CERV 2015

Dynamic Power Transfer: A look into the future of wireless power transfer

Session #5
4:00-5:30PM

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Overview

- The Vision
- Magnetic Topologies
  - Non-polarized, polarized and multi-coil
- Buses and Private EVs
- Present dynamic systems
- Challenges of stationary and dynamic coexistence
- Future Roadway Systems

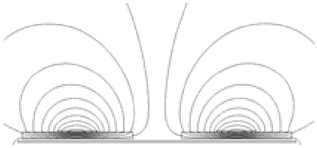
The Vision: A dynamic highway

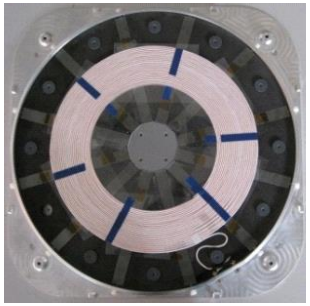
Allows lower battery weight but Gaps 20-40cm

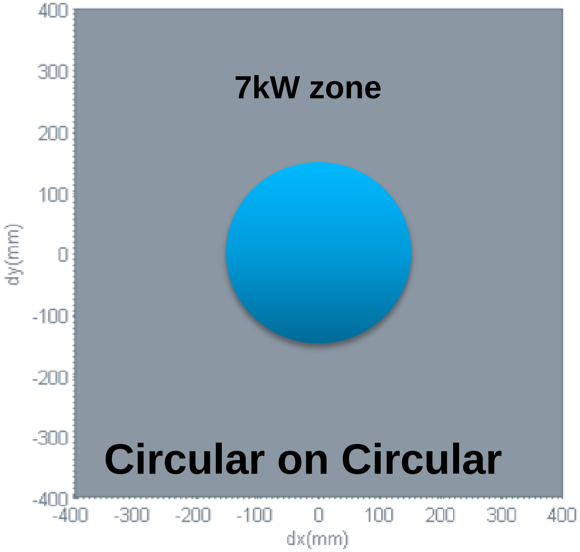
MAGNETIC TOPOLOGIES

Non-Polarized vs. Polarized

Transfer height d/4

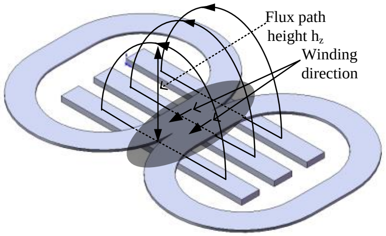


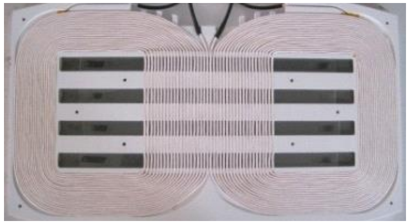


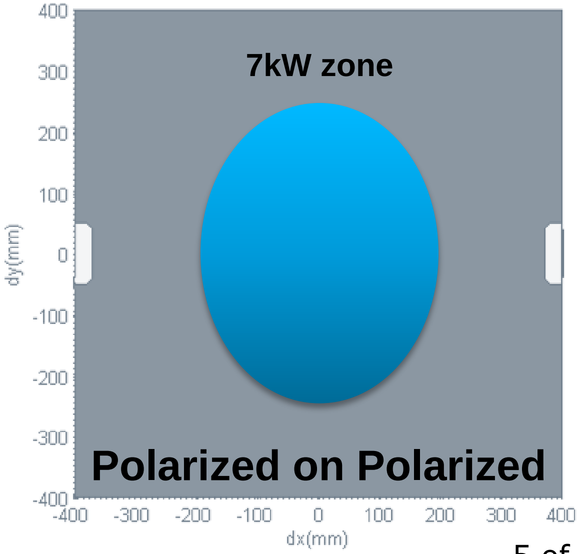


Charging Area
Circular < 2x Polarised

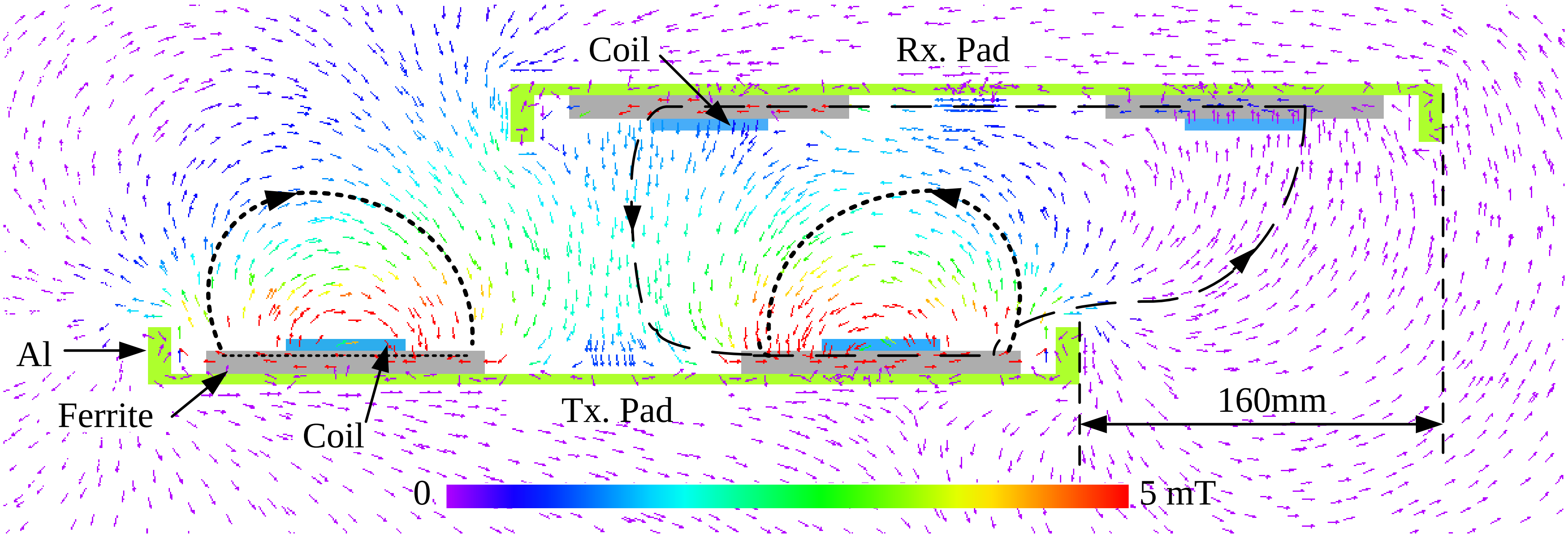
Transfer height d/2







Circular Coupler Limitation



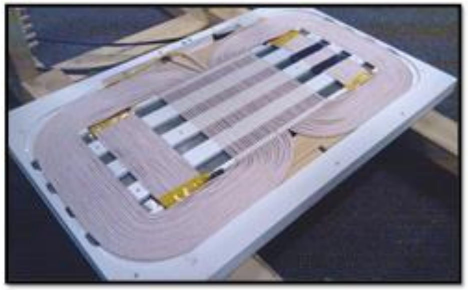
- ☐ Power null in all directions (around 80% pad radius)
  - Suited to stationary applications
  - Requires multiple offset secondary's for dynamic
- ☐ Size of pad must also be large for high Z
  - Undesirable for private vehicles

Dynamic Evaluations

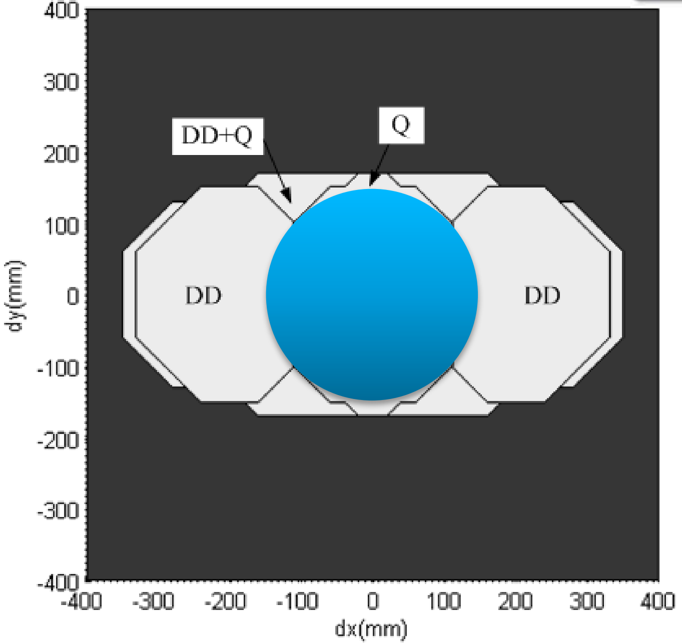
Oakridge National Laboratory

- Power Pulses followed by Nulls
- Overcome using two offset coils and ultra capacitors
  - But reduces potential capture
- Concluded Polarised needs attention

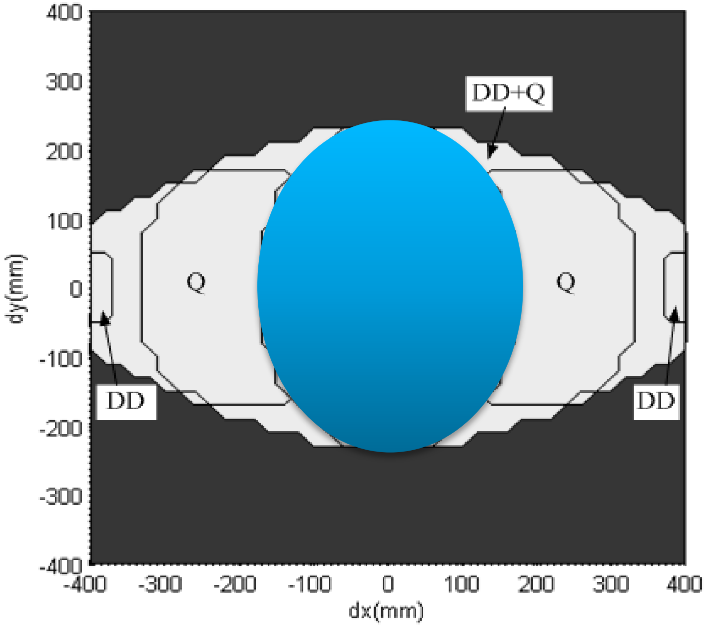
Multi-coil on Various Primaries



Non-Polarized Primary

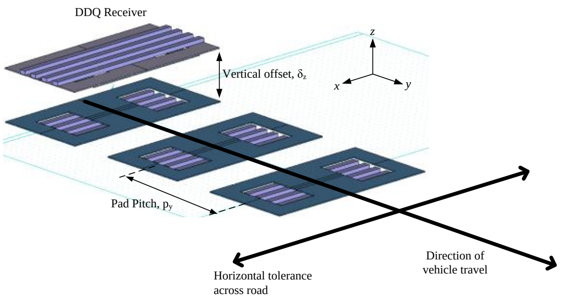


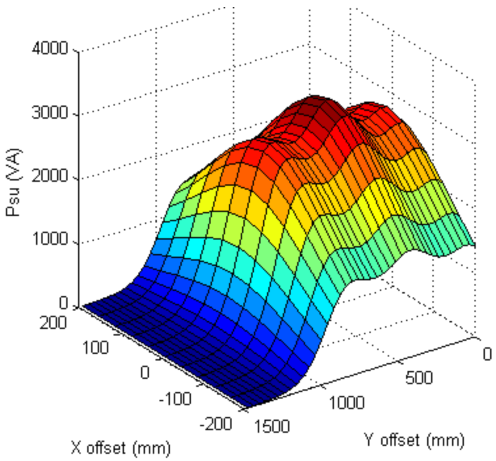
Polarised Primary



Charging area 3 x greater

IPT Evaluations: Auckland

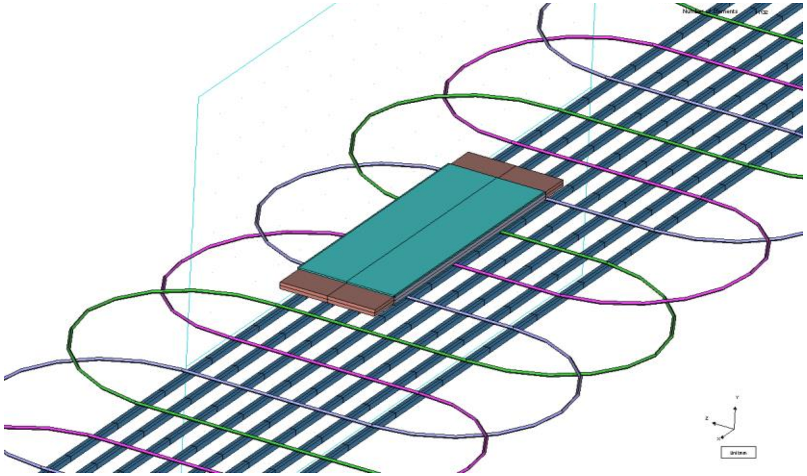


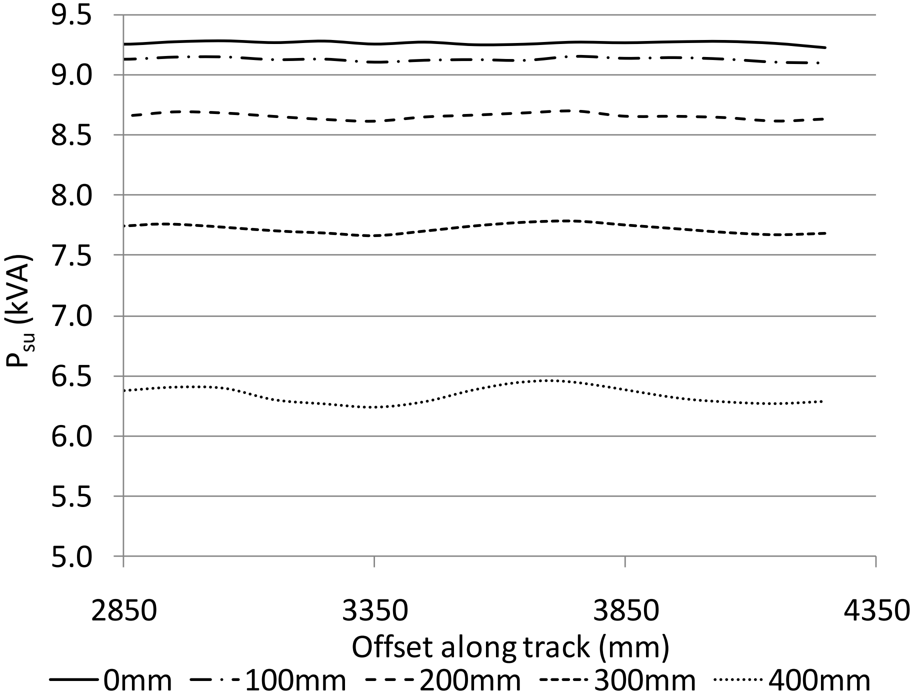


600mm lateral tolerance @ full power
using multi-coil vehicle pads

Multiphase Track Evaluations

- Three Phase Track (ferrite backing)
  - Horizontal coil only





240A/phase, 20kHz, 200mm vehicle gap

P_{out} > 50kW

Reference [25]

BUSES & PRIVATE VEHICLES

Bus Charging

Genoa, Porto Antico

- 60kW 20kHz Charger (2002)
  - 2 x 30kW oval chargers
  - Lowered to within 1-2 inches

WAVE IPT Charged Bus

- (2014) 50kW charger
  - Circular Pads, gaps above 9 inches

KAIST OLEV Systems

17 cm gap

- 2013 KAIST
  - Polarised Primary and Secondary couplers
  - Sized for bus
  - 20-100kW

http://olev.kaist.ac.kr/en/index.php

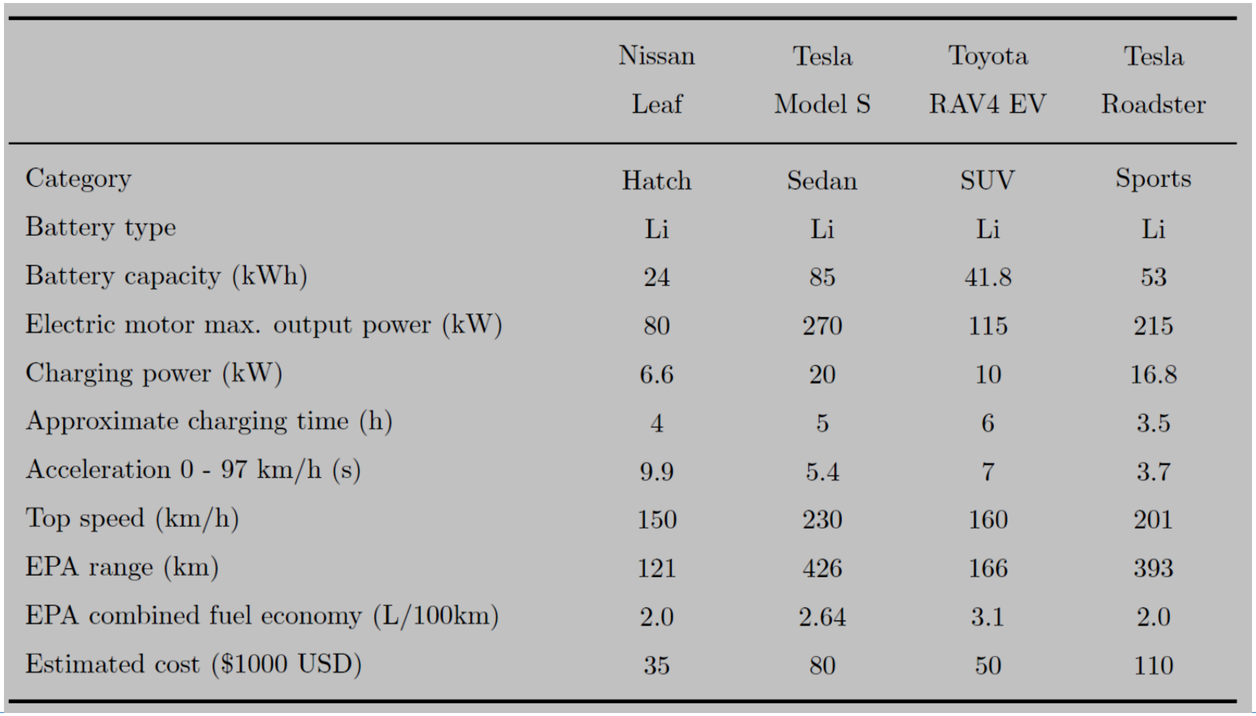
Bombardier Primove Wireless

- Bombardier (2013) Primove
  - Polarized Multiphase tracks and Pads
- 100-200kW transfer

*www.primove.**bombardier**.com*

Private Vehicle Charging

- Hybrids 3kW and pure EVs up to 7kW
  - Main focus of commercial effort
- SUVs and Sports EVs and 10-20kW
  - Varying ground clearance



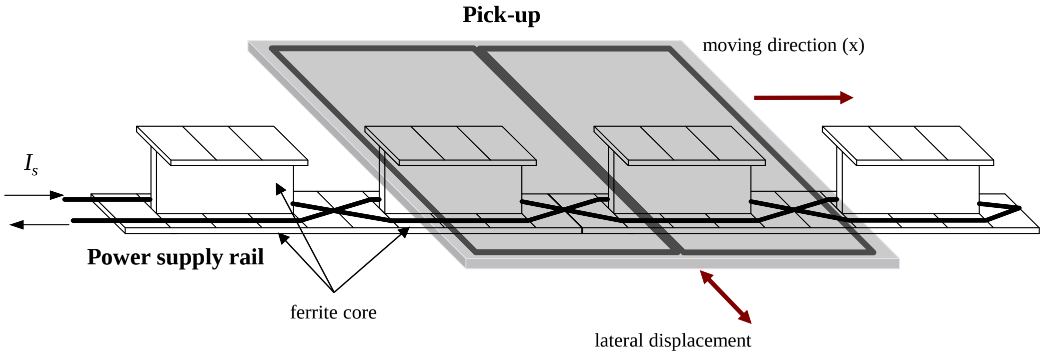
	Nissan Leaf	Tesla Model S	Toyota RAV4 EV	Tesla Roadster
Category	Hatch	Sedan	SUV	Sports
Battery type	Li	Li	Li	Li
Battery capacity (kWh)	24	85	41.8	53
Electric motor max. output power (kW)	80	270	115	215
Charging power (kW)	6.6	20	10	16.8
Approximate charging time (h)	4	5	6	3.5
Acceleration 0 - 97 km/h (s)	9.9	5.4	7	3.7
Top speed (km/h)	150	230	160	201
EPA range (km)	121	426	166	393
EPA combined fuel economy (L/100km)	2.0	2.64	3.1	2.0
Estimated cost ($1000 USD)	35	80	50	110

Stationary Charging Comparisons

- Frequency
  - 85kHz announced by SAE J2954 for private
  - 20kHz considered for buses
- Magnetic designs Private EVs
  - Focus on low Z systems at 3kW & 7kW
  - Size constrained (Hybrids 250 mm^2 secondary)
  - Simplest topologies (min: size, weight, cost, electronics)
  - In garage or building with controlled tolerances and gaps
  - Higher Z & Power still under discussion
- Magnetic designs Public transport
  - Bus topologies all vary between suppliers
  - Assumes defined parking locations
- No systems optimised for roadway
  - Heights, tolerances or power
  - Lateral Tolerances Limited by Design
  - All assume parking guidance

PRESENT DYNAMIC SYSTEMS

KAIST OLEV Systems



20-100kW
17 cm gap
Inductive strips sized for Bus

- 2013 KAIST
  - Polarised only track and secondary has power nulls
  - Two phase DQ track smooth's power transfer

Dynamic IPT Systems

Light Rail: Continuous 270kW power, buried cables replaces catenaries

Bus: Dynamic trials
lowered pads at controlled height

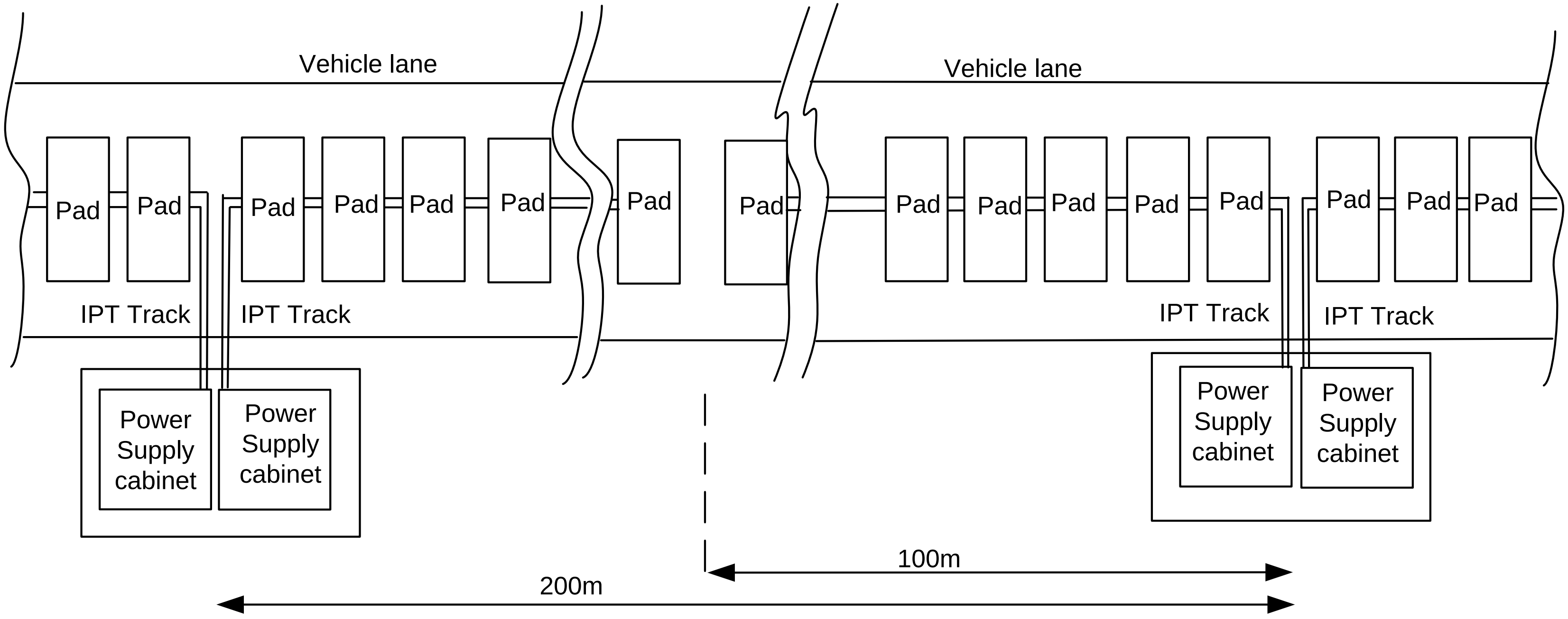
- Bombardier Primove Multiphase using multiple pads

CHALLENGE OF COEXISTENCE

Sharing the Highway

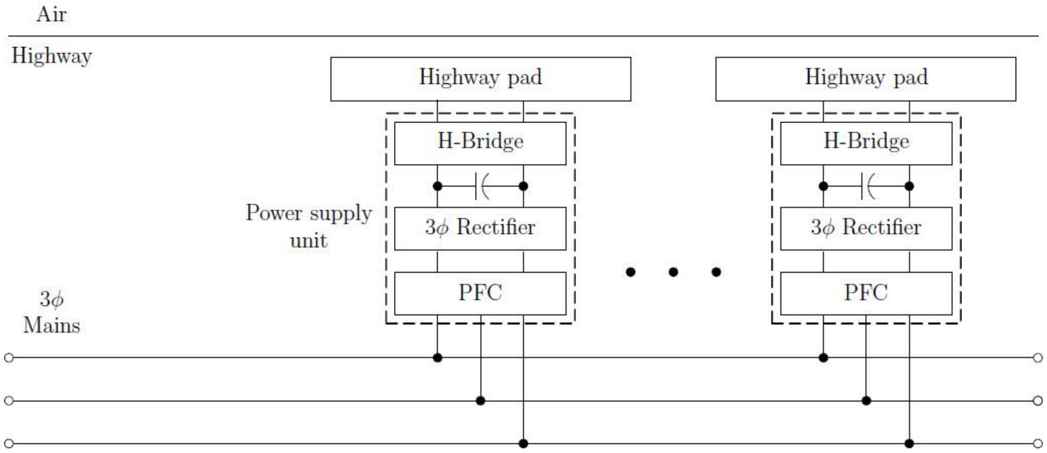
- Characteristics of Dynamic Bus Systems
  - Lower frequency (typically ~20kHz)
  - Larger or matched Secondary's
    - Lowers roadway cost, helps emissions
  - Large length primaries (2.5m or above)
- Desirable Requirements for Powering EVs
  - Ideally future stationary pads compatible with dynamic
    - Present in-garage or parking buildings too small
  - Multiple power pads each ~ 10-20kW could be suitable
    - Use one for stationary and more as required for highway
- Polarised Pads can Interoperate
  - single, two-phase and three phase if pole pitches similar
  - Smaller EVs and charge emissions may dictate
- Need a Common Frequency for Private and Public
  - To accommodate private EV size, 85kHz seems better

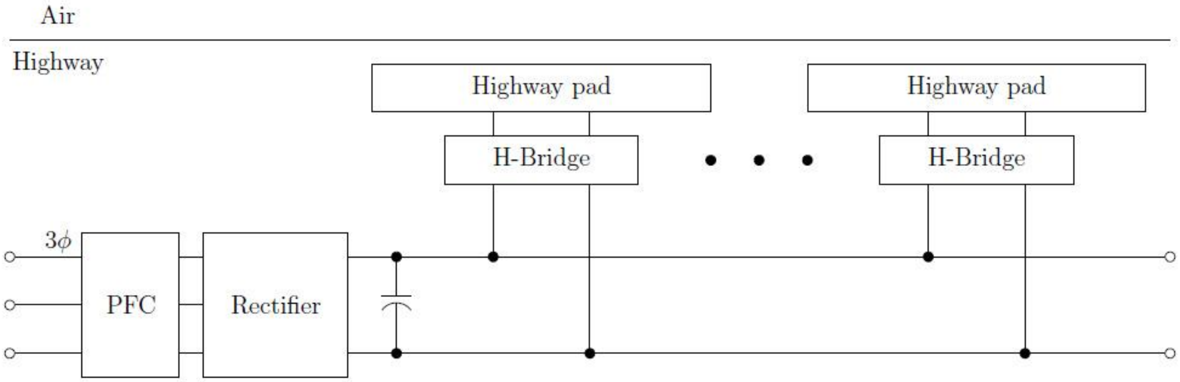
A Roadway Vision



- ☐ Sequentially Energised Pads under the Vehicle
  - Pad length dictated by smallest vehicles
- ☐ Meeting varying power demand of traffic
  - Larger vehicles have more pads

Options #1

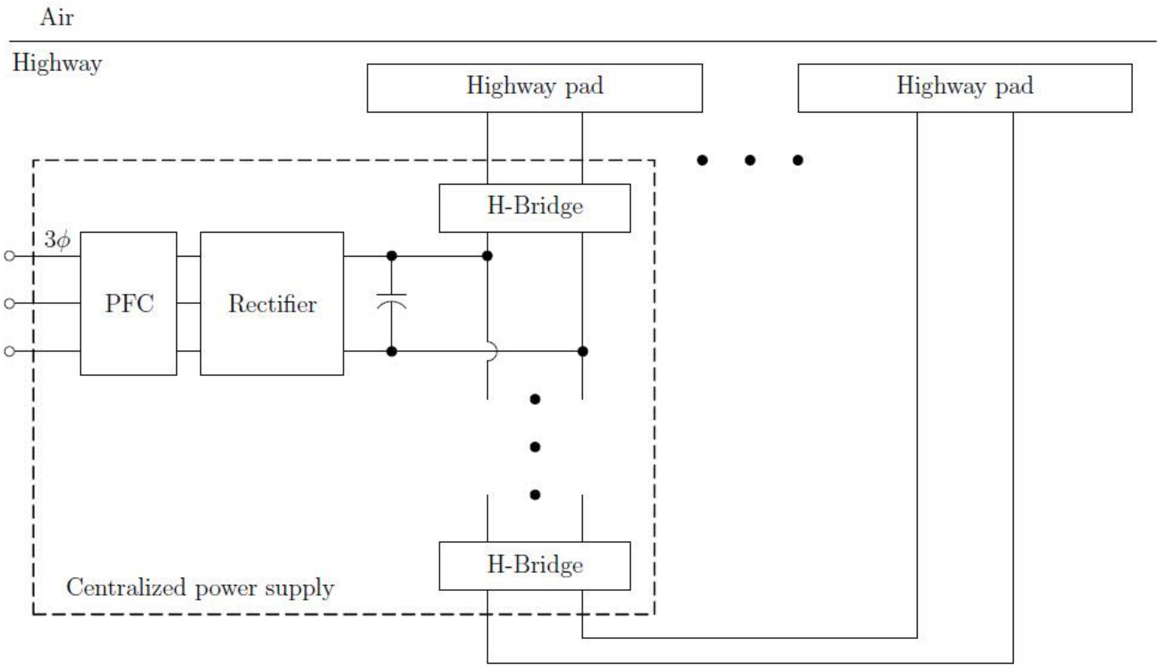




Challenges

- ☐ Mains or DC under roadway
  - Prohibited in some countries or buried several feet

Option #2



Challenges

- ☐ All pads in a group must be on
- ☐ Central PS handles all reflected VARS
- ☐ Long track lengths at the resonant frequency
  - Ok at 20kHz maybe issue at 85kHz

Option#3

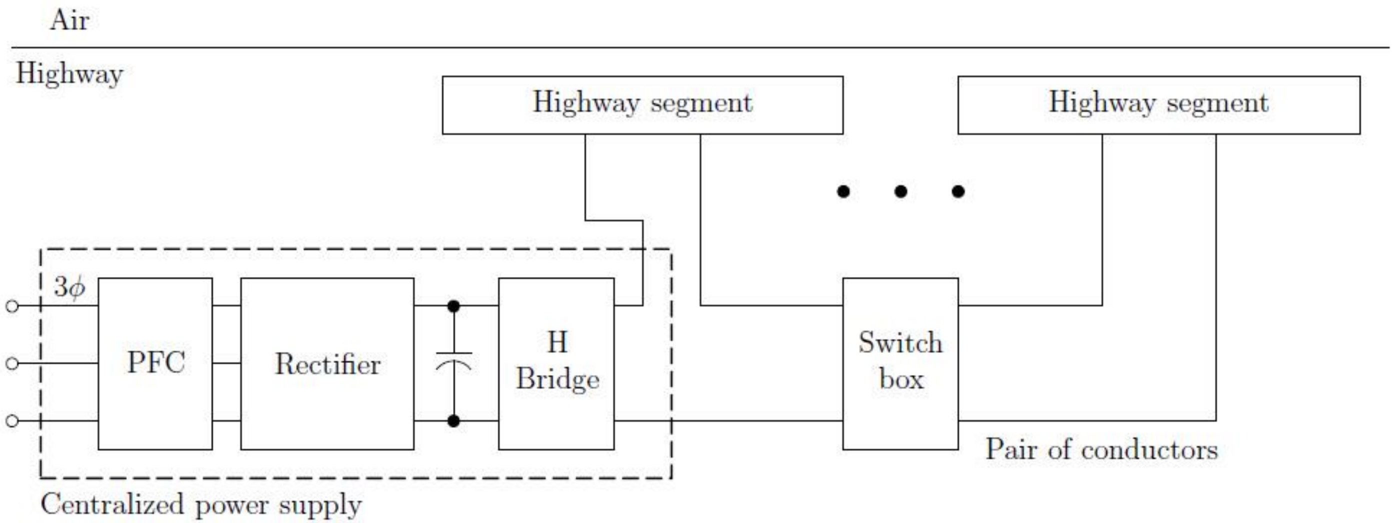


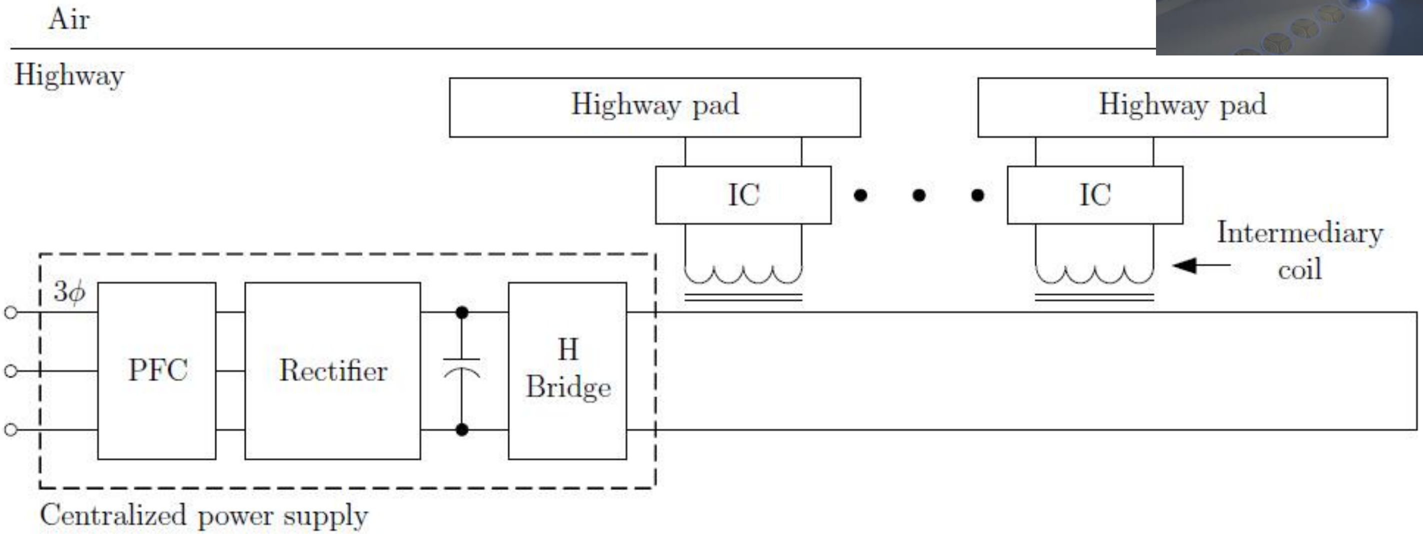
Figure 1.4: X-Rail based IPT EV highway.

- ☐ Individual Pads can be controlled & switched

Challenge

- ☐ Long track lengths at the resonant frequency
  - Ok at 20kHz maybe issue at 85kHz

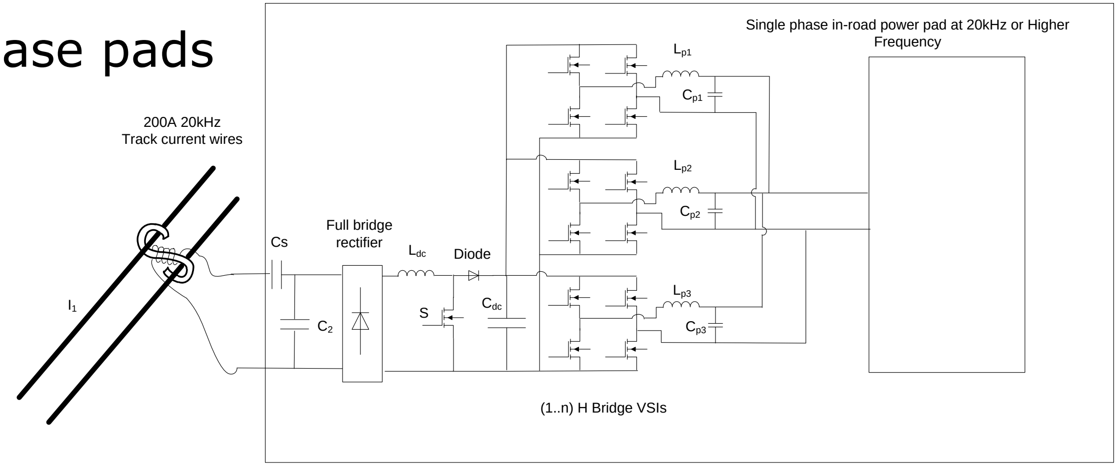
Auckland’s Vision



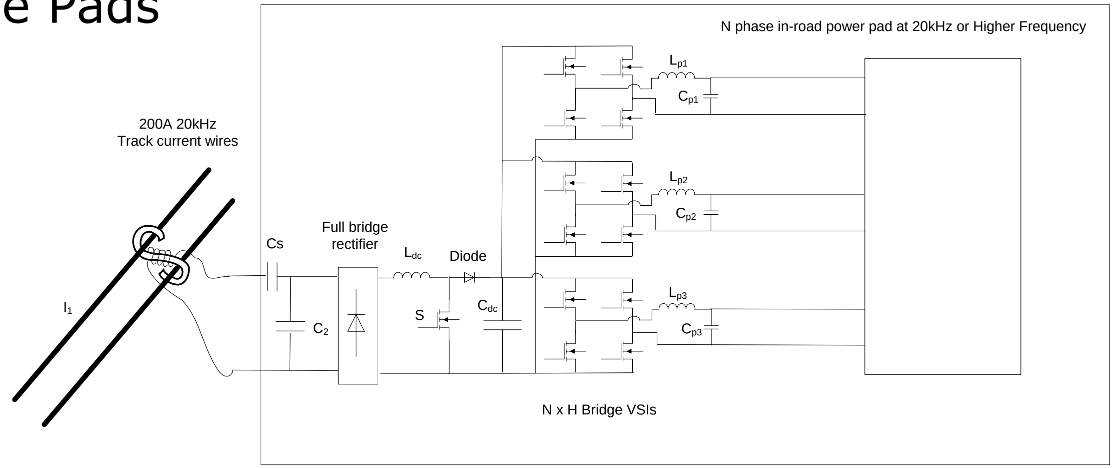
- ☐ Individual Pads can be controlled & switched
- ☐ Long track lengths at the low resonant frequency
- ☐ Higher Frequency at pad
- ☐ No VAR reflections, no DC or mains under the road

Dynamic Highway Options

- Intermediate Controllers
  - Single phase pads



  - Multiphase Pads



Laboratory Scale Dynamic Highway

- ☐ Pad detection and energisation

Research Questions

- Robustness of highway Pads
  - Roadway flex and longevity (at least 10 years needed)
- Impact of mineral surface of highway
- Required tolerances?
  - What type of vehicle gap can we support
  - Lowering secondary pads on trucks/busses?
- What cost is acceptable?