UNIVERSITY OF MICHIGAN-DEARBORN

Unplugging the Electric Car

- Wireless charging of electric vehicles with extremely high efficiency and misalignment tolerance

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Conventional EV Charging

1

Normal charging

AC charging using level 1 or level 2, voltage at 110V, 220V, 6-10 hours per charge Charge at home or public space, need large installation of charge stations

2

Fast charging

Mostly DC charging in 15 to 30 minutes.

For an EV with a 24kWh battery pack, charging in 15 minutes means 96kW. This is way over the power available in private homes.

3

Battery swapping

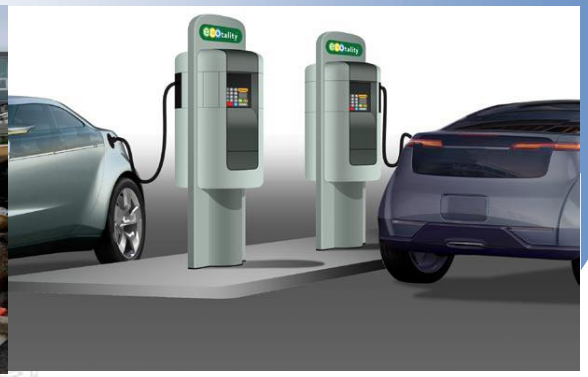
Investment of battery packs; standardization is difficult; swapping stations need a lot investment, space and manpower; safety and reliability is of concern

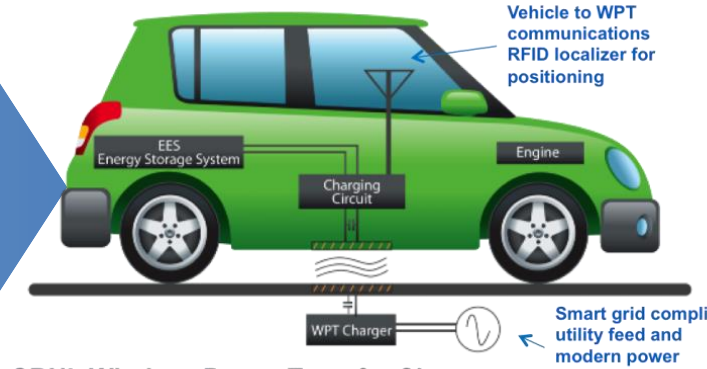
Issues of Con. Charging and Battery Swapping

Electric safety is of concern: electric shock due to rain, etc.

Charge station, plug and cable can be easily damaged, stolen

Charge/swap station takes a lot of space and affect the views

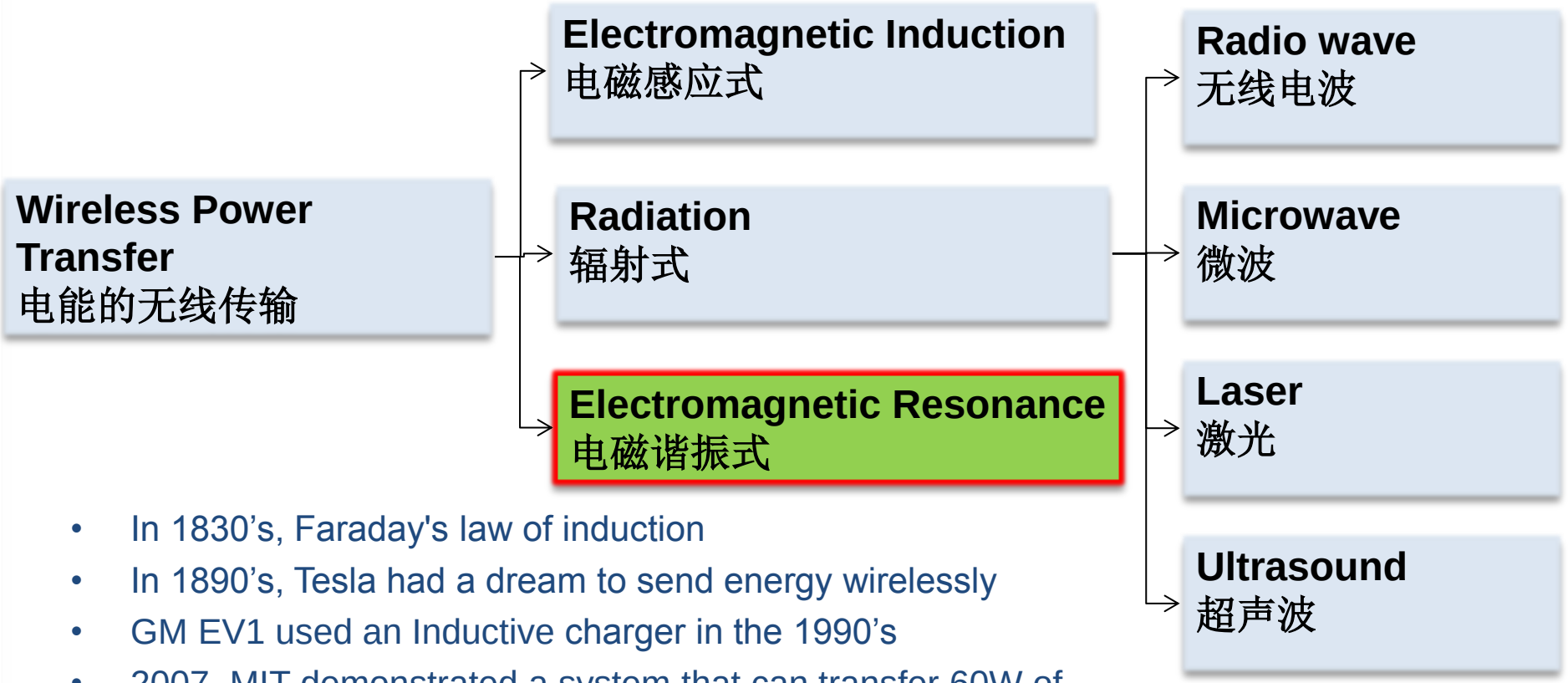




ORNL Wireless Power Transfer Charger

Wireless Charging

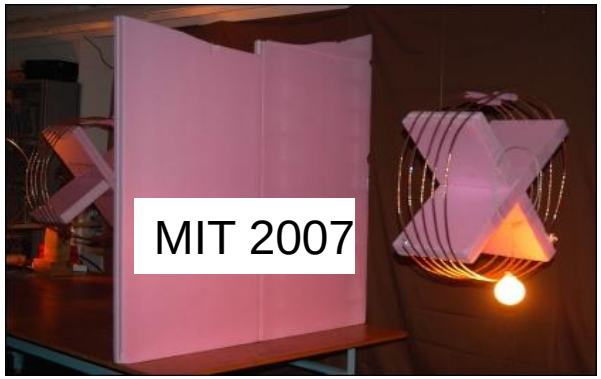
Methods of WPT



- In 1830's, Faraday's law of induction
- In 1890's, Tesla had a dream to send energy wirelessly
- GM EV1 used an Inductive charger in the 1990's
- 2007, MIT demonstrated a system that can transfer 60W of power over 2 m distance at very low efficiency
- Wireless/inductive chargers are available on the market
- **Qualcomm**, Delphi (Witricity), Plugless Power, KAIST, etc. have developed EV wireless charger prototypes

Wireless market
$17 Billion in 2019

Latest Development in Wireless EV Charging



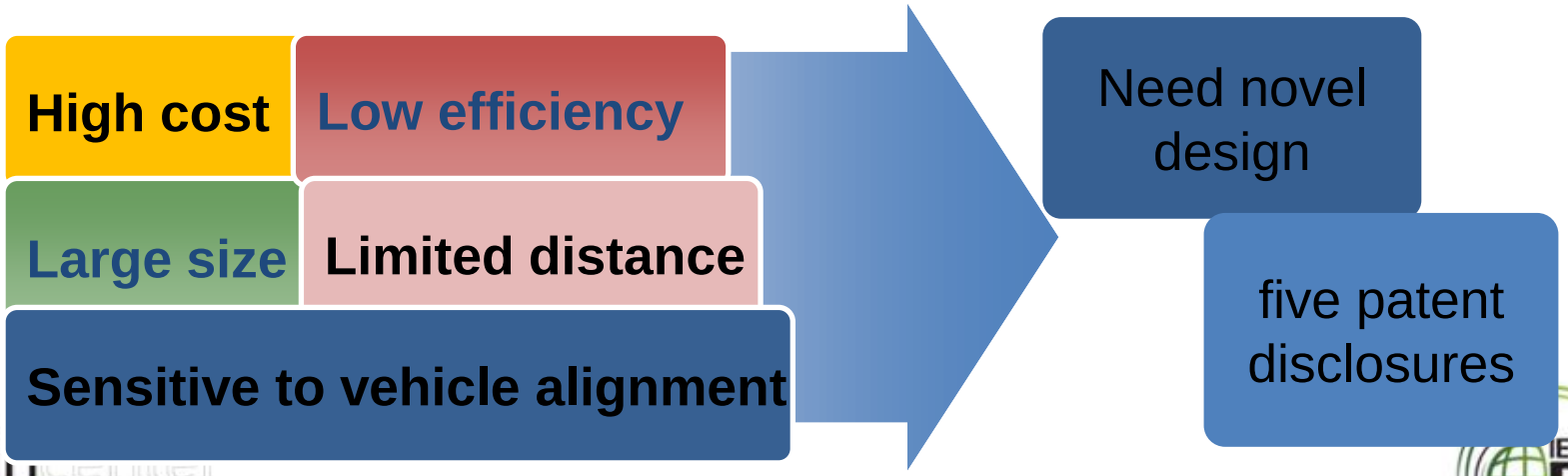
Witricity/Delphi

Korea KAIST

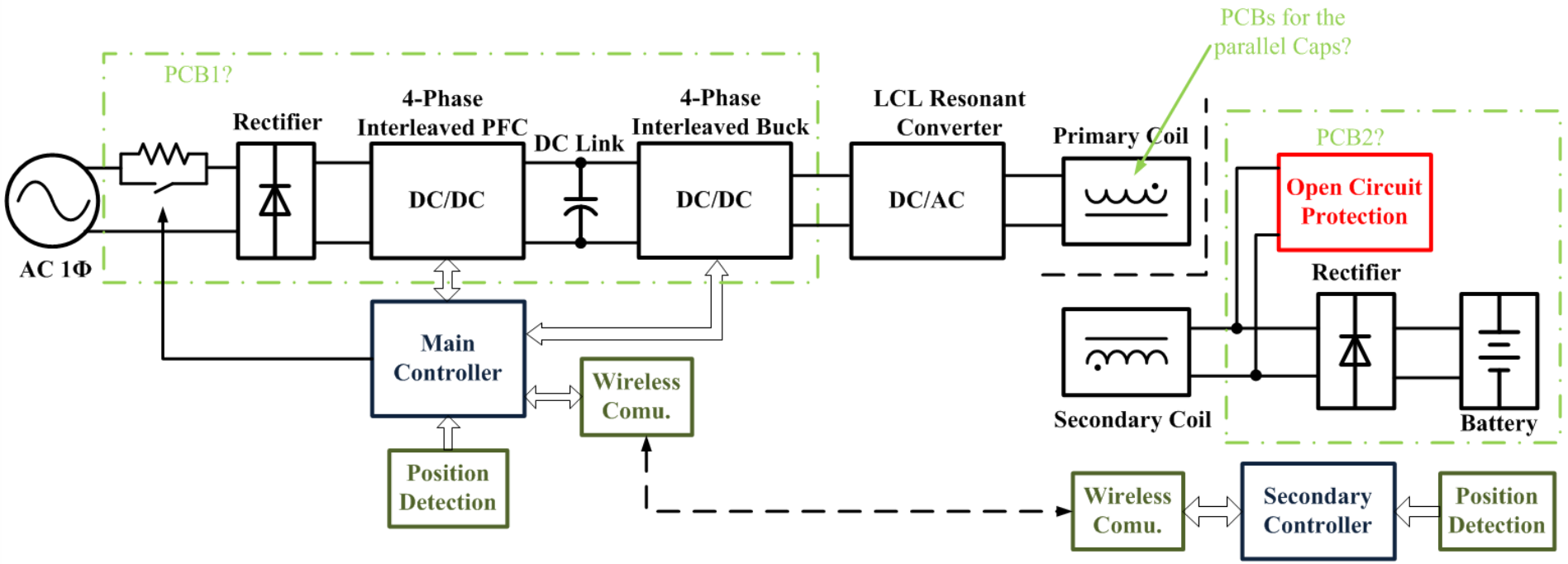
Japan

Problems and Difficulties

- Magnetic field is diminishing proportional to$1/r^3$
- Often the mutual inductance is less than 20% or 10% of the self inductance
- Analytical calculation of coil mutual inductance is next to impossible
- Further analytical method is needed
- Numerical simulation and coupled field - lumped parameter simulation is also of paramount importance
- High frequency HFSS instead of static FEM for high frequency



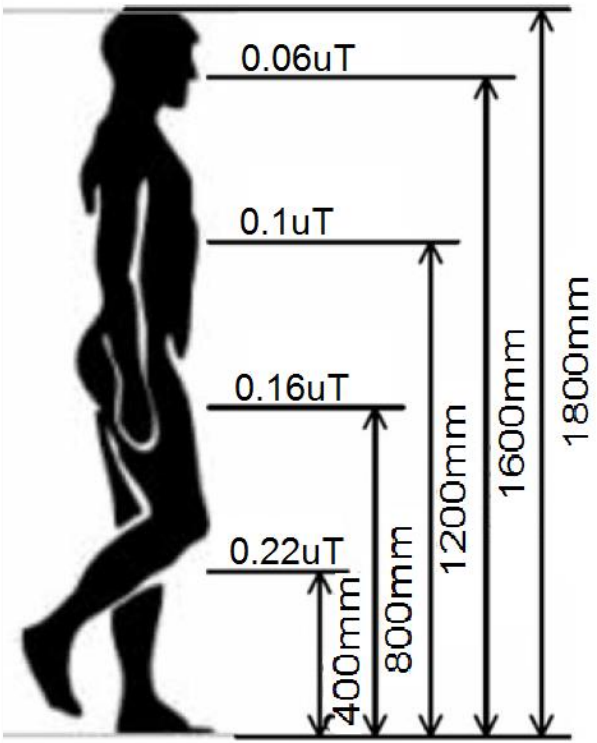
The Topology

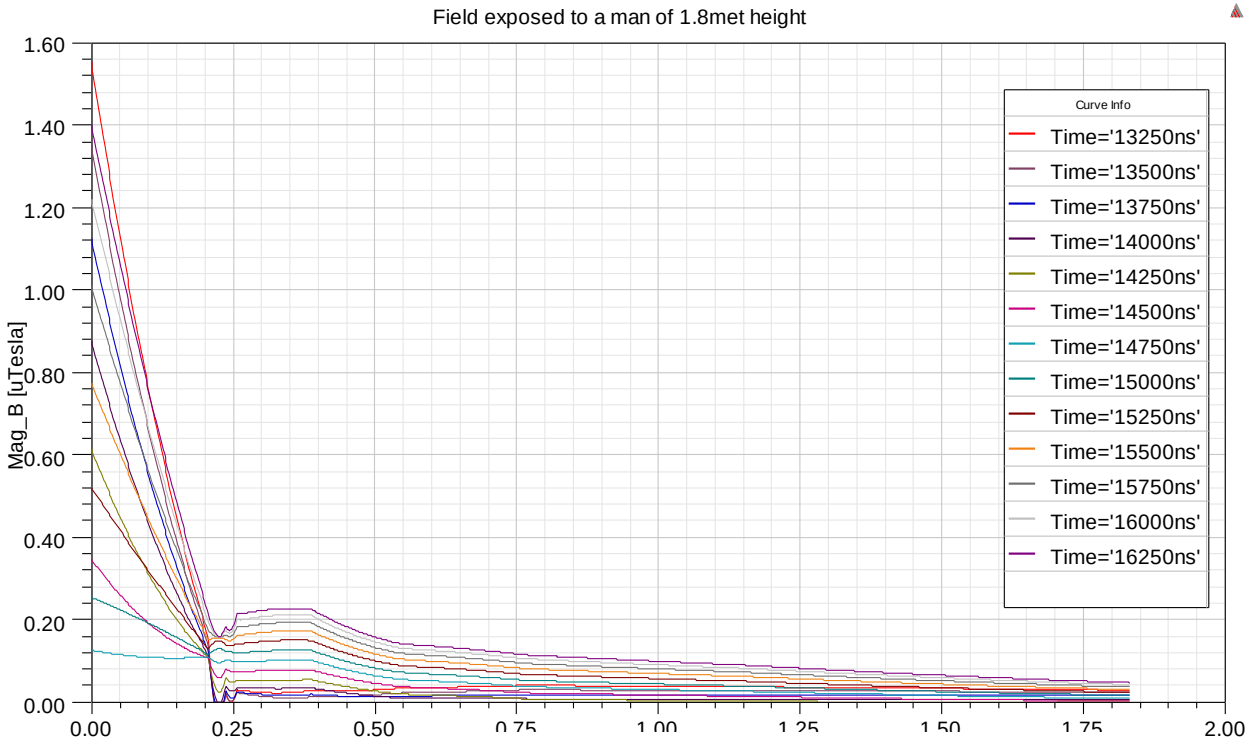


- Analytical
  - Equivalent circuit analysis; S-parameter analysis; Analytical solutions of inductance and capacitances
- Numerical
  - Finite element analysis – electromagnetic; High frequency structure simulation - HFSS
  - Coupled field and lumped parameter analysis
- Experimental

Exposed field to a human of 1.8-meter high

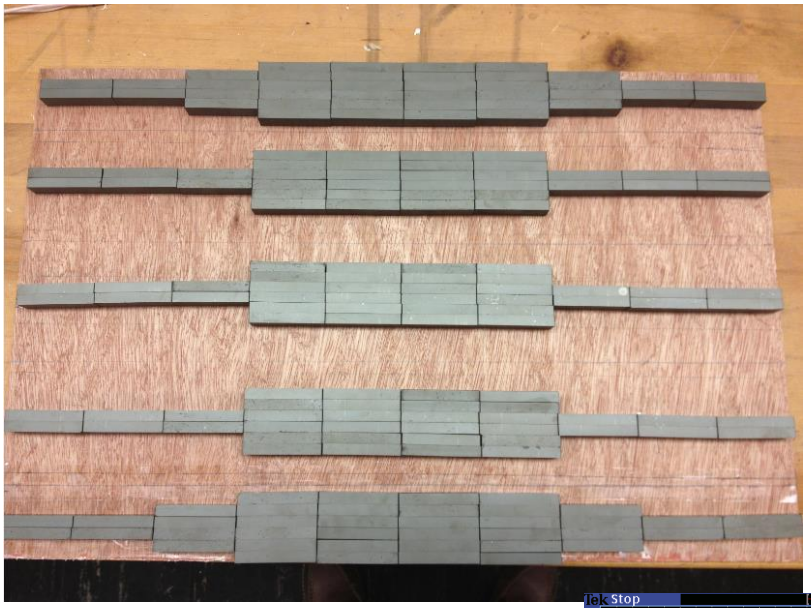
Human body is exposed to maximum about 1.6uTesla in foot area while about 0.06uT in head area.

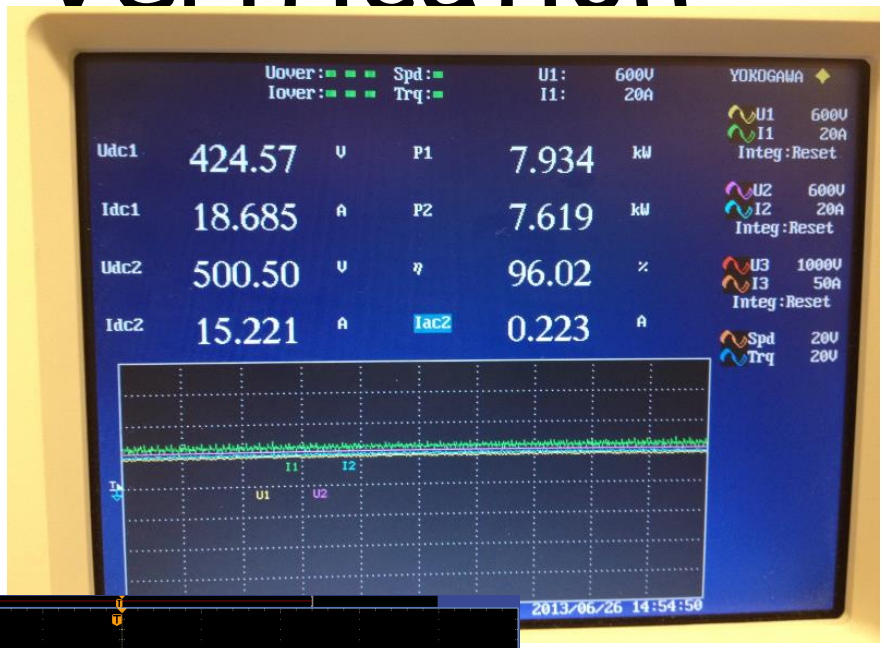


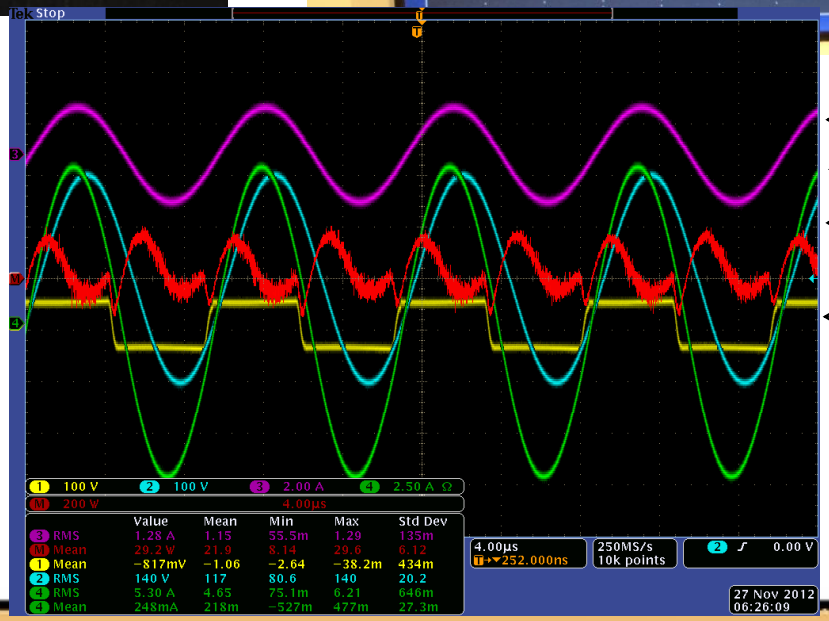


Human's height [in meter]

Experimental Verification

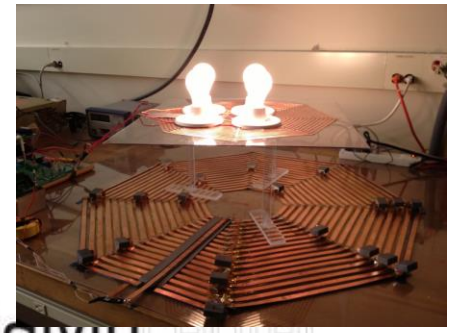






← Output current
← Input current
← Output voltage

← Input voltage



Max power: 8kW
Max Eff.: 97%

Vehicle Demonstration

- Working closely, we are making a vehicle level demonstration by end of 2013 or early 2014
- We are also working with DENSO to bench mark the design with existing wireless charging systems
- UM is also signing an agreement with Mia Motors, Inc. to commercialize the wireless charging for electric buses.