Transmission of energy and information from road to electric vehicle

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Abstract

We have developed a prototype that transmits electric power and driving-control information to a model vehicle from the road. It is based on a magnetic resonance wireless power-transmission technology and has a high efficiency.

Keywords : Electric vehicle Wireless Power Transmission Communication ITS

1. Introduction

Electric vehicles (EVs) are increasing in popularity. However, they have several limitations such as low mileage, slow battery charging, and large battery volume and weight. Therefore, EVs are best suited for local transportation. If EVs are to replace vehicles with internal combustion engines, the battery will need to be replaced by an improved energy source. For example, electric power could be supplied to the vehicle from the road.

Recently, the magnetic resonance method [1], which can transmit electric power efficiently over 1 to 2 m, has attracted attention, and applications to cell phones and home electronics have been investigated. For vehicle applications, the power transmission must be efficient, safe, and applicable to vehicles of different heights. Therefore, the magnetic resonance method is appropriate.

To verify the feasibility of this system, we developed a prototype that transmits electric power and control information to the vehicle from the road, and we performed experiments [2] [3].

2. Outline of Experimental System

2.1 **Integration of wireless power transmission and communication**

Figure 1 shows the configuration of the system. We use a conventional radio communication system and add a coupler and a rectification circuit to the receiving side and a power amplifier to the transmitting side. It is thus possible to transmit power and to communicate at the same time.

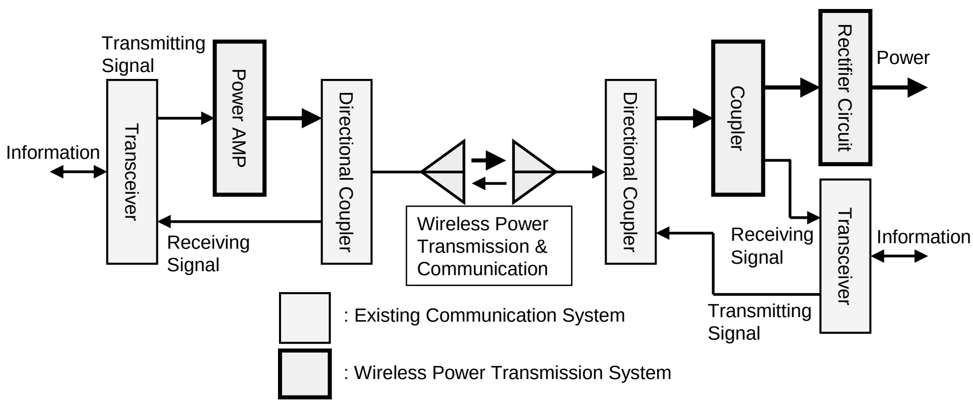


Figure 1: Wireless system integrating power transmission and communication.

2.2 **Configuration of prototype**

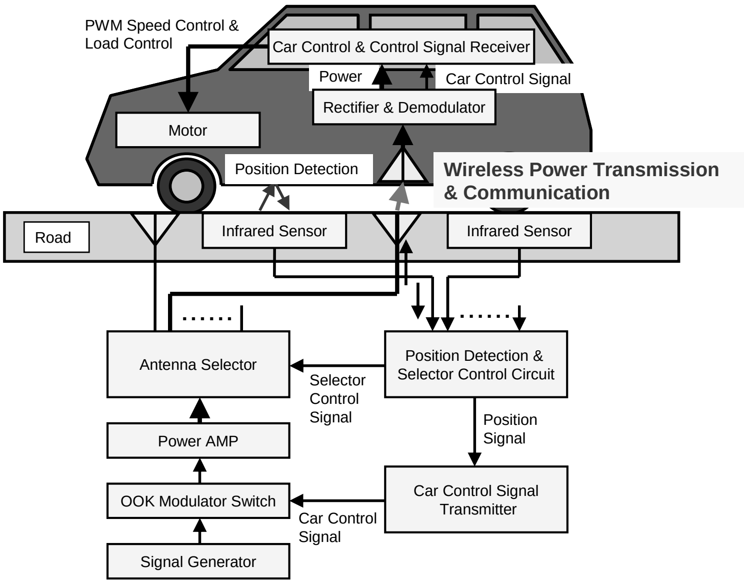


Figure 2: Configuration of prototype.

Figure 2 shows the configuration of the prototype**.** A model electric vehicle is automatically driven by the vehicle to road communication system which also operates the hazard lights, turn signal, and horn. The components are as follows.

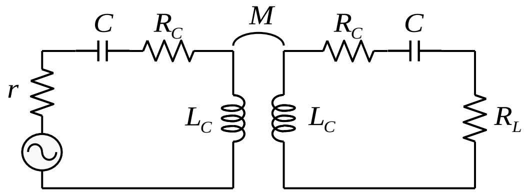
- Signal Generator: Generate a signal of 40 MHz.
- OOK Modulator: Modulate the CW signal generated by the signal generator by on-off keying (OOK).
- Power Amplifier: Amplify the modulated signal to 500 mW.
- Antenna Selector: Select the transmitting coil on the road.
- Position Detection and Selector Control Circuit: Detect the vehicular position using the infrared sensor, and then, select an antenna near the vehicle to transmit power.
- Car Control Signal Transmitter: Obtain the vehicular position from the Position Detection and Selector Control Circuit, and then generate the signal for the OOK Modulator to control the vehicle.
- Antenna (road and vehicle): Magnetic resonant coil.
- Infrared Sensor: Transmit the infrared ray to the vehicle, and then, detect the vehicular position by the reflected infrared ray.
- Rectifier and Demodulator: Rectify the received radio wave, and then, output the electric power and the demodulated signal for vehicular control, separately.
- Car Control and Control Signal Receiver: Control the vehicle based on the demodulated signal. Pulse width modulation (PWM) technologies are applied to drive the vehicle.
- Motor: Use the DC motor for vibration in the cell phone.

3. Design

3.1 **Wireless power transfer using magnetic resonances**

The equivalent circuit for the power transfer by magnetic resonance is shown in Figure 3(a). The same coil is used for both reception and transmission. To introduce resonance, capacitor C is inserted in series. When the distance between the coils is reduced, coupling of the magnetic field occurs and two resonant frequencies appear [4].

$$f_r = \frac{1}{2\pi\sqrt{(L_c \pm M)C}} \qquad (1)$$



(a) Equivalent circuit

(b)Spiral coil (modelled by IE3D)

Figure 3: Wireless power transfer using magnetic resonances.

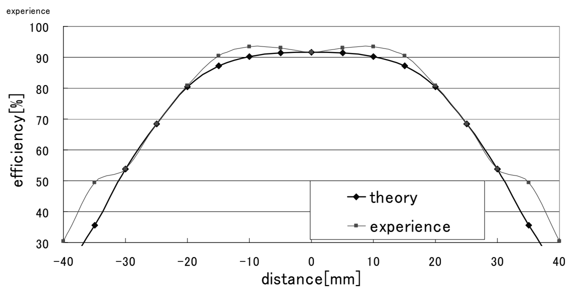
Here, L_c and M are the self and mutual inductance, respectively, of the coil. When the distance between the coils is increased, the two resonant frequencies approach each other because M reduces.

For the experiment, we used a spiral coil on the printed circuit board in the model vehicle for reduction of size and easy fabrication. The coil was designed using electromagnetic simulator IE3D. f_r is 40 MHz (M=0). A designed coil is shown in Figure 3(b). The width of the wire is 4 mm, the interval 0.1 mm, and the thickness 35 μm. The outer diameter of the coil is 68 mm and the inner diameter 30 mm. There are 4 wire turns. The coil is mounted on a dielectric substrate of thickness 1.6 mm and permittivity 2.6.

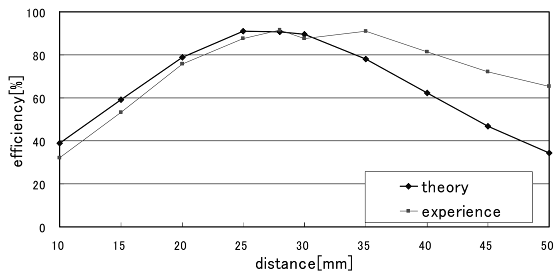
4. Trial Manufacture and Evaluation

4.1 **Wireless power transfer using magnetic resonances**

Figure 4 shows the S_{21} characteristic of the transmitting and receiving coils. For reference, simulation results are also shown. For the efficiency evaluation of the movement of the vehicle in Figure 4(a), the distance between the coils is maintained at 28 [mm]. When the coil on the vehicle and the coil on the road are positioned correctly, the power-transmission efficiency is 92% and when the vehicle is between two coils on the road, it declines to 30 %. The average power-transmission efficiency given the movement is 70 %. For the vertical movement of Figure 4(b), when the transmitting and receiving coils are positioned correctly, the power-transmission efficiency is 92 % for heights of 25 to 30mm.



(a) Movement in horizontal plane



(b) Movement in vertical plane

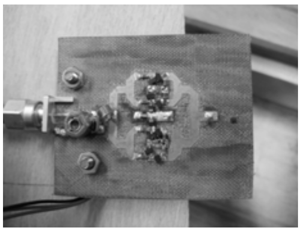
Figure 4: S_{21} between two coils

4.2 **Rectifier**

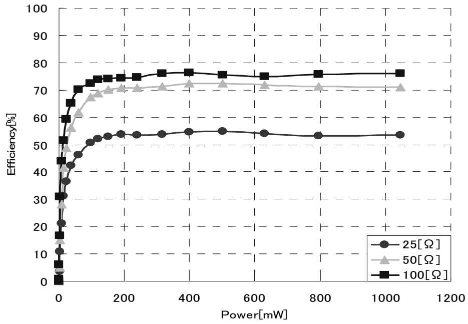
Figure 5 shows a photograph of the rectifier and the results for the rectification efficiency. For a load of 50 Ω, the calculated and measured values agree. However, for a load of 25 Ω, the measured value is smaller than the calculated value; and for a load of 100 Ω, the measured value is larger than the calculated value. It is believed that the Spice parameter used by the simulation was different from the actual value.

4.3 **EMI**

Figure 6 shows the emission value 30 cm from the course. The x-axis denotes a zenith angle. Non-radiating is the emission value when there is no vehicle on the road, while radiating is the

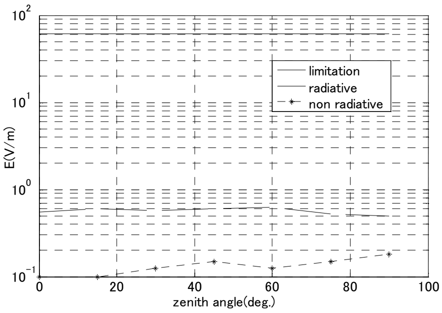


(a) Overview

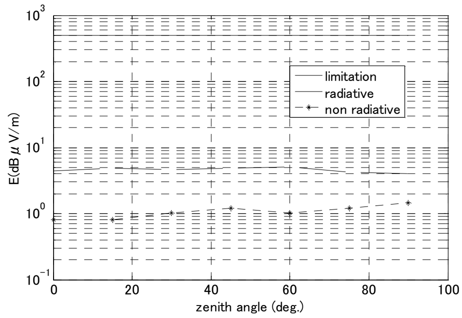


(b) Efficiency

Figure 5: Rectifier



(a) Radio wave protection guideline



(b) Radio law

Figure 6: Emission value

emission value when there is vehicle on the road. This result is below the electric-wave protection guideline and satisfies the radio law of Japan.

5. Conclusions

We have developed a system that operates a model vehicle automatically by wireless power transmission and vehicle to road communication. The conversion efficiency of the rectifier was 76.5%, the average transmission efficiency between the transmitting and receiving coils was 70%, and the average power-transmission efficiency was 54%. The information and electric power are transmitted from a common coil. We confirmed that by using the control-information from the road, it is possible to start, stop, reverse, and control the speed of the model vehicle and operate the horn, the hazard lights, and the turn signals.

References

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