Evaluation of Electromagnetic Field Radiation from Wireless Power Transfer Electric Vehicle

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***Abstract* – In this paper, the electromagnetic field radiation from wireless power transfer electric vehicles is discussed. As the high power is wirelessly transferred using low frequency, the near field characteristic should be considered and conventional standard measurement is no more valid. To analyze the electric or magnetic fields, the current spectrum was extracted using the circuit simulation with an equivalent circuit model, and 3D EM simulation has been done. Finally, standard measurement to guarantee the radiation regulation is suggested.**

***Index Terms* — Electromagnetic field, Radiation, Wireless power transfer, Electric vehicle.**

1. Introduction

The application of wireless power transfer (WPT) systems is rapidly expanding, and especially electric vehicle with stationary or dynamic charging technology in Fig. 1, is expected to have huge market, and is already commercialized in some countries [1][2].

However, as the WPT electric vehicle system is transmitting and receiving high power wirelessly, strong magnetic field can be generated around the WPT system and should be minimized to avoid electromagnetic interference and to satisfy the regulations [3]. Some researches on the reduction of leakage electromagnetic field have been done [4]. However, the characteristics of the electric vehicle and WPT system have thus far received little attention [5].

In this paper, the low frequency electromagnetic field radiation from the wireless power transfer system in electric vehicles is discussed. To transmit the high power wirelessly, the WPT system operates in low frequency range. Therefore, the characteristic of the electromagnetic wave should be considered in near-field region. As the generation of the magnetic field depends on the structure and orientation of both TX and RX coils, the magnetic fields of the 3-axis should be measured.

2. Electromagnetic Field Distribution in WPT System

In the WPT system, the TX coil generates resonant electromagnetic field and the RX coil receives the generated magnetic field wirelessly. Even though there is an air gap of 150 mm as shown in Fig. 2(a), the power can be transferred from the TX coil to the RX coil by the magnetic field at the resonant frequency of 20 kHz. Fig. 2(b) shows the equivalent circuit model of the WPT system. At a resonance frequency, inductances of the TX and RX coils are compensated for by the capacitance and the reactance is minimized.

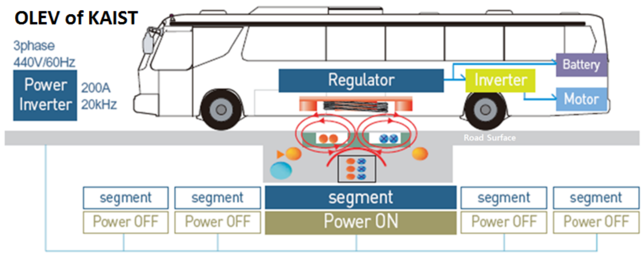


Fig. 1. Example of an electric vehicle with wireless power transfer (WPT) technology.

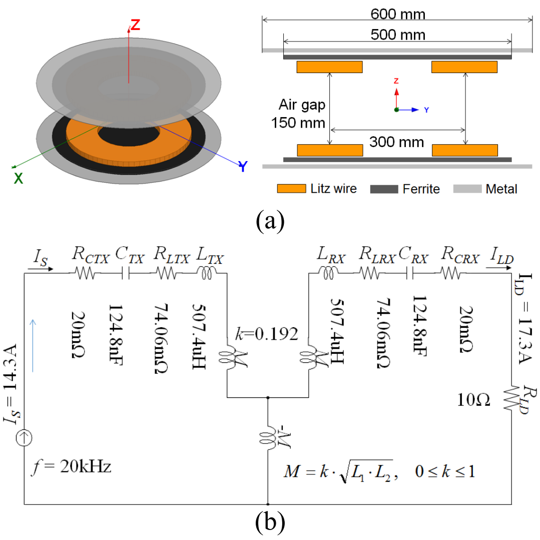
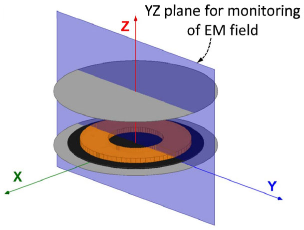


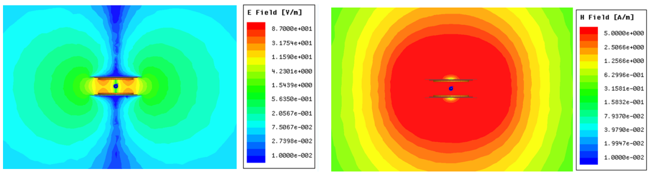
Fig. 2. Wireless power transfer system in electric vehicle. (a) Coil structure and dimensions (b) Equivalent circuit model of the TX and RX coils in the WPT system.

3. Electromagnetic Field Distribution in WPT System

The electromagnetic field distribution around the TX and RX coils is simulated at a resonance frequency of 20 kHz by using ANSYS Maxwell as shown in Fig. 3. In light of the guideline from the International Commission on Non-Ionizing Radiation Protection (ICNIRP), while the electric field is much smaller than 87V/m, the magnetic field around the TX and RX coils is much larger than 5A/m. As the TX and RX coils also generate magnetic field noise and the magnetic field is used to transfer power from the TX coil to the RX coil wirelessly, the magnetic field should be evaluated separately.



(a)



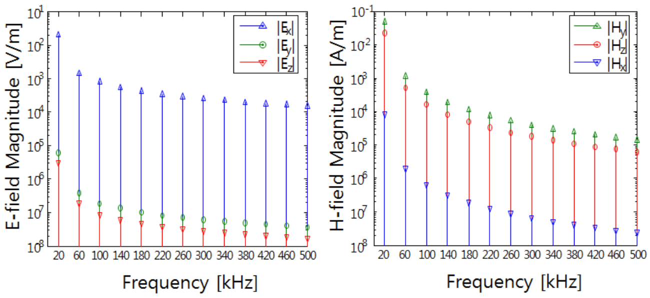
(a) (b)

Fig. 3. Electromagnetic field distribution around the TX and RX coils (a) Perspective view of observation plane (b) Electric field distribution (c) Magnetic field distribution.

4. Electromagnetic Field Measurement for Standard

The calculated electric and magnetic fields are described in Fig. 4(a) and (b), and the Ex component is much greater that the Ey and Ez components. Although the electric field at a fundamental frequency (20 kHz) is higher than that of other harmonic frequencies, the electric field at harmonic frequencies still exists and it can be stronger in a WPT system. Therefore, the electric field as well as the magnetic field should be also measured individually. Hx is negligible when compared to the magnitude of Hy and Hz as shown in Fig.4(b). This is consistent with the results in Fig. 3. The wave impedance in frequency domain varies from about 1 Ω to 10 Ω as shown in Fig. 5, which is much smaller than the 377 Ω of the intrinsic impedance. Therefore, the electric field cannot be calculated by the intrinsic impedance and the measured magnetic field. Ex, Ey, Ez, Hx, Hy, and Hz need to be measured.

Any field conversion from electric field to magnetic field or vice versa, which is commonly used in measurement standard cannot be applied because the wave impedance is smaller than the intrinsic impedance (377 ohm) and depends on the frequency, the structure of the coil, and the distance from the source as shown in Fig. 5 and 6. In this case, the wave impedance is much smaller than the intrinsic impedance because the magnetic field is dominant.



(a) (b)

Fig. 4. Electromagnetic field in frequency domain at the observation point. (a) Ex, Ey, and Ez. (b) Hx, Hy, and Hz.

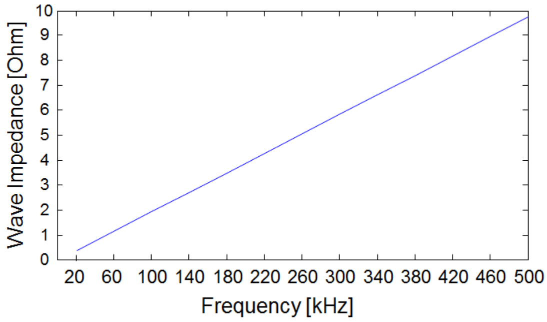


Fig. 5. Wave impedance in frequency domain.

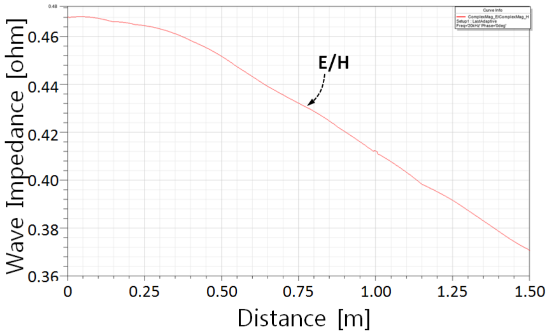


Fig. 6. Wave impedance on the distance from the source.

5. Conclusion

This paper presented an EMI evaluation methodology for electric vehicles with WPT systems. The electric field that generated from a complex WPT system cannot be calculated by intrinsic impedance and measured magnetic field because the wave impedance in near-field region is very different from that in the far-field region. Therefore, all Hx, Hy, Hz, Ex, Ey, and Ez fields must be measured and evaluated to ensure that all fields meet standards.

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