For wireless charging of electric vehicle (EV) batteries, high-frequency magnetic fields are generated from magnetically coupled coils. The large air-gap between two coils may cause high leakage of magnetic fields and it may also lower the power transfer efficiency (PTE). For the first time, in this paper, we propose a new set of coil design formulas for high-efficiency and low harmonic currents and a new design procedure for low leakage of magnetic fields for high-power wireless power transfer (WPT) system. Based on the proposed design procedure, a pair of magnetically coupled coils with magnetic field shielding for a 1-kW-class golf-cart WPT system is optimized via finite-element simulation and the proposed design formulas. We built a 1-kW-class wireless EV charging system for practical measurements of the PTE, the magnetic field strength around the golf cart, and voltage/current spectrums. The fabricated system has achieved a PTE of 96% at the operating frequency of 20.15 kHz with a 156-mm air gap between the coils. At the same time, the highest magnetic field strength measured around the golf cart is 19.8 mG, which is far below the relevant electromagnetic field safety guidelines (ICNIRP 1998/2010). In addition, the third harmonic component of the measured magnetic field is 39 dB lower than the fundamental component. These practical measurement results prove the effectiveness of the proposed coil design formulas and procedure of a WPT system for high-efficiency and low magnetic field leakage.