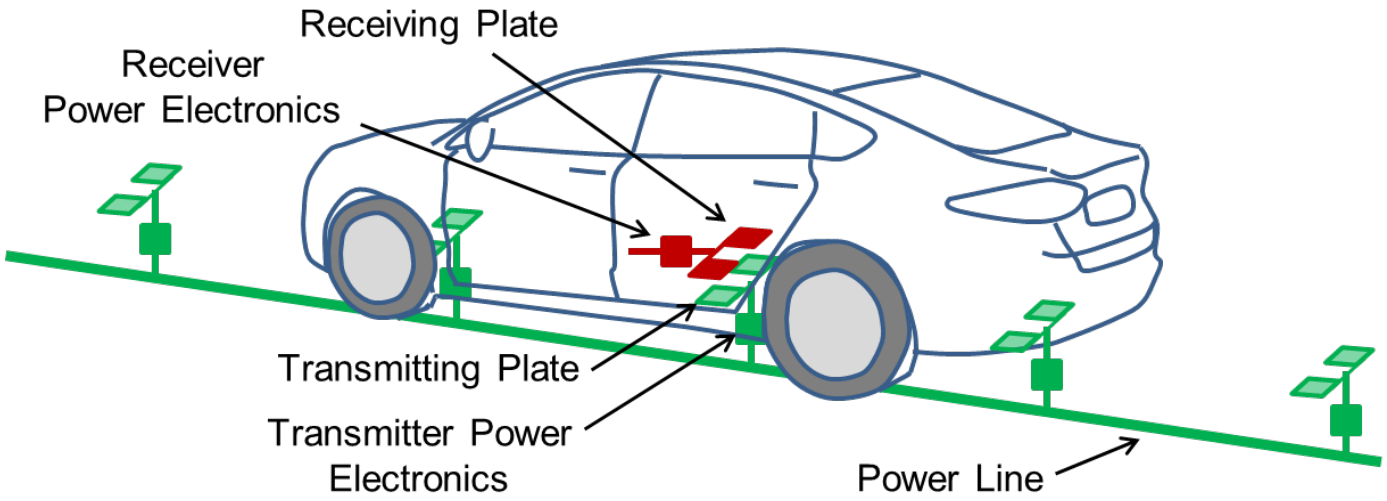
Limitations of Inductive Wireless Charging

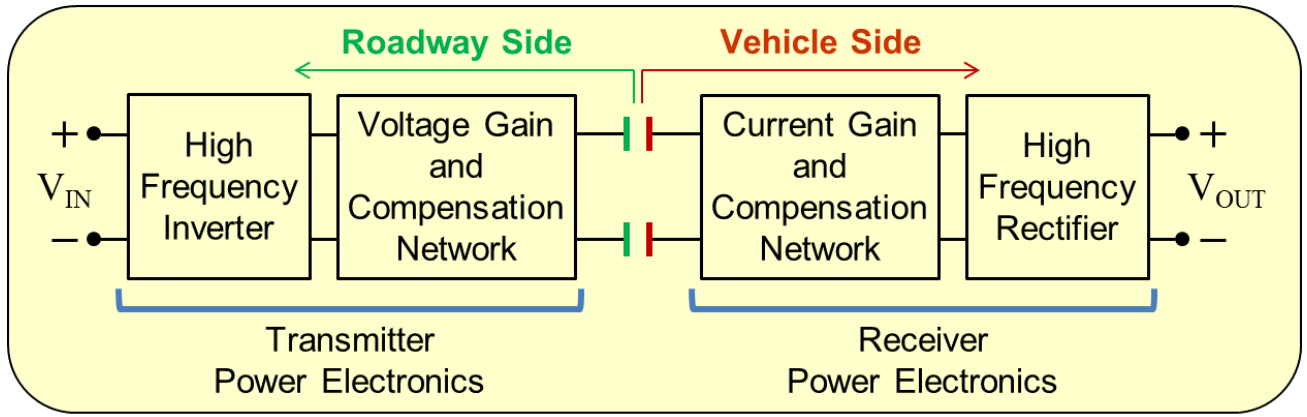
- Inductive systems require ferrite cores for magnetic flux guidance and shielding
  - Fragile
  - Difficult to embed in road
  - Expensive
- Inductive systems operate at relatively low frequencies to limit ferrite losses
  - Large and Heavy


Source: ORNL


Source: KAIST

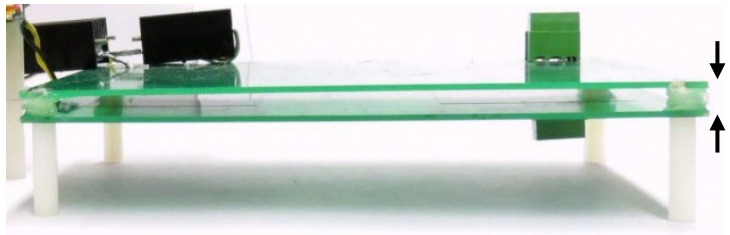
Capacitive Wireless Charging

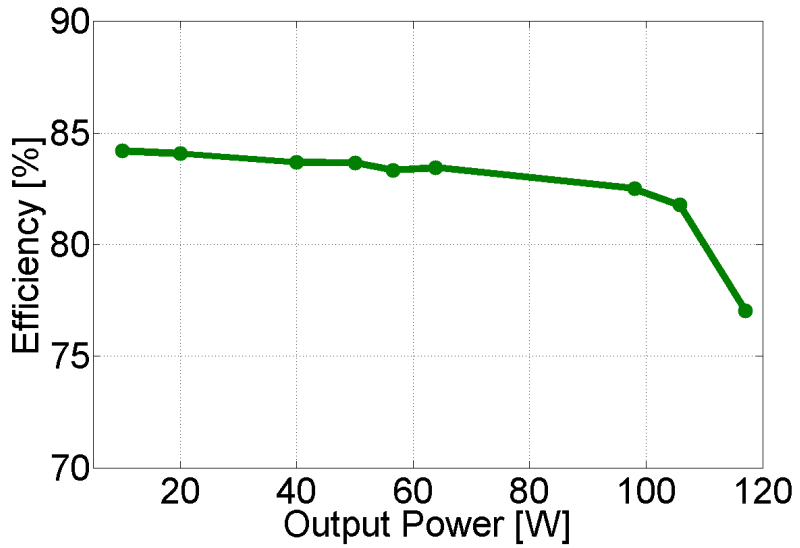


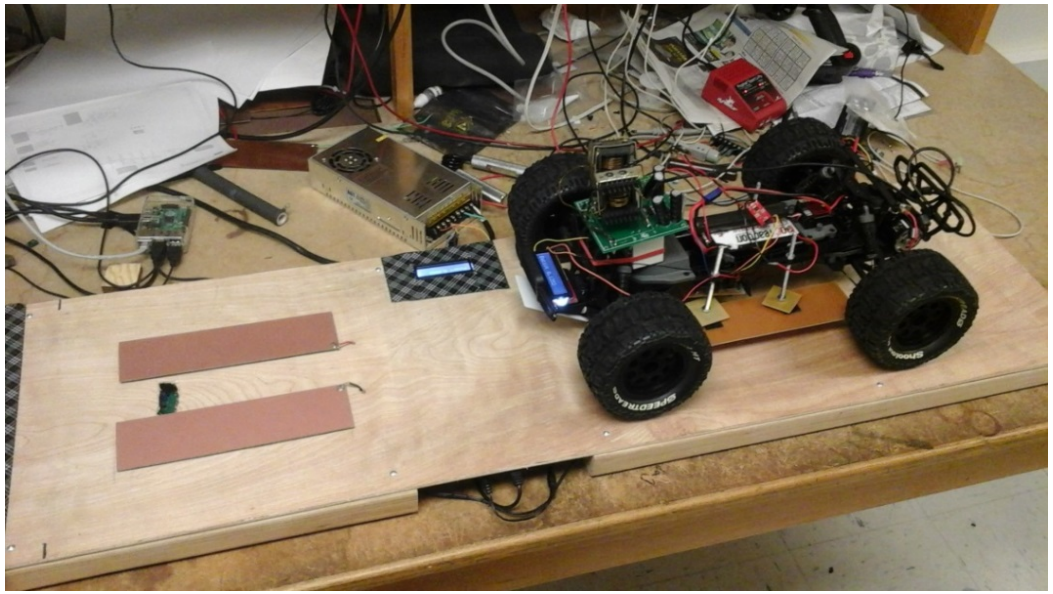


- Capacitive systems do not have ferrites & Litz wire and can be:
  - Less expensive
  - Smaller
  - Lighter
  - Easier to embed in roadway
  - More misalignment tolerant
  - More immune to foreign objects

Our Early Experiments with Capacitive WPT

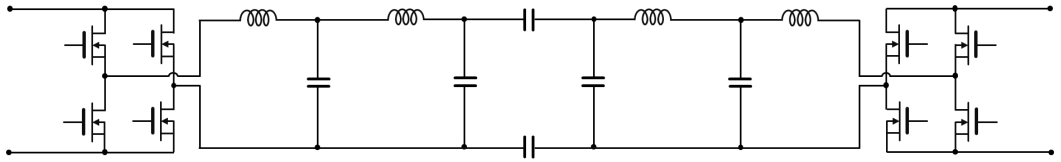






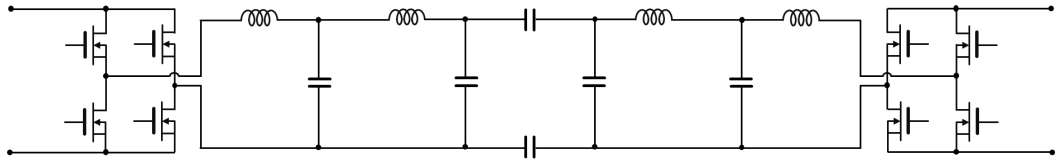
Matching Networks for Gain and Compensation

Gain Compensation Gain

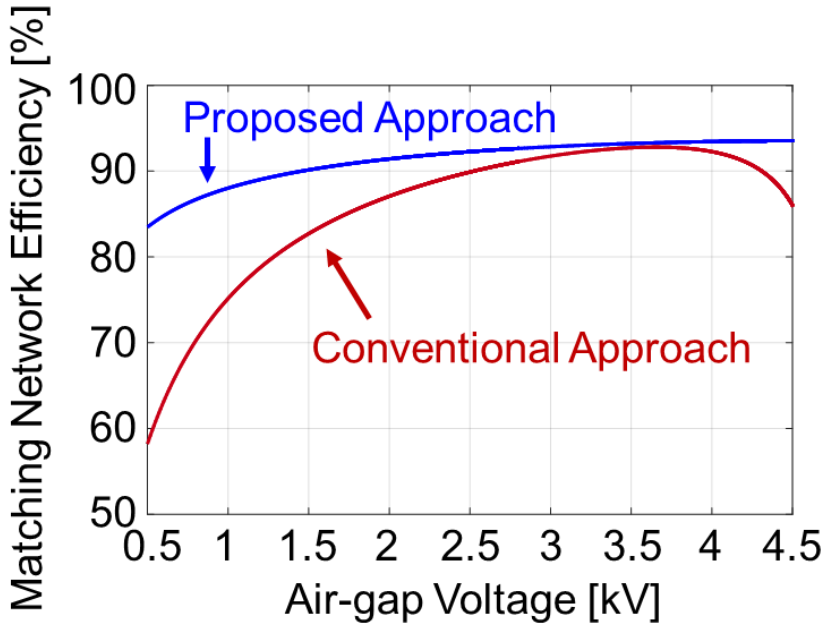


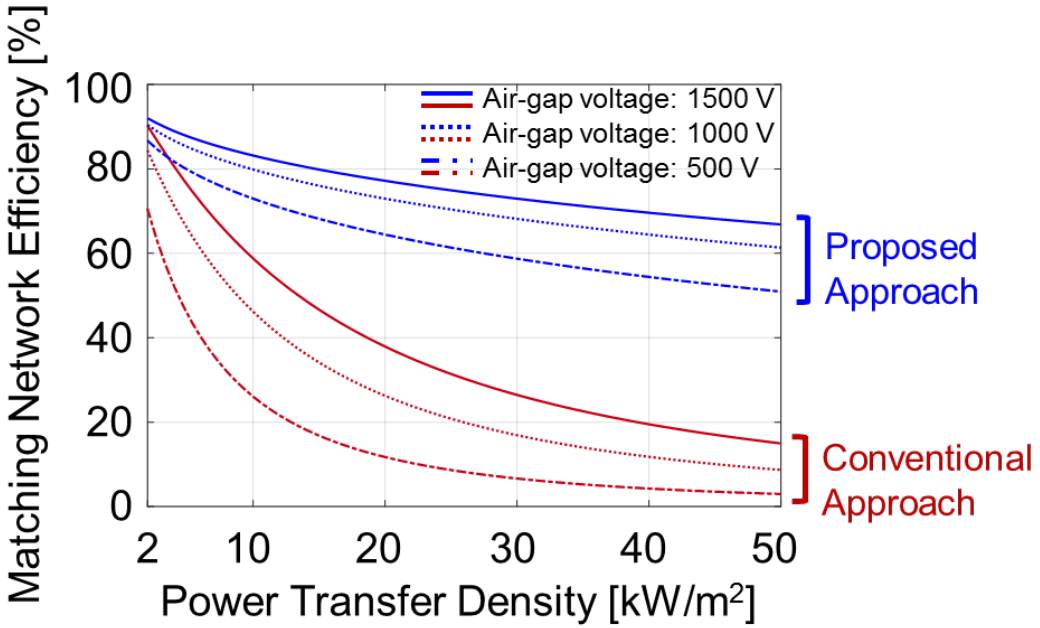
Conventional Approach

Optimally Distributed
Gain and Compensation

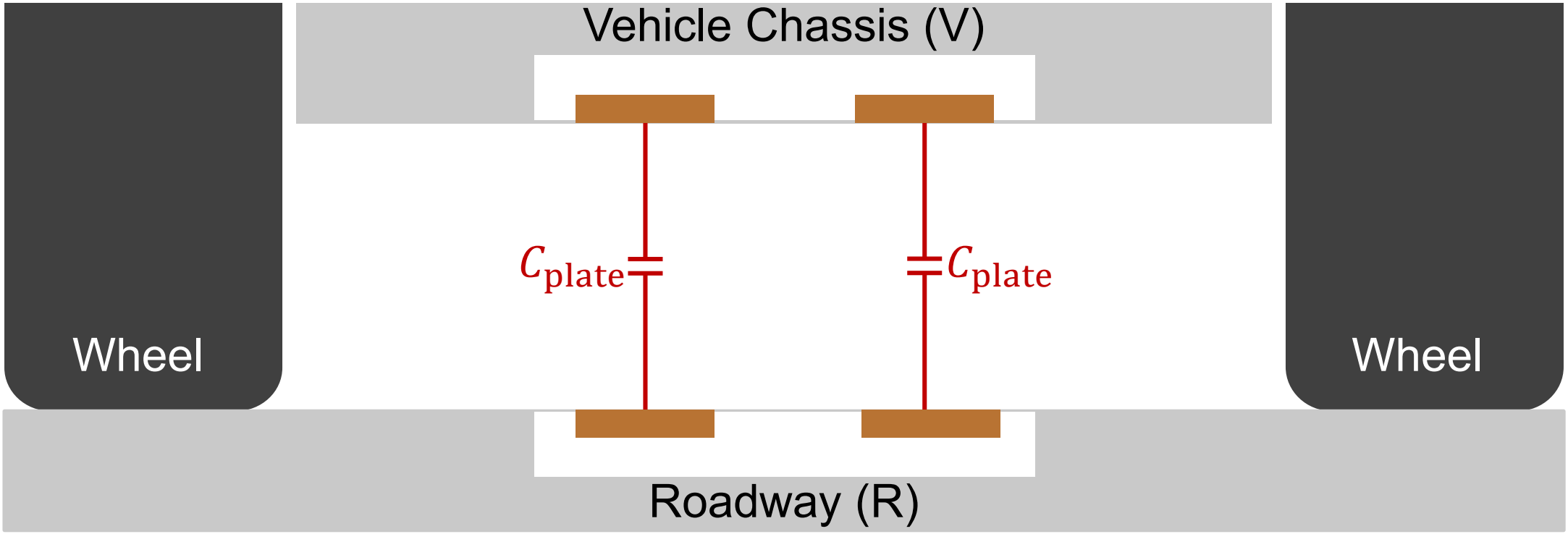


Proposed Approach

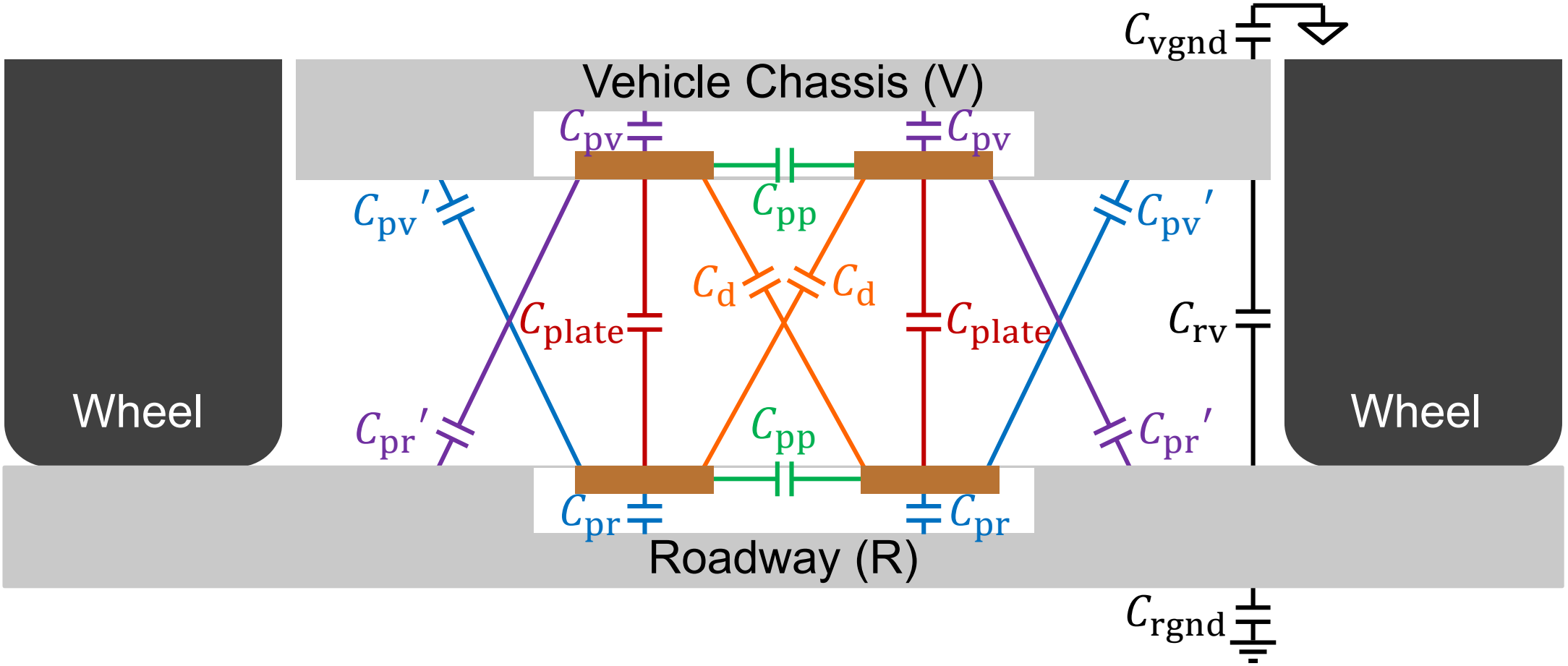




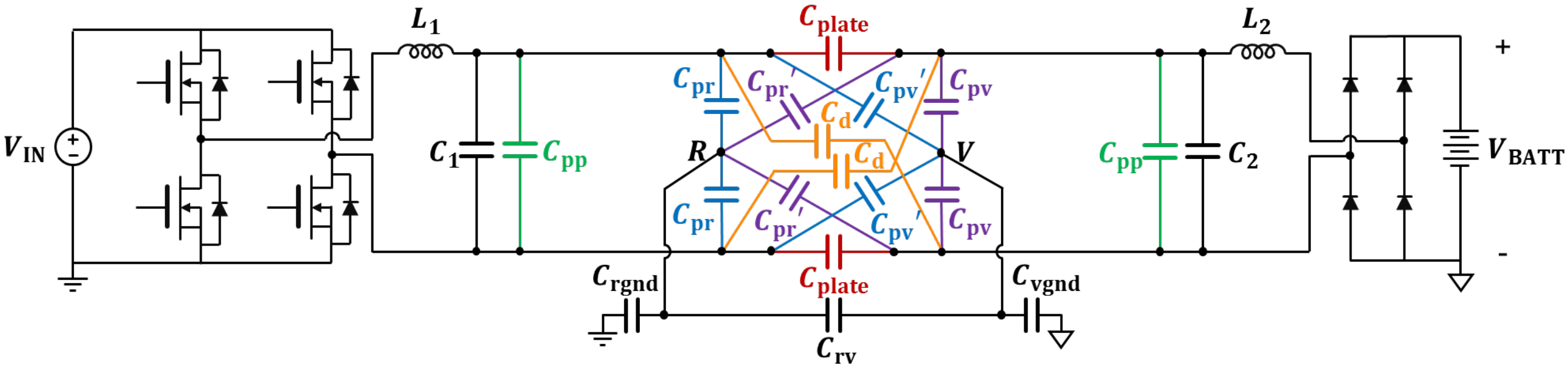
Electric Vehicle Charging Environment



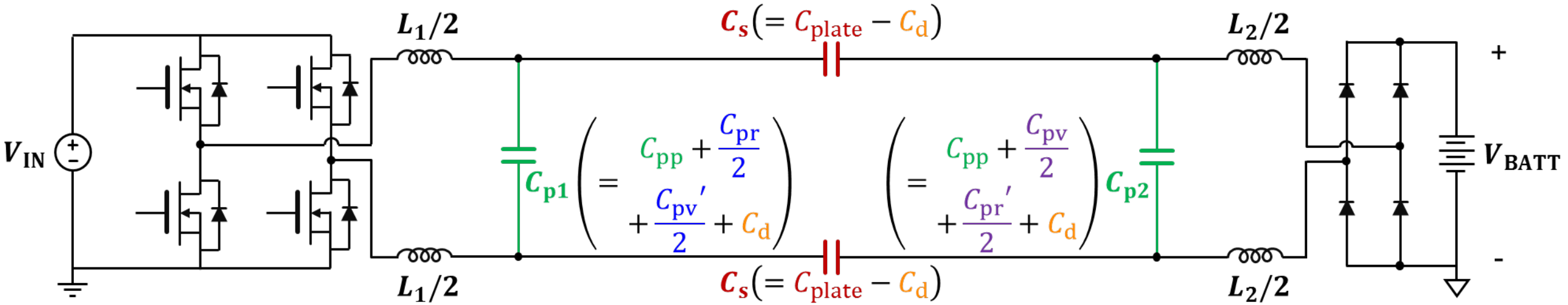
Overwhelming Parasitic Capacitances



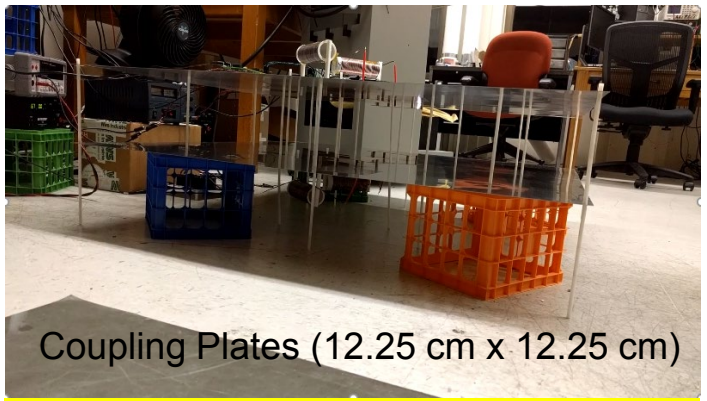
Circuit Including Parasitic Capacitances



Capacitance Network Simplification

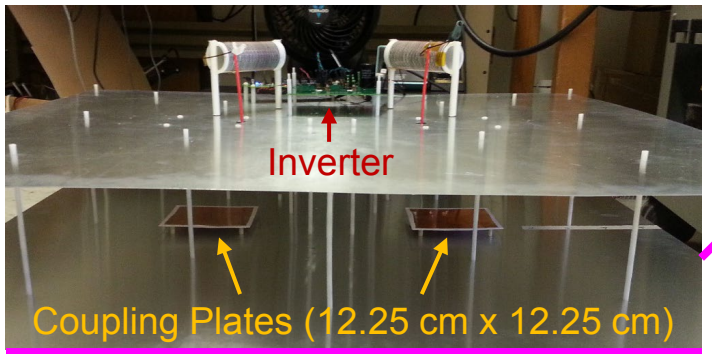


6.78-MHz Capacitive Wireless Charging Systems



Gen-1 System

Output Power: 146 W

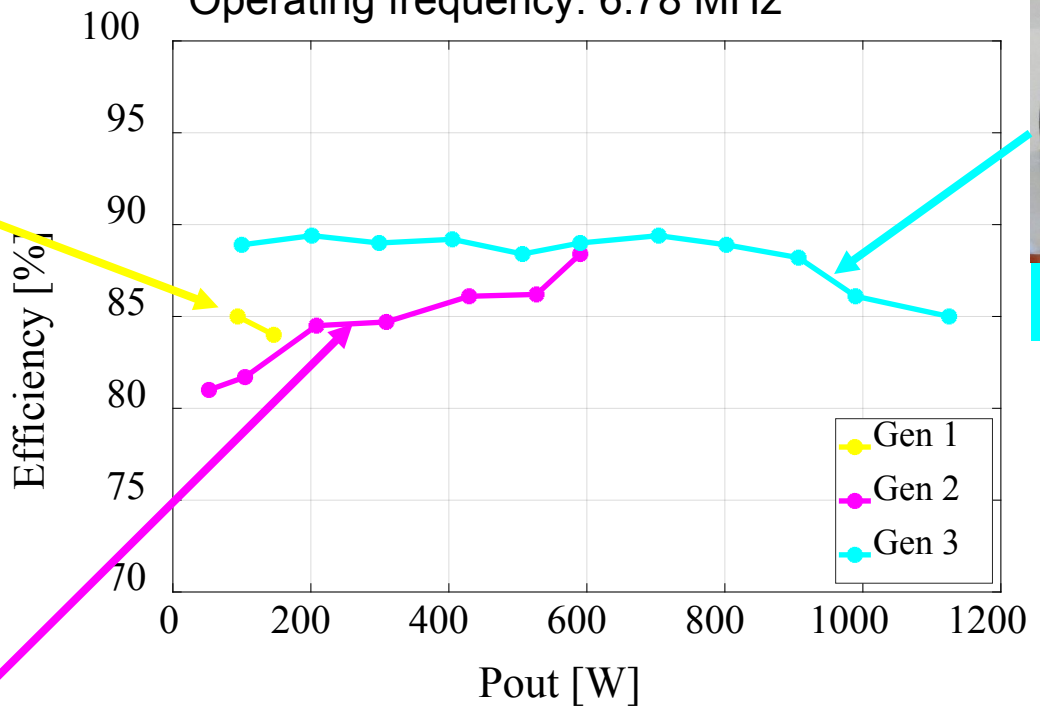


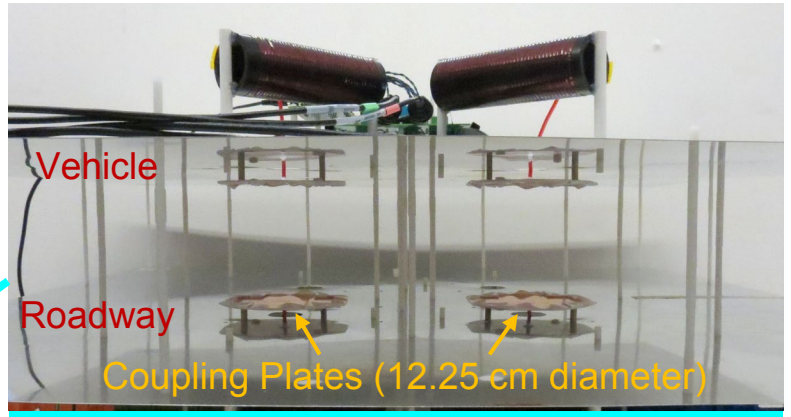
Gen-2 System

Output Power: 589 W

Air gap: 12 cm

Operating frequency: 6.78 MHz



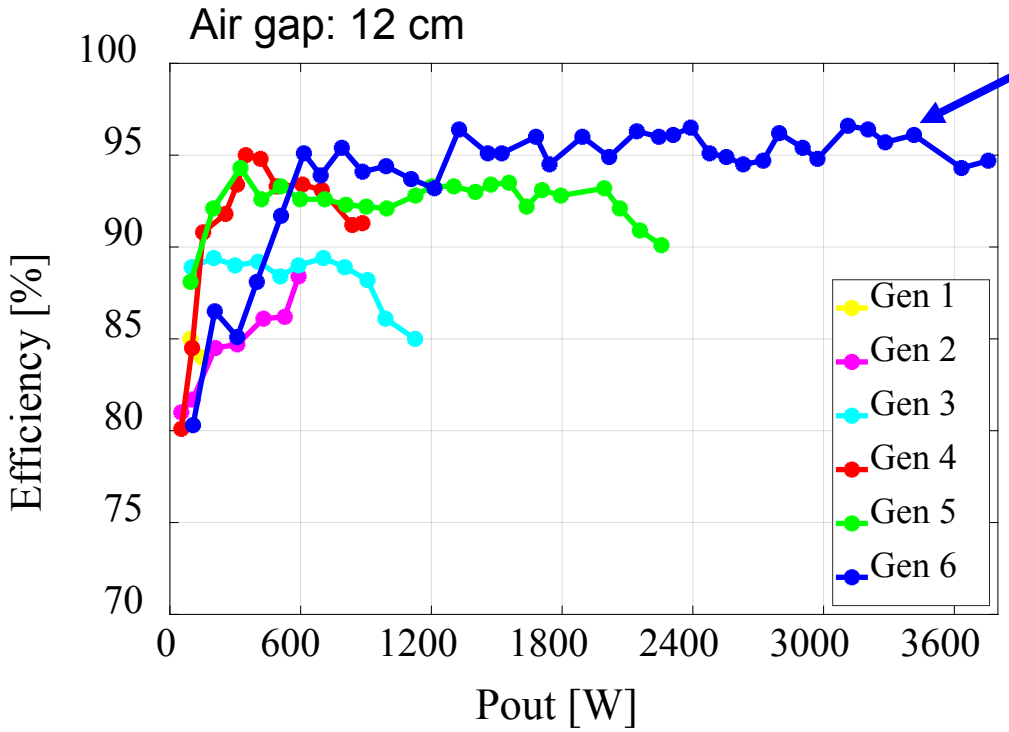


Gen-3 System

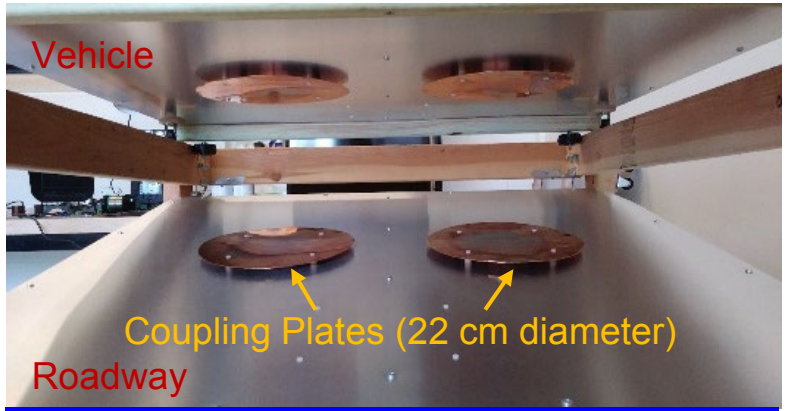
Output Power: 1216 W

Power Transfer Density: 51.6 kW/m^2

13.56-MHz Capacitive Wireless Charging System



Operating frequency: 13.56 MHz

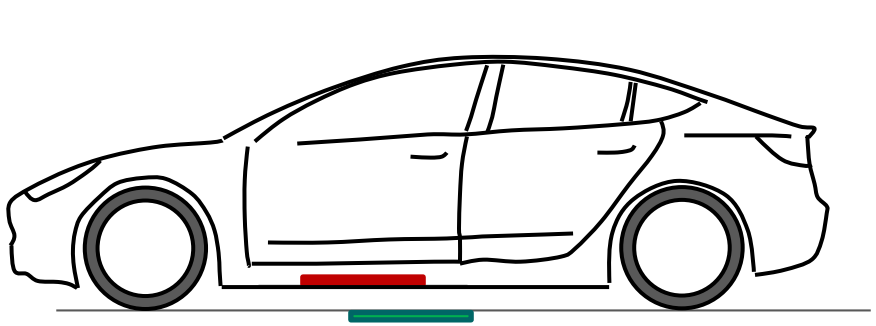


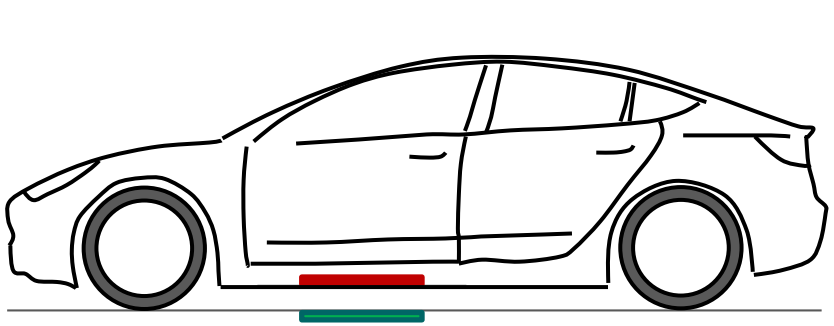
Gen-6 System

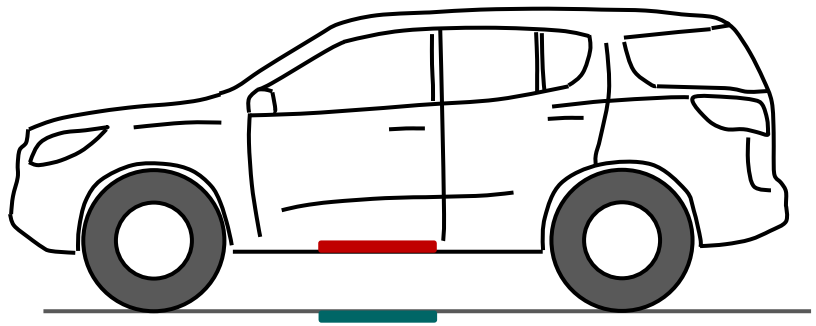
Output Power: 3756 W

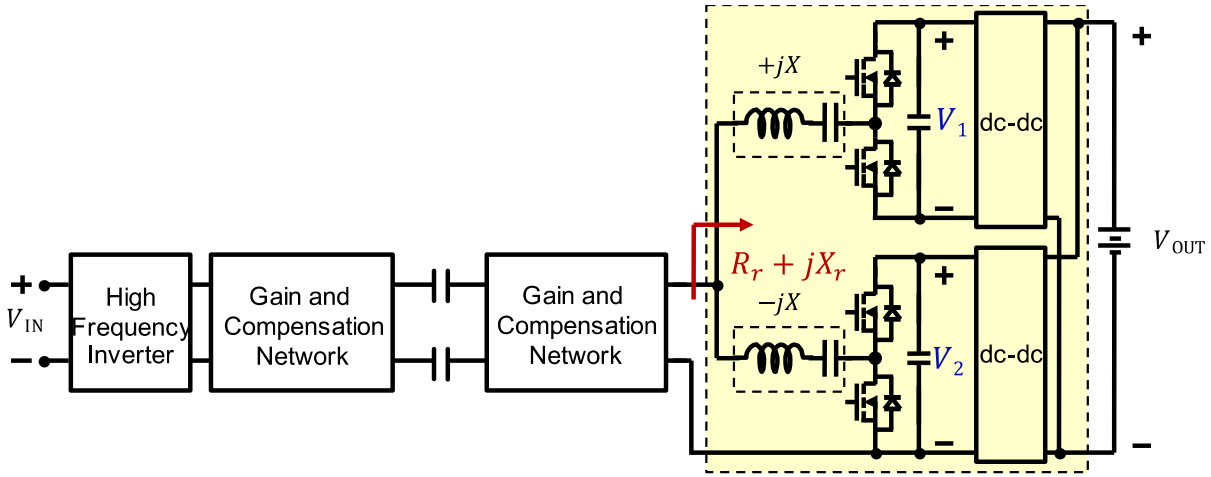
Power Transfer Density: 49.4 kW/m^2

Dynamic Wireless Charging using AVR Rectifier

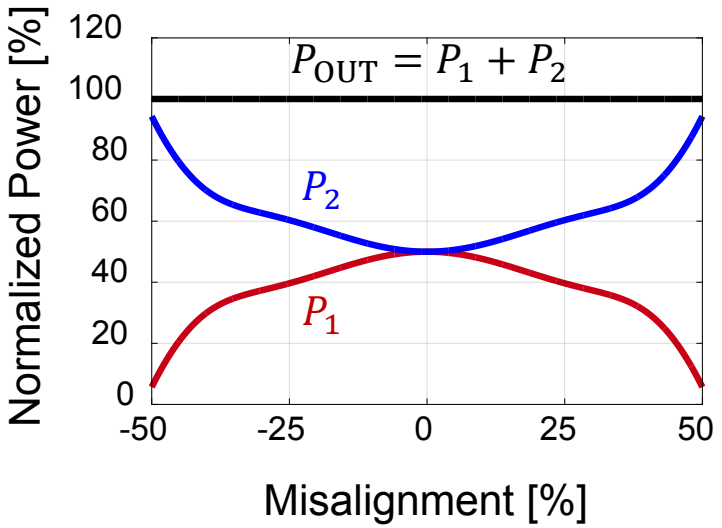




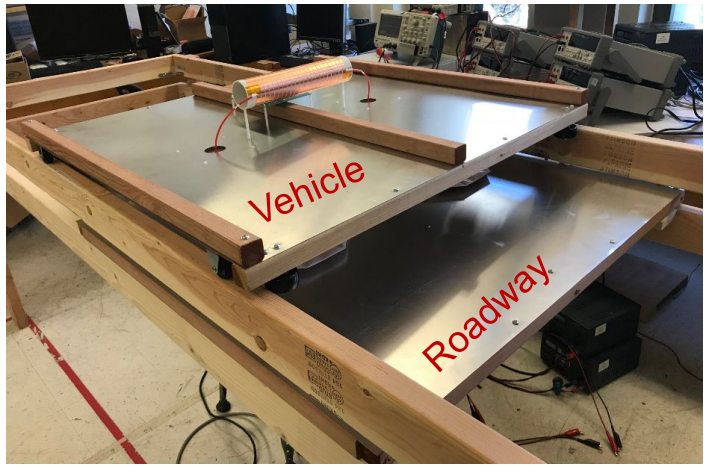


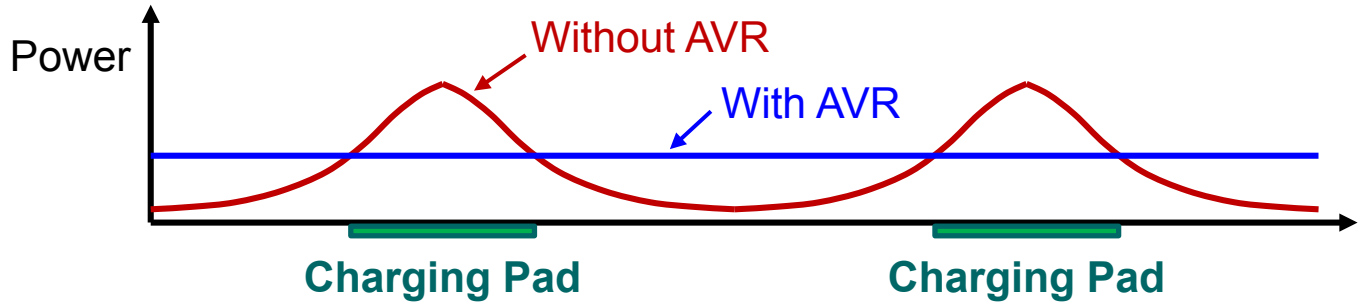


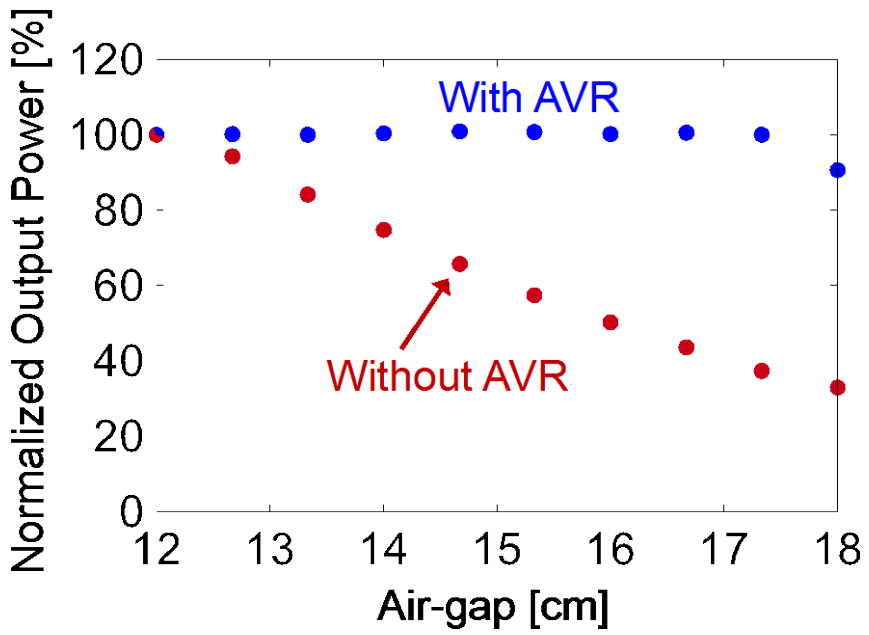
Active Variable Reactance (AVR) Rectifier

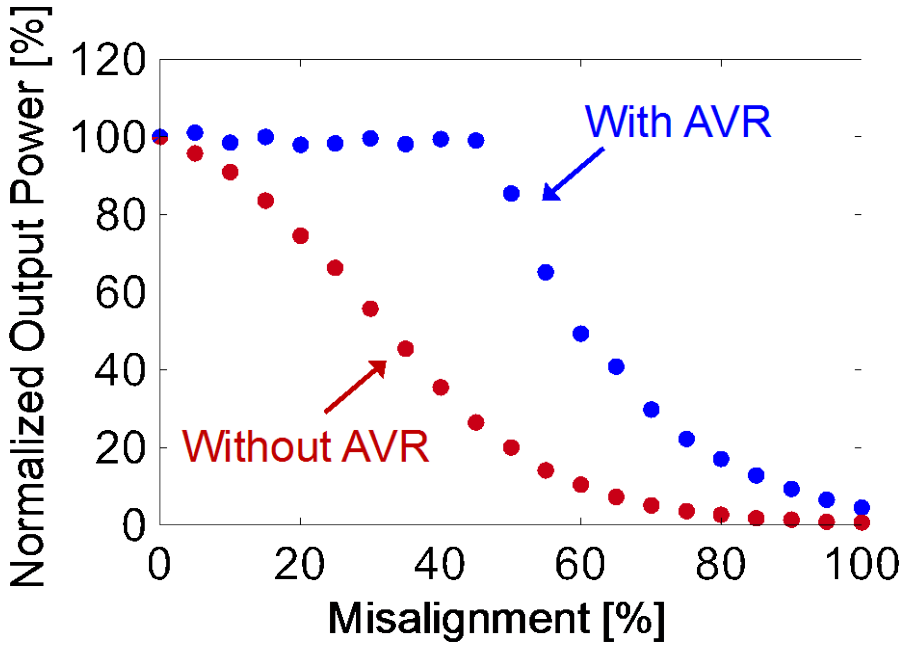


Dynamic Capacitive Wireless Charging Prototype

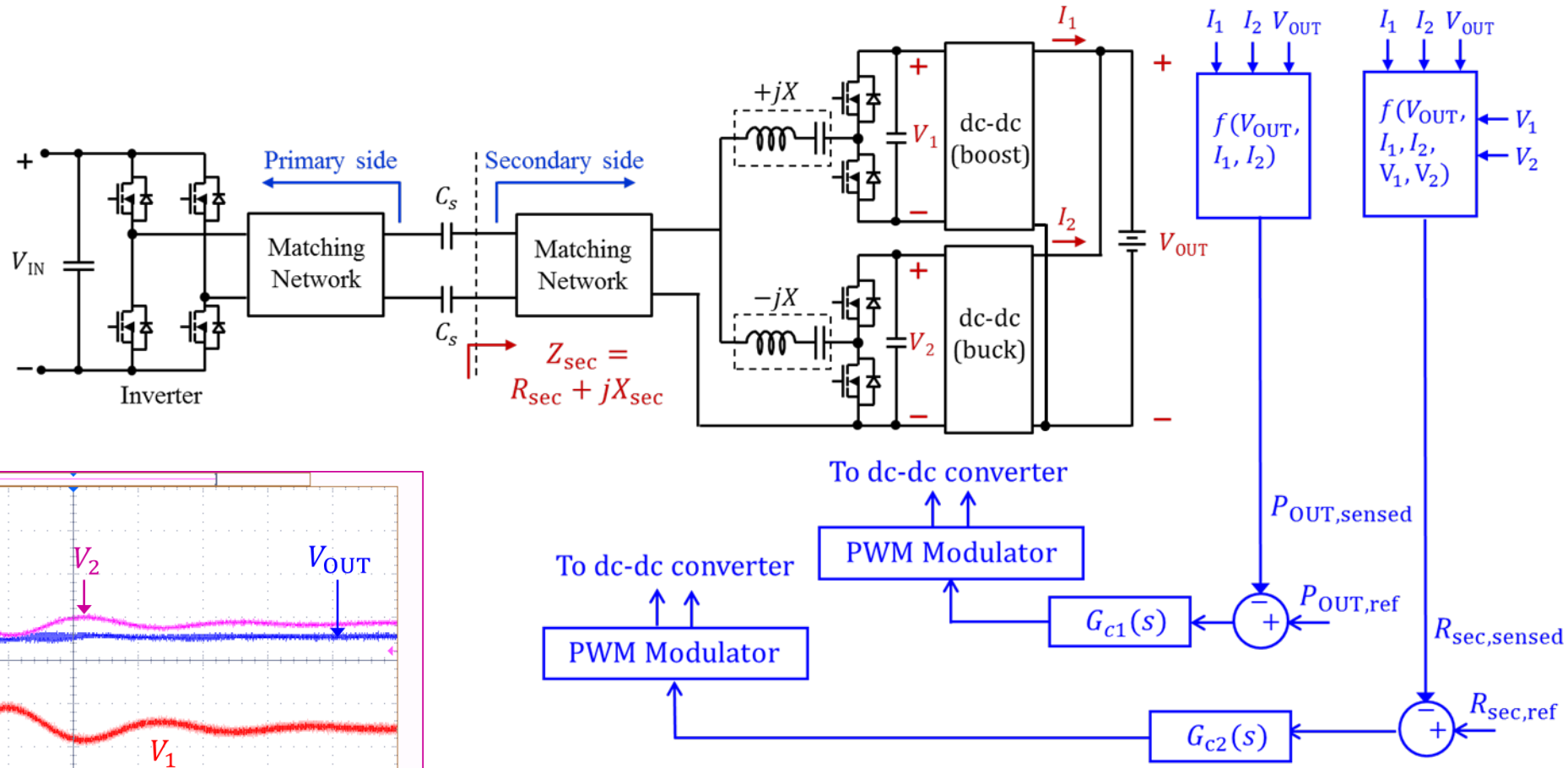


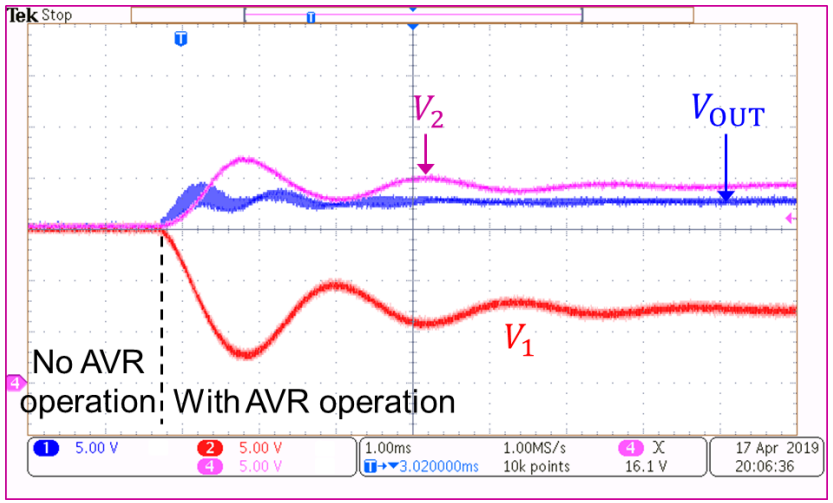




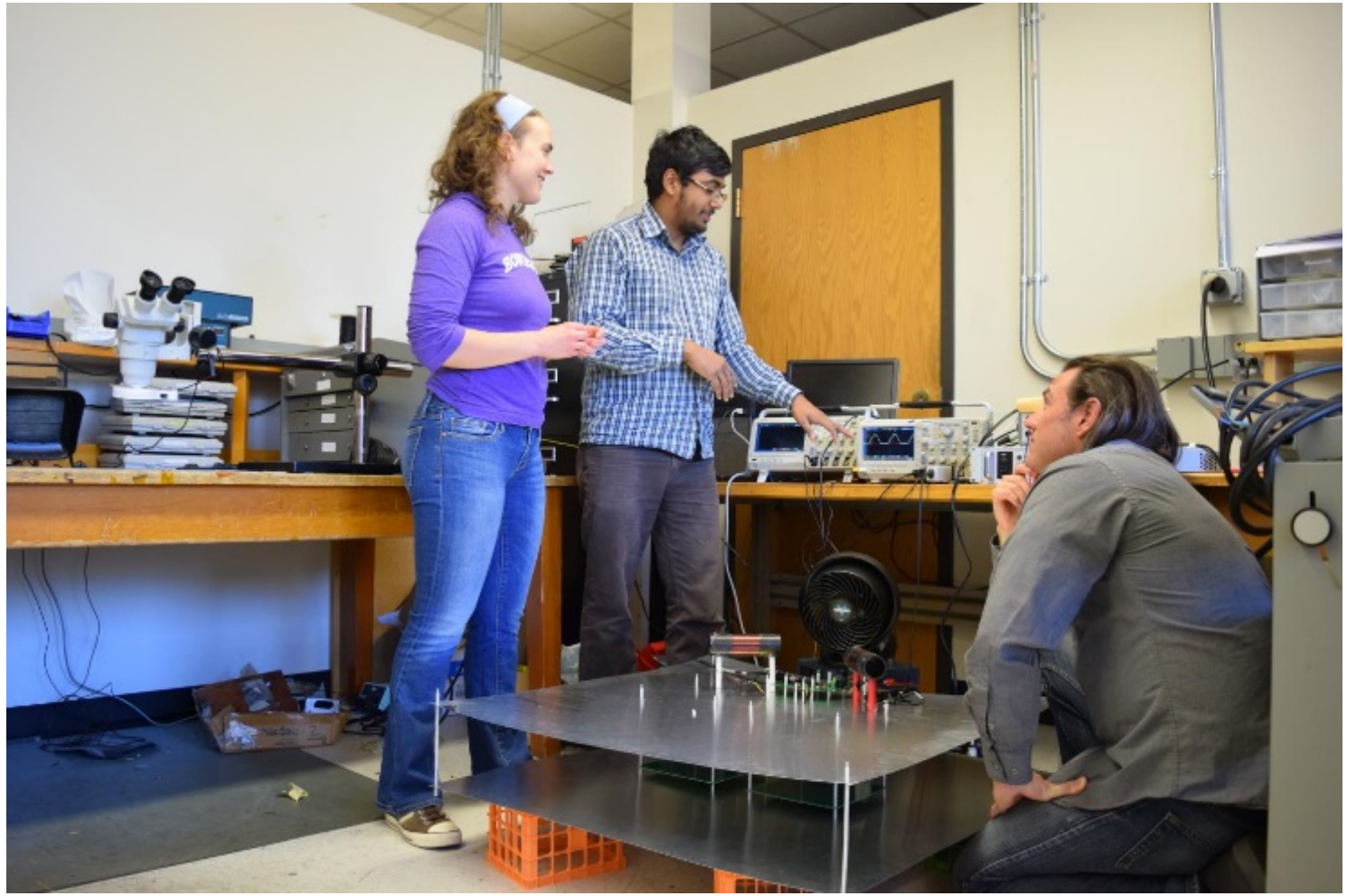


Dynamic WPT Control Architecture





Acknowledgements



arpa·e

NSF