Surface-wave Analysis of a
Magnetic Field Wireless Power Transfer System
Operating over Real/Imperfect Ground

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Magnetic field wireless power transfer (MF-WPT) systems for the charging of hybrid and electric vehicle batteries constitute an emerging technology and one which is being rapidly standardized by several international organizations such as IEC, JARI and SAE. Recent global harmonization efforts tend to favor a fundamental charging operation centered at frequencies around 85 kHz, which lies in the LF frequency range. The attendant wavelengths, on the order of 3.5 km, would seem to preclude the radiation of any significant power by a single such system, at least at the fundamental frequency.

One commonly used winding topology is termed the "circular" coupler (M. Budhia, J. T. Boys, G. A. Covic, and C. Y. Huang, *IEEE Trans. Industrial Electronics*, pp. 318-328, Dec. 2011) and is shown in Fig. 1. As can be seen, this geometry consists of two multi-turn, ferrite-loaded loops with coaxial vertical axes. Thus, the system consists of two coupled vertical magnetic dipoles with a net or residual vertical (*z*-directed) magnetic dipole moment. This is true in spite of the electrostatic shield.

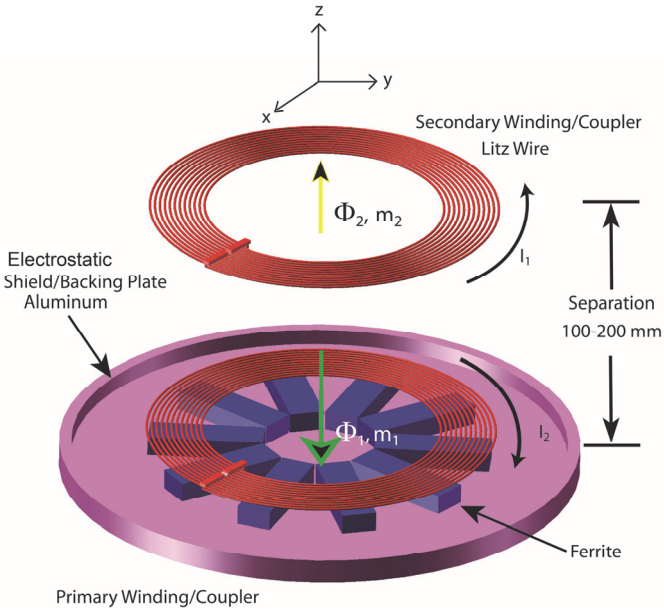

Figure 1: Circular coupler geometry which produces a net vertical magnetic dipole moment located at ground.

The net vertical magnetic dipole moment of the circular coupler system acts as a vertical magnetic dipole (VMD) located at the road or driving surface. Thus, it is a source for the TE type surface waves (M. Parise, *Progress In Electromagnetics Res. B*, Vol. 23, 69–82, 2010). Here we employ the surface-wave field solution for the VMD to analyze a single MF-WPT system as well as an array of such systems representing a large-scale vehicle charging facility. The net magnetic dipole moment of the VMD is determined from a full-wave numerical (finite element) analysis of the MF-WPT system. The surface wave VMD solution then provides a rigorous representation of the near and far fields of the isolated MF-WPT system as well as the array of such systems.