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Basic Study on Waveguide Power Transfer for Mobility Applications

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Magnetically coupled wireless power transfer (WPT) has been widely studied for electric-vehicle charging. For mobility applications, 2-D waveguide power transfer (2DWPT) is one possible configuration. In this method, the electricmagnetic waves propagates along a waveguide sheet, and a receiving coil extracts waves through magnetic coupling. This structure enables power transfer over a wide area. However, the transfer efficiency depends on receiver position because standing waves are formed on the waveguide. In particular, the termination region can be represented by a termination impedance Z_{term} seen from the coupled region, and the efficiency becomes high when the receiving coil is located near a standing-wave antinode.

To reduce this position dependence, this paper proposes a reflection coil as a passive reflector for the guided electromagnetic wave. The reflection coil is implemented as a short-circuited series-resonant coil and is placed downstream of the receiving coil. By keeping the spacing d_1 between the receiving coil and the reflection coil constant, the termination impedance seen by the receiving coil can be governed mainly by the reflection coil, rather than by the termination at the end of the waveguide. This passive arrangement is intended to keep the receiving coil near a favorable standing-wave condition without complex control. The equivalent-circuit analysis also indicates that a sufficiently large kQ product and a spacing of approximately one quarter wavelength are important for reducing the termination impedance and improving the transfer efficiency.

Fig. 1 shows the experimental setup used to verify this concept. A 2-m waveguide sheet was driven by an 85-kHz sinusoidal voltage using a high-speed bipolar amplifier. The receiving coil and the reflection coil were placed 100 mm above the waveguide. The receiving coil was tuned to series resonance and connected to a resistive load, while the reflection coil had the same coil parameters and was short-circuited. The overall efficiency was evaluated from the input power to the waveguide and the power dissipated in the load.

Fig. 2 shows a representative result for the short-termination condition. Without the reflection coil, the efficiency changes strongly with receiver position and exhibits a deep drop at a specific position, which is consistent with the effect of standing-wave nodes. In contrast, when the reflection coil is added, the efficiency remains higher over the entire measured range and the large positional fluctuation is suppressed. Similar tendencies were also confirmed under matched and open terminations. These results indicate that fixing the coil-to-coil spacing on the receiver side is effective for mitigating standing-wave-induced position dependence.

In summary, the proposed reflection coil provides a simple passive method for stabilizing the standing-wave condition in magnetically coupled 2DWPT. The experiments at 85 kHz confirmed that the reflection coil can work as an effective reflector and significantly reduce efficiency variation with receiver position. This result suggests that the proposed configuration is a promising approach for mobility-oriented waveguide power transfer systems requiring both wide-area coverage and stable efficiency.

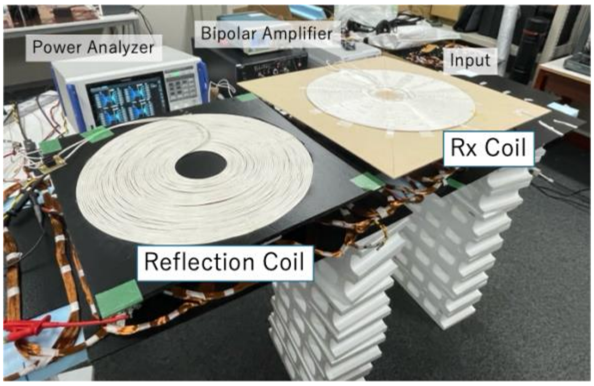

Fig. 1. Photograph of the experimental setup: waveguide sheet, receiving coil, reflection coil, high-speed bipolar amplifier, and power analyzer.Equivalent-circuit model used in the analysis.

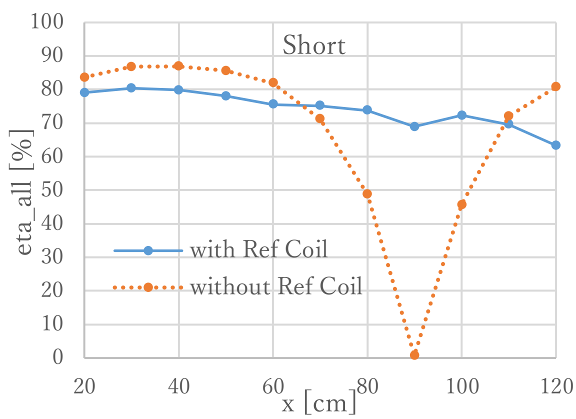

Fig. 2. Measured efficiency versus load resistance R_L with $d_1 \approx \lambda/4$.