The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION
BARCELONA
17th-20th November 2013

NISSAN MOTOR COMPANY

Design and Evaluation of a Wireless Power Transfer System with Road Embedded Transmitter Coils for Dynamic Charging of Electric Vehicles

EV System Lab., Nissan Research Center

Kraisorn Throngnumchai

Organized by Fira Barcelona, avele

Hosted by AVERE, nea, Ajuntament de Barcelona

In collaboration with EVAAP, EDTA

Supported by European Commission

Agenda

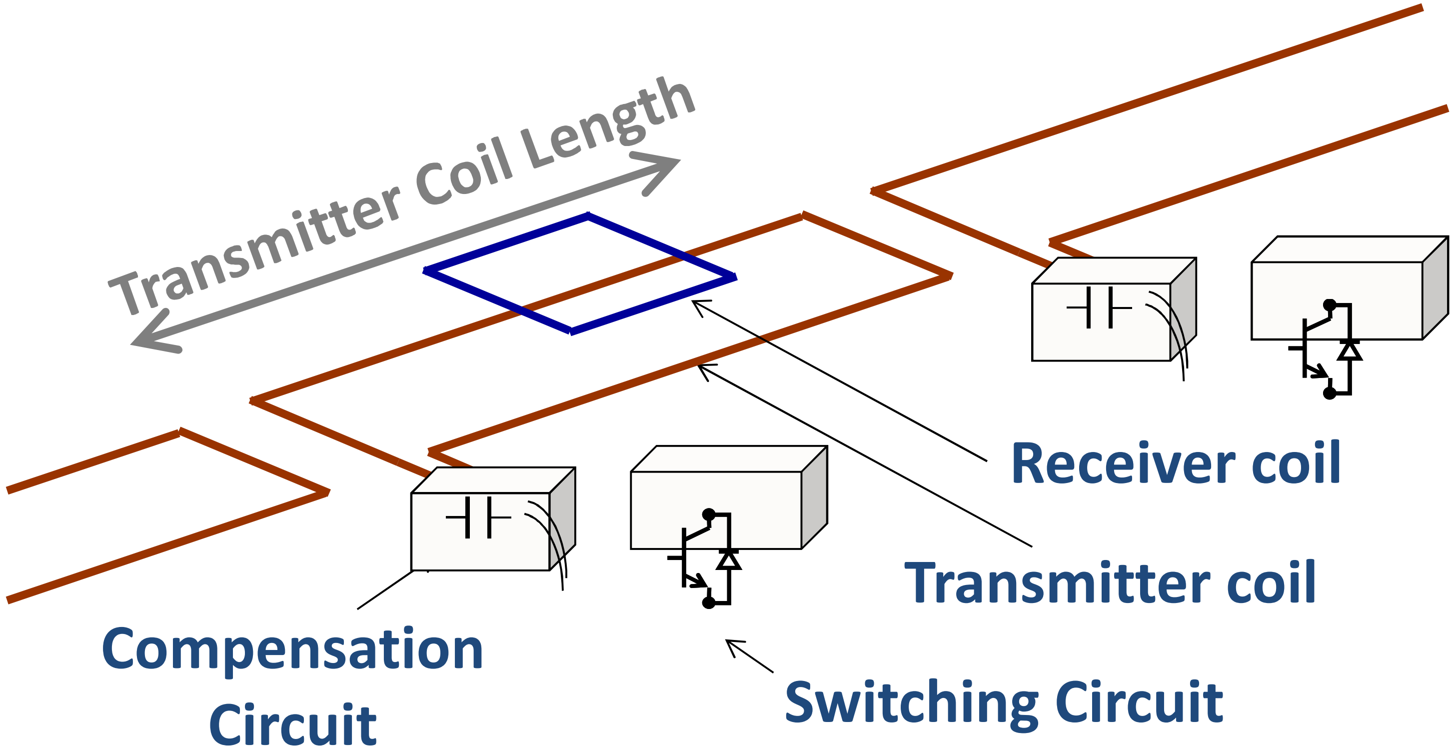
1. Introduction
2. Coils Design and Evaluation
3. Compensation Circuits Design and Evaluation
4. Test Road Construction
5. Demonstrations
6. Conclusions

1. INTRODUCTION

Nissan LEAF

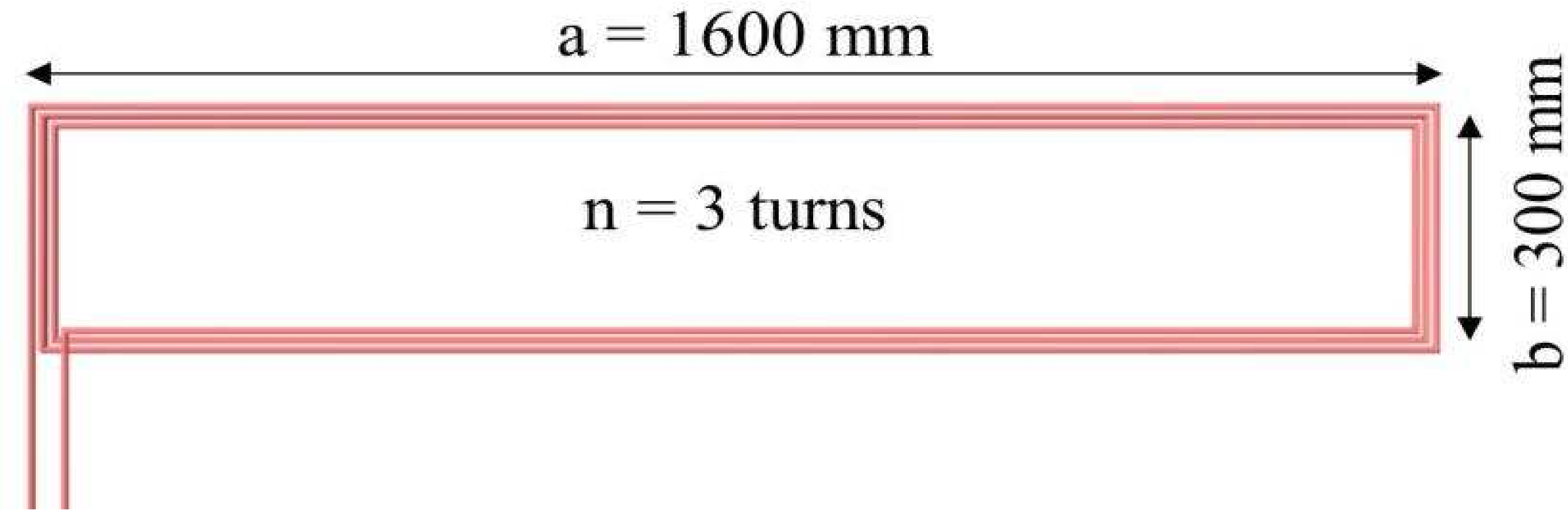
Illustration of Dynamic Charging

Schematic Illustration of a Dynamic Charging System



2. COILS DESIGN AND EVALUATION

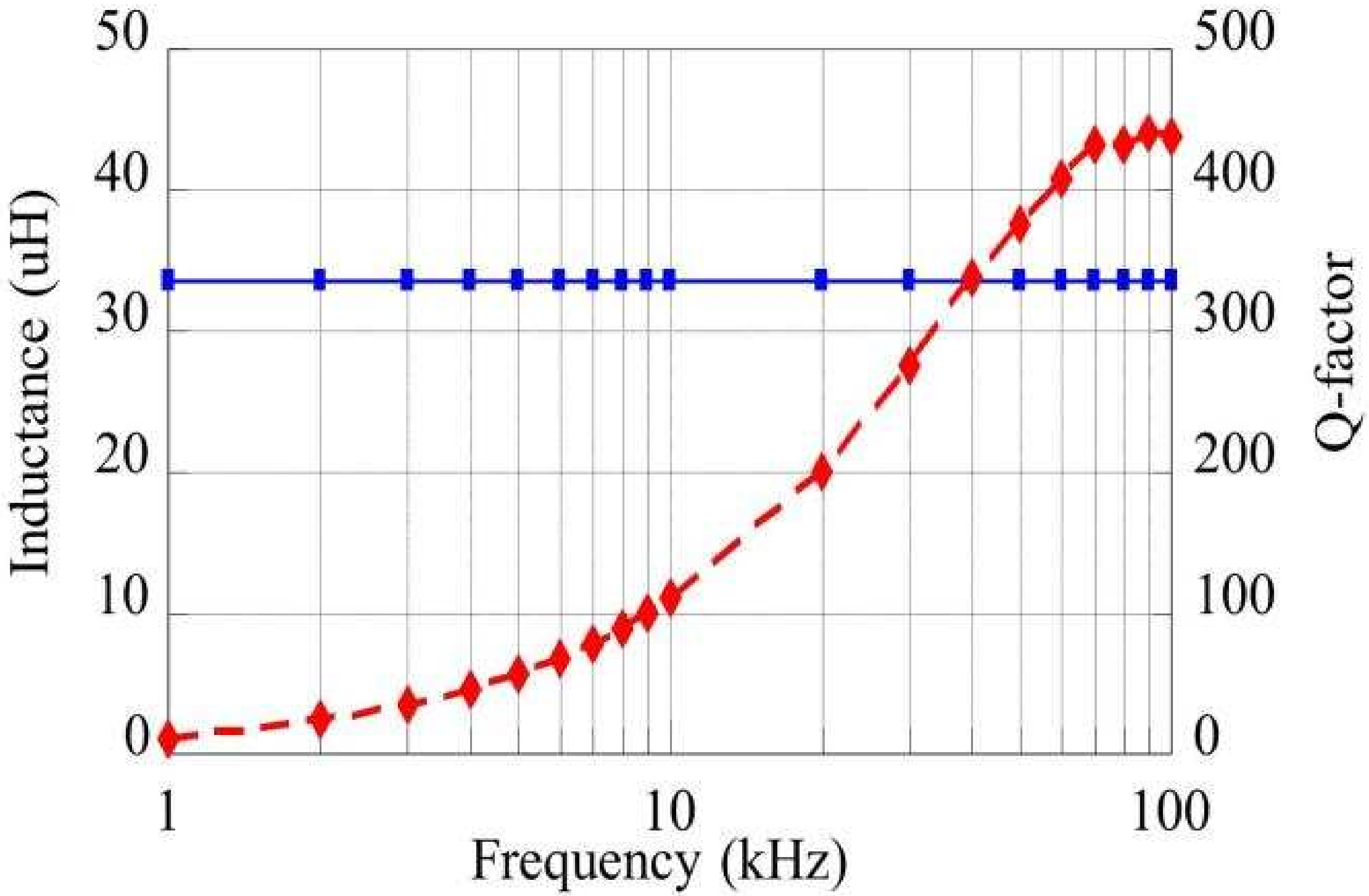
Schematic Illustration of the Transmitter Coil



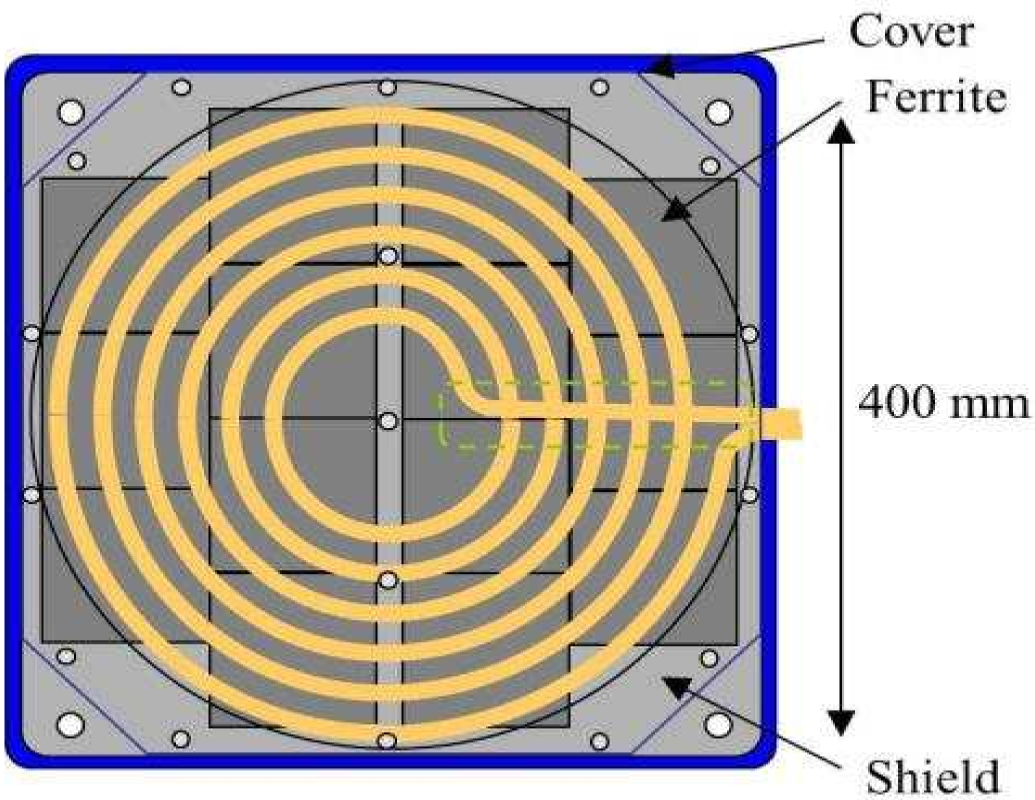
$$L = \frac{\mu_0 \cdot n^2}{\pi} \cdot \left(b \cdot \ln \frac{a}{r} + a \cdot \ln \frac{b}{r} \right)$$

Photograph of the Transmitter Coil

Self Inductance and Q-factor

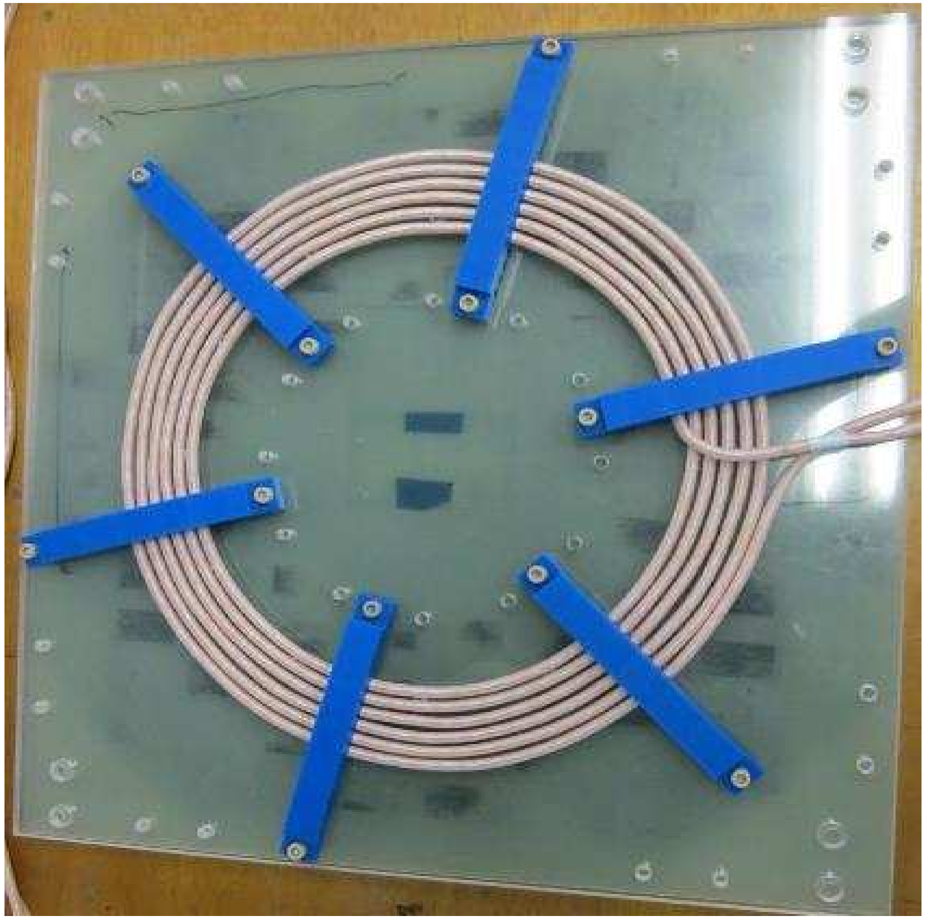


Schematic Illustration of the Receiver Coil

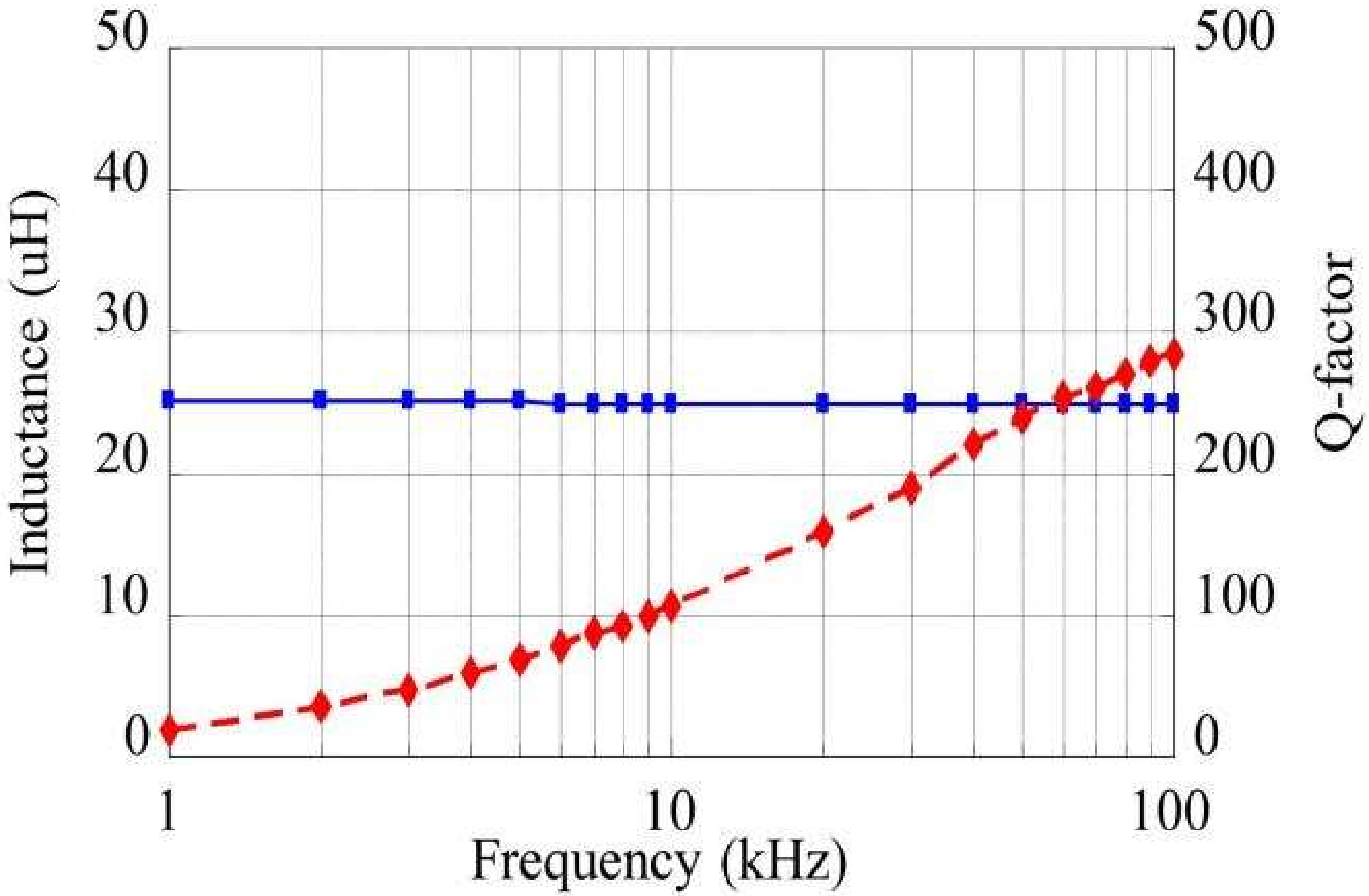


$$L = \mu_0 \cdot R \cdot n^2 \cdot \left(\ln \frac{8R}{r} - 2 \right)$$

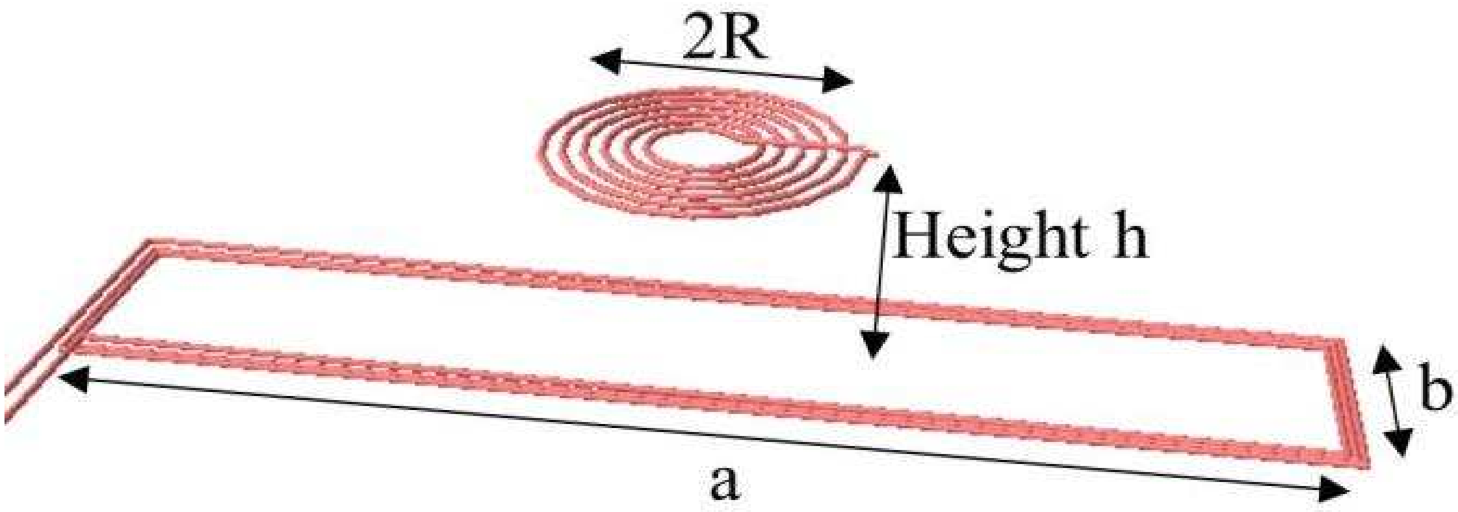
Photograph of the Receiver Coil



Self Inductance and Q-factor

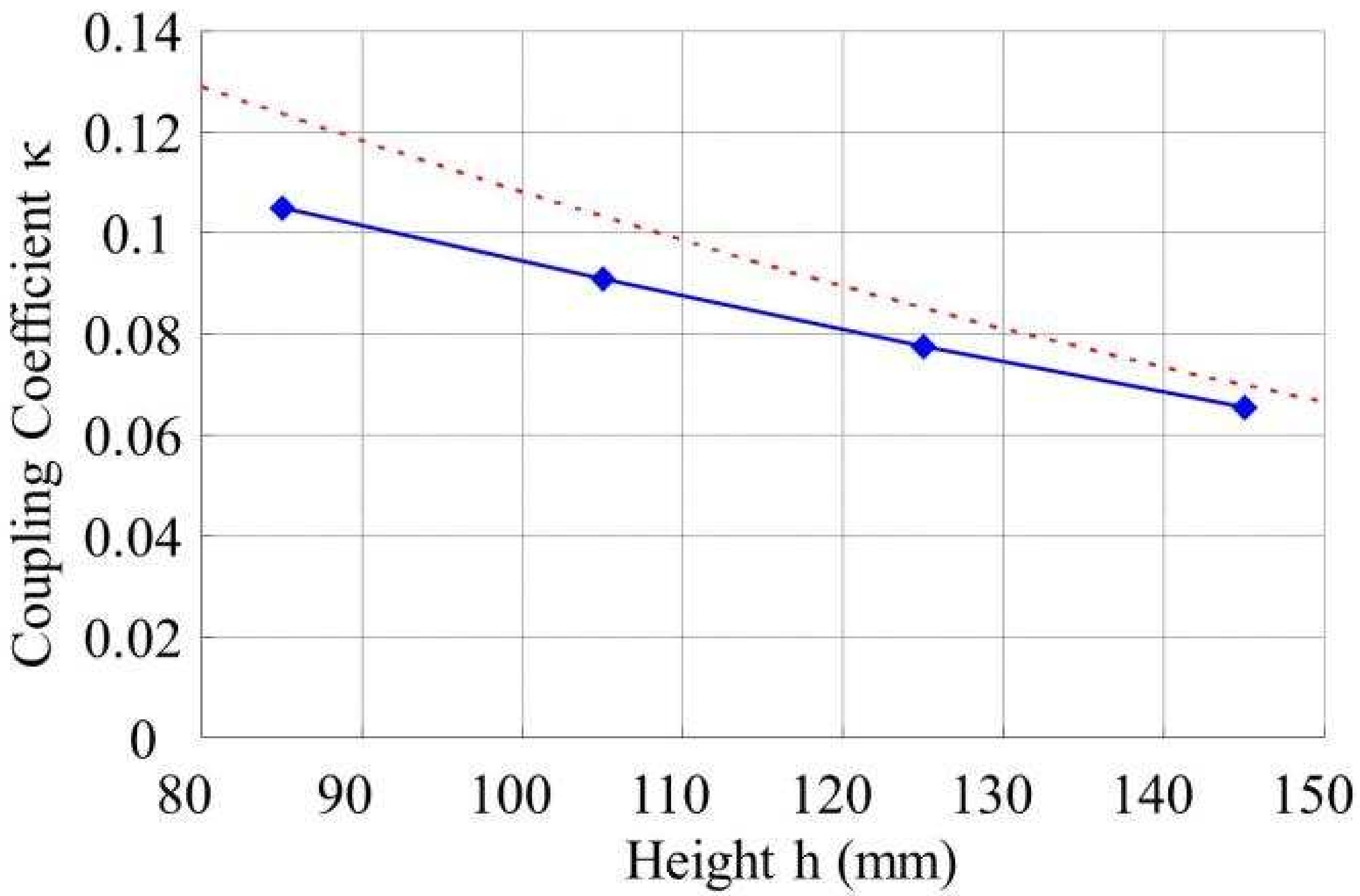


Coupling Coefficient κ

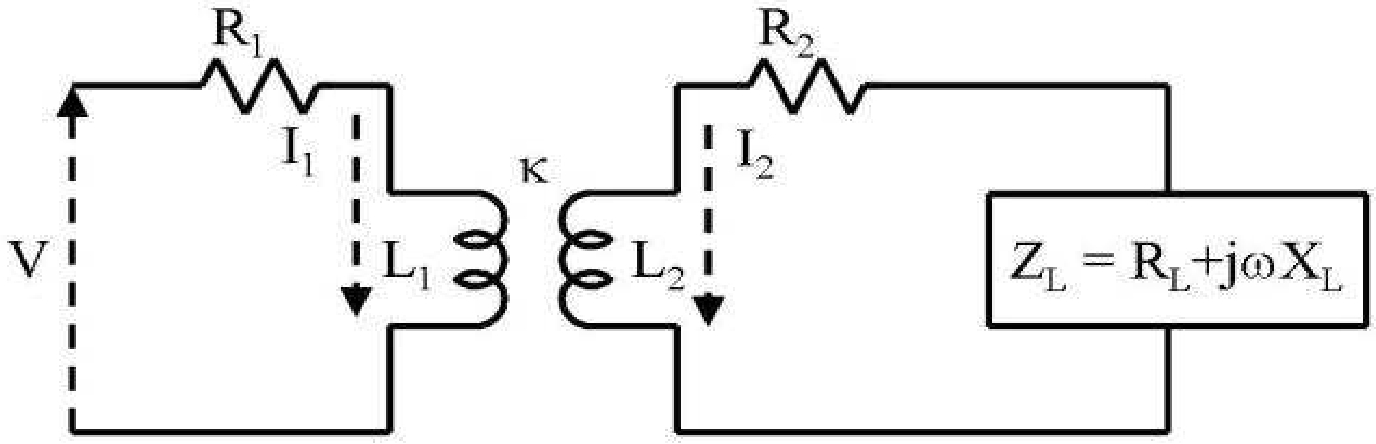


$$\kappa = \frac{2R}{a} \cdot \left(\frac{R}{\sqrt{b^2 + 4h^2}} \right)^3$$

Coupling Coefficient κ



Analyzing of Theoretical Maximum Power Transfer Efficiency η

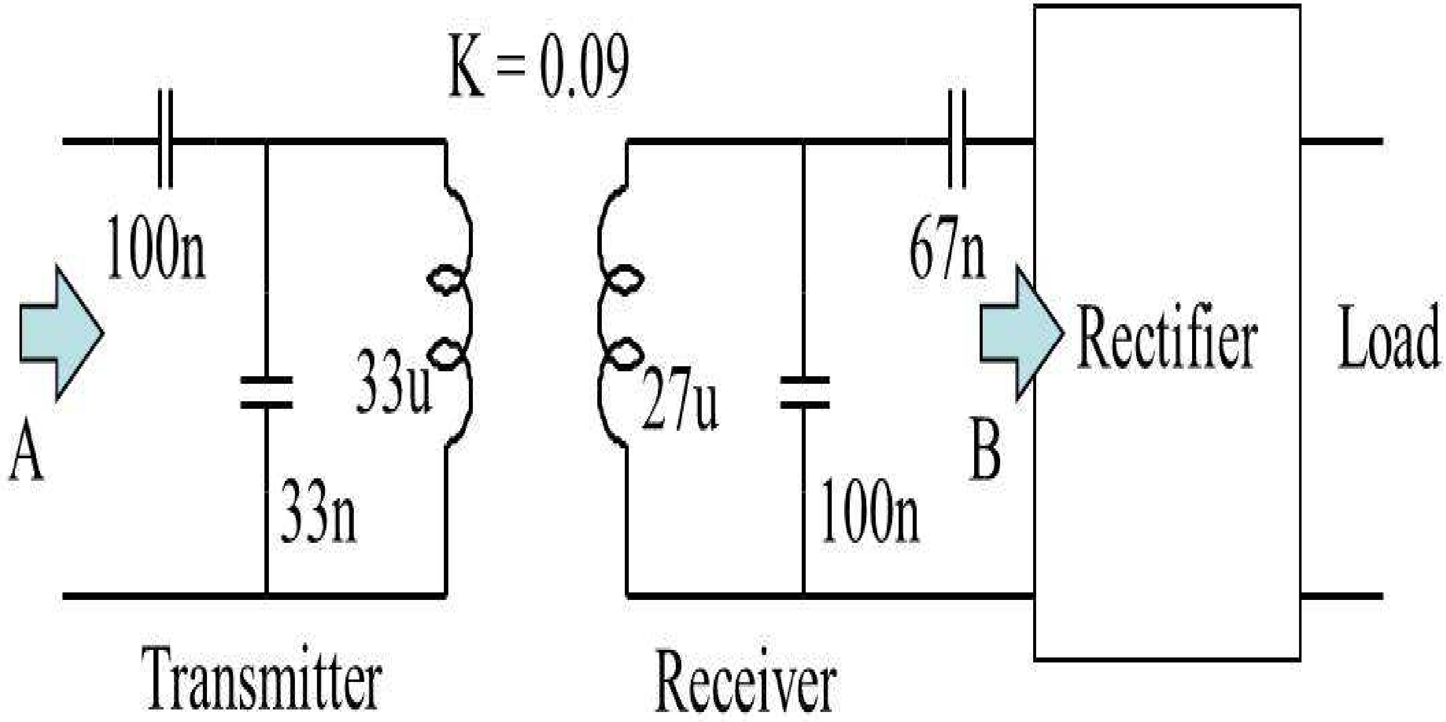


$$\eta = \frac{I_2{}^2 R_L}{I_1{}^2 R_1 + I_2{}^2 R_2 + I_2{}^2 R_L} = \frac{R_L}{\frac{(R_2 + R_L)^2 + (\varpi L_2 + X_L)^2}{(\varpi M)^2} R_1 + R_2 + R_L}$$

$$\therefore \eta_{\max} = \frac{1}{1 + \frac{2}{\kappa^2 Q_1 Q_2} + 2\frac{\sqrt{\kappa^2 Q_1 Q_2 + 1}}{\kappa^2 Q_1 Q_2}} \Rightarrow \boxed{\eta_{max} = 94\ \%}$$

3. COMPENSATION CIRCUITS DESIGN AND EVALUATION

Schematic Circuit Diagram of the Compensation Circuits

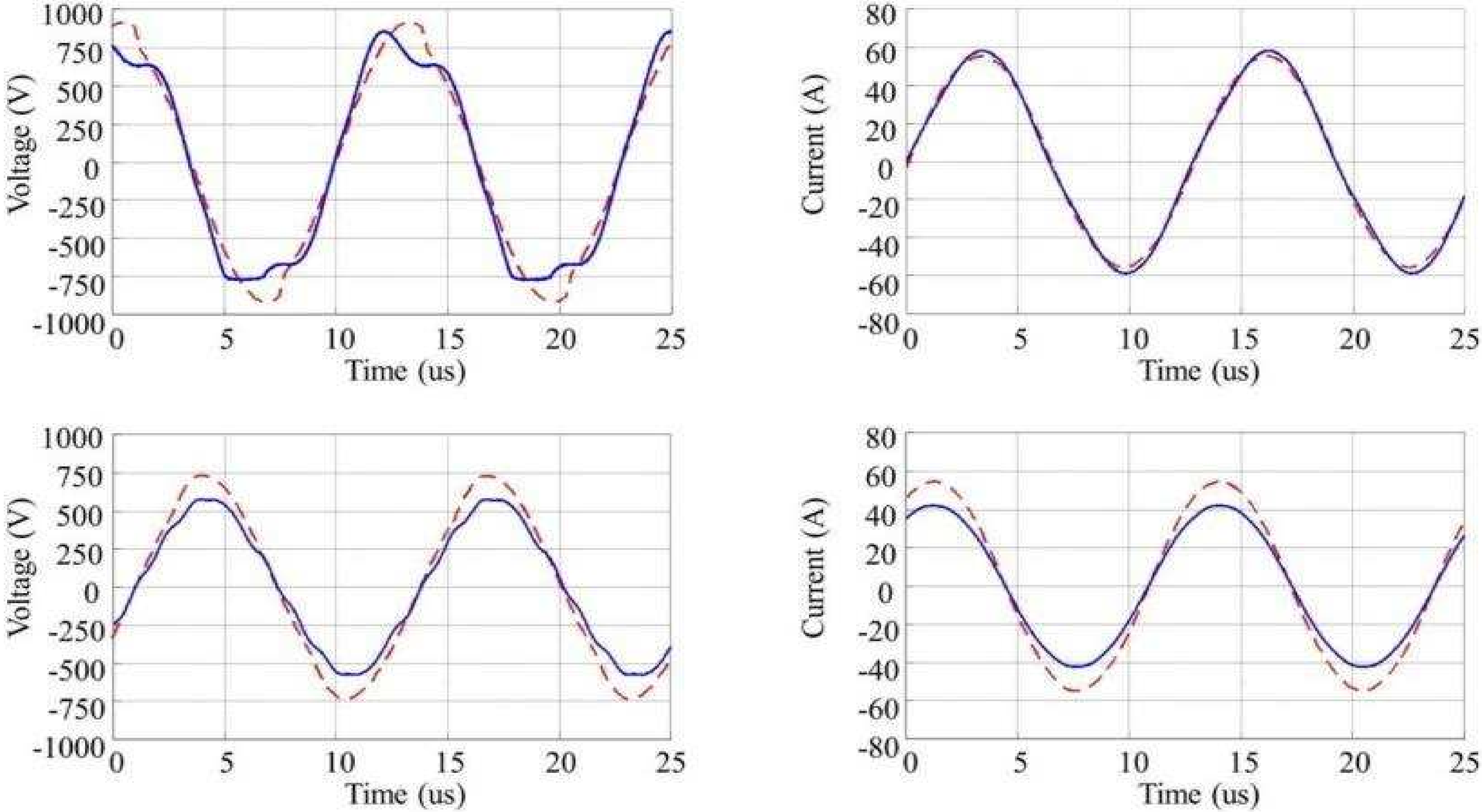


K. Throngnumchai et. al., *A Study on Receiver Circuit Topology of a Cordless Battery Charger for Electric Vehicles,* IEEE ECCE 2011, 843-850

Results Measured in a Shielded Room

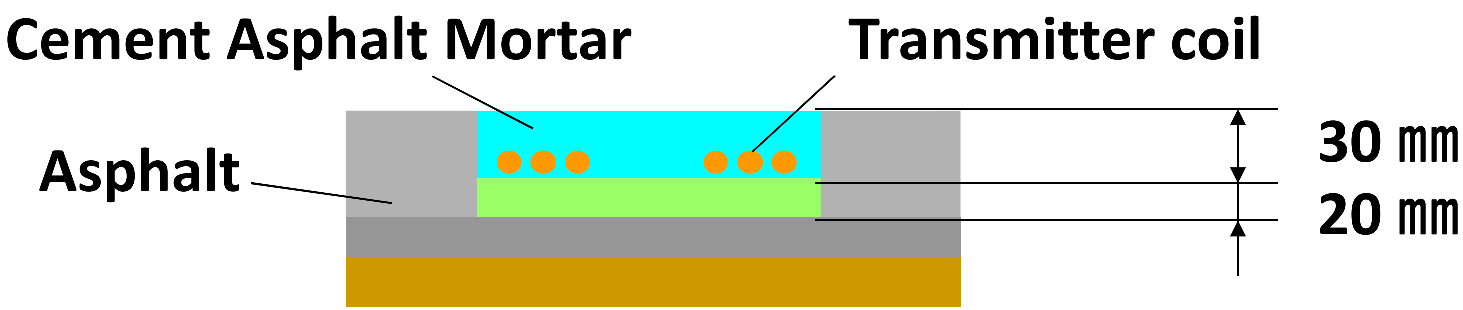
Frequency	78 kHz
Load	12 Ω
Transferred Power	1.2 kW
Efficiency (Coil-to-Coil)	92.8 %

Voltage and Current Waveforms of the Transmitter and Receiver Coils



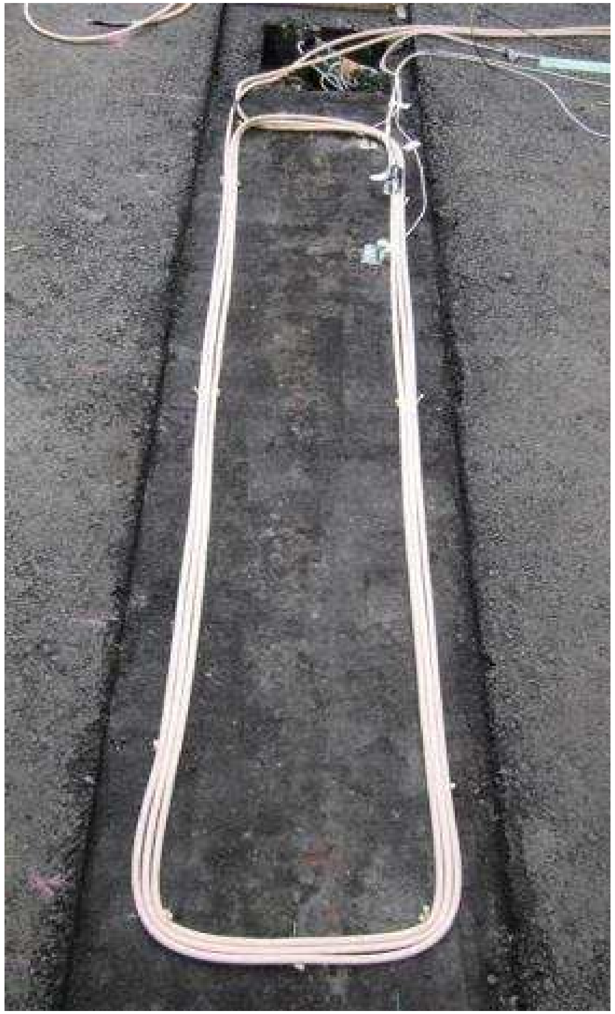
4. TEST ROAD CONSTRUCTION

Cross Sectional View of the Test Road



Removal of Surface Layer

Transmitter Coil to be Embedded



Hot Mix Asphalt Concrete Needs Compaction after Paving

Cold Mix Asphalt Concrete

Emulsified Asphalt in Water with Soap 1.4 / Cement 1 / Silica Sand 1

Constructed Test Road after Paving and Lane Mark Painting

5. DEMONSTRATIONS

2-seater Electric Vehicle used in the Demonstration

Power < 50 W

(To meet RF-regulation in Japan)

Power < 50 W

(To meet RF-regulation in Japan)

6. CONCLUSIONS

Conclusions

1. A design and evaluation of road embedded transmitter coils and EV installed receiver coil has been presented.
2. A compensation circuit with 2 resonators has been designed for both the transmitter and receiver.
3. A cold mix asphalt concrete has been selected as the material for constructing the test road to avoid exposing the transmitter coils to high temperature and high pressure.
4. A demonstration using a 2-seater EV has been presented.

Thank you for your attention

t-kraisorn@mail.nissan.co.jp