Wireless Power Transfer to Moving Vehicles

Investigators
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Abstract

This project aims at the possibility of charging the electric vehicles wirelessly with a resonant inductive power transfer scheme. We are exploring a key enabling element that will overcome these challenges and which, if successful, will demonstrate the feasibility of wireless power transfer directly to vehicles cruising at highway speed, via magnetically-coupled resonating coils located in the roadbed and in the vehicles. We have numerically demonstrated that the energy can be transfer efficiently between two dielectric disks and two magnetically coupled resonating coils.

Introduction

Electric vehicles offer superior energy efficiency while offering an enormous potential for reducing CO_2 emissions if the electricity is supplied from a renewable or nuclear source. However, they are presently neither range- nor cost-competitive compared to conventional vehicles, due to limited options for recharging, and expensive energy storage (batteries). This project aims at extending the wireless power transfer to the charging of moving electric vehicles. The success of this program may prove to be a very significant step forward towards the possibility of unlimited range electric mobility. By extending the range of electric vehicles, this project will contribute to overcoming a critical limitation of existing electrical vehicles, by offering range at competitive costs.

Background

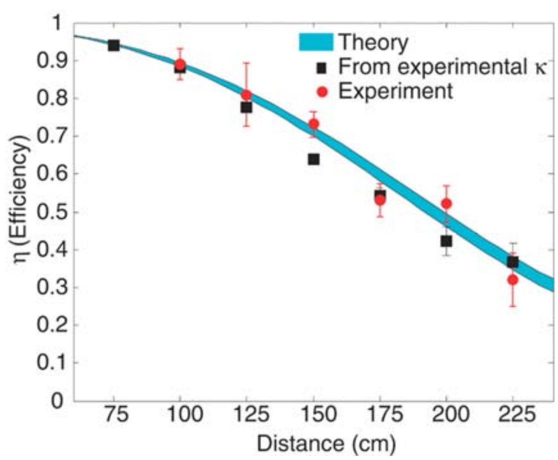

Figure1. Efficiency of wireless energy transfer as a function of distance between coils.

In recent years there has been renewed interest in wireless power transfer. In particular, a recent experiment, conducted at MIT, has demonstrated that two resonant circuits, with their magnetic fields strongly coupled in the near-field regime, allows highly efficient power transfer over a distance of approximately one meter. (See Figure 1). The MIT experiment, utilizes a magnetic field that oscillates at a few MHz for power transfer purposes. The use of such oscillating magnetic fields is crucial for safety reasons since they interact very weakly with biological organisms. Additionally power transfer occurs only when the two circuits are in resonance with each other. This ensures, on the one hand, a highly selective power transfer scheme between the two circuits, and on the other hand, the possibility of tuning power transfer on or off simply by tuning the resonant frequency of either circuit such that they are either on or off resonance.

Their experiments demonstrated power transfer of 60W between two objects that have no relative motion with respect to one another. In delivering power wirelessly to a moving vehicle, we envision a system in which a sequence of coils placed beneath the roadway will deliver the power wirelessly to cars moving above (See Figure 2).

We estimate that a power transfer of about 10-20kW will be quite sufficient for steady-state operation and the strength of the magnetic field generated will be less than 160A/m, which is only about five times stronger than the earth's magnetic field. Moreover, such a magnetic field largely exists between the road and the vehicle, and is located far from where people are sitting in the vehicle.

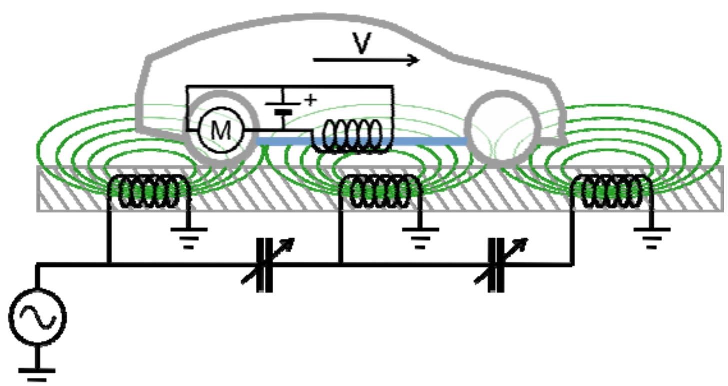

Figure 2. Magnetic Power Transmission to Vehicle on Highway.

Results

During the past few months, we have numerically demonstrated that mid-range non-radiative energy transfer can be achieved by using long-live oscillatory resonant electromagnetic modes. The proposed energy transfer scheme utilizes the result that energy can be efficiently coupled between objects in the extremely near field. It requires high quality factors Q = $\omega/2\Gamma$ (ω is the frequency and Γ is the intrinsic loss rate); strong coupling rate κ and subwavelength size of the resonant object.

We start our simulation with two quite different electromagnetic resonant systems: dielectric disks and capacitivly-loaded conducting wire loops. Figure. 3 shows the electric field pattern of two dielectric disks surrounded by air and seperated by distance D=4r, where r is the radius of the disk. The dielectric constance of the disks is $\varepsilon = 147.7 + 0.00147i$. Our simulation shows that the transfer efficiency is nearly 100%.

We also demonstrated that with the presence of an extraneous object, the transfer scheme is still applicable.

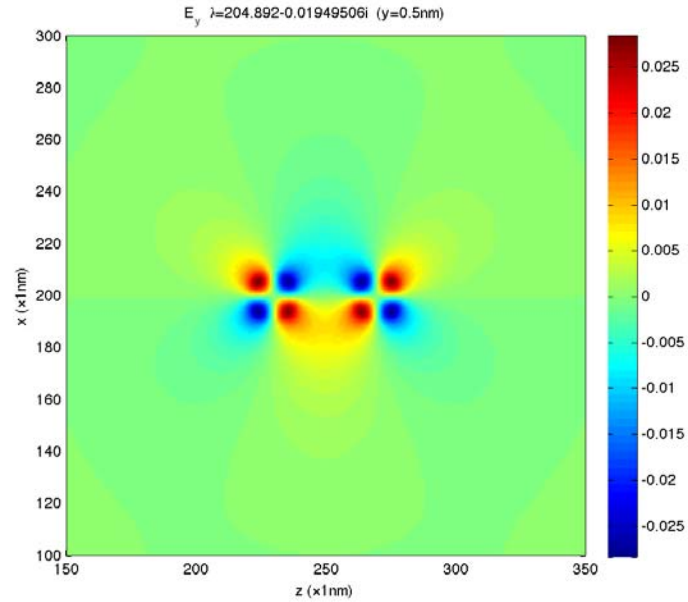

Figure 3: Electric field pattern of a system of two identical dielectric disk separated by medium distance D=4r, wavelength $\lambda \approx 20r$, where r is the radius of the disks.

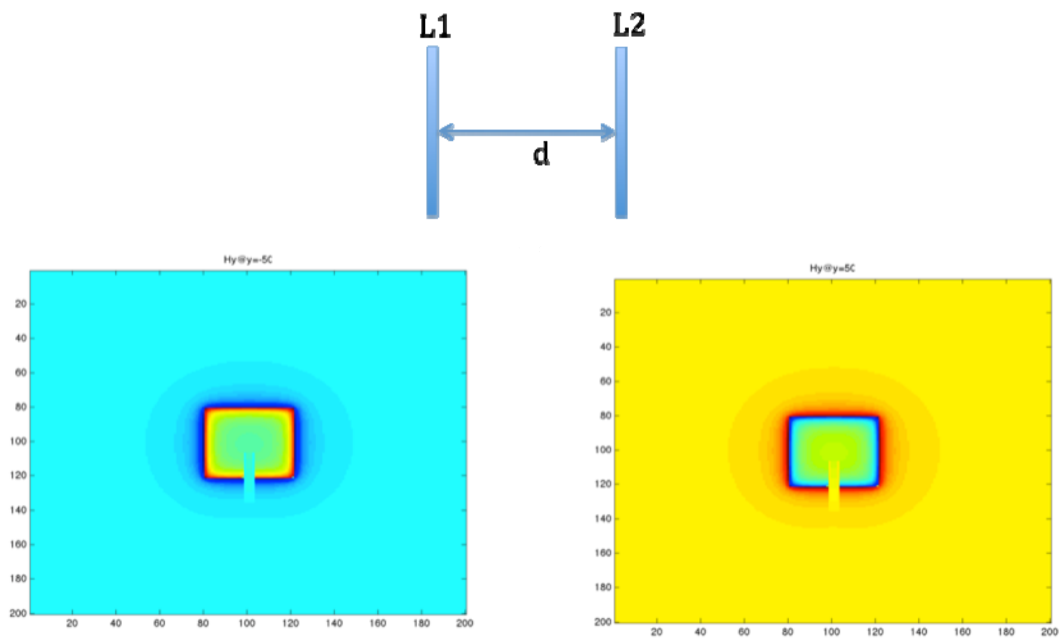

Figure 4: (Top) System of two same 3D capacitively-loaded conducting loops separated by distance D=5L, where L is the dimension of the loop.

(Bottom left) Magnetic field pattern at the source loop. (Bottom right) Magnetic field pattern at the device loop.

Figure 4. shows the coupling between two same capacitively-loaded conduction loops (L1 and L2) in the air. The loops are coupled predominantly through the magnetic field. Since almost all everyday materials are non-magnetic, the disturbance of the resonance of a conducting loop is small. Figure 5 shows the time evolution of the magnetic field at the source and device loop, and from this we extract the energy transfer efficiency and time. In the radio frequency range, the distance between the source and the device is a few meters. Even without the optimization of the device design, the energy transfer efficiency is shown to be around 85%. The energy exchange time is about $10\mu s$.

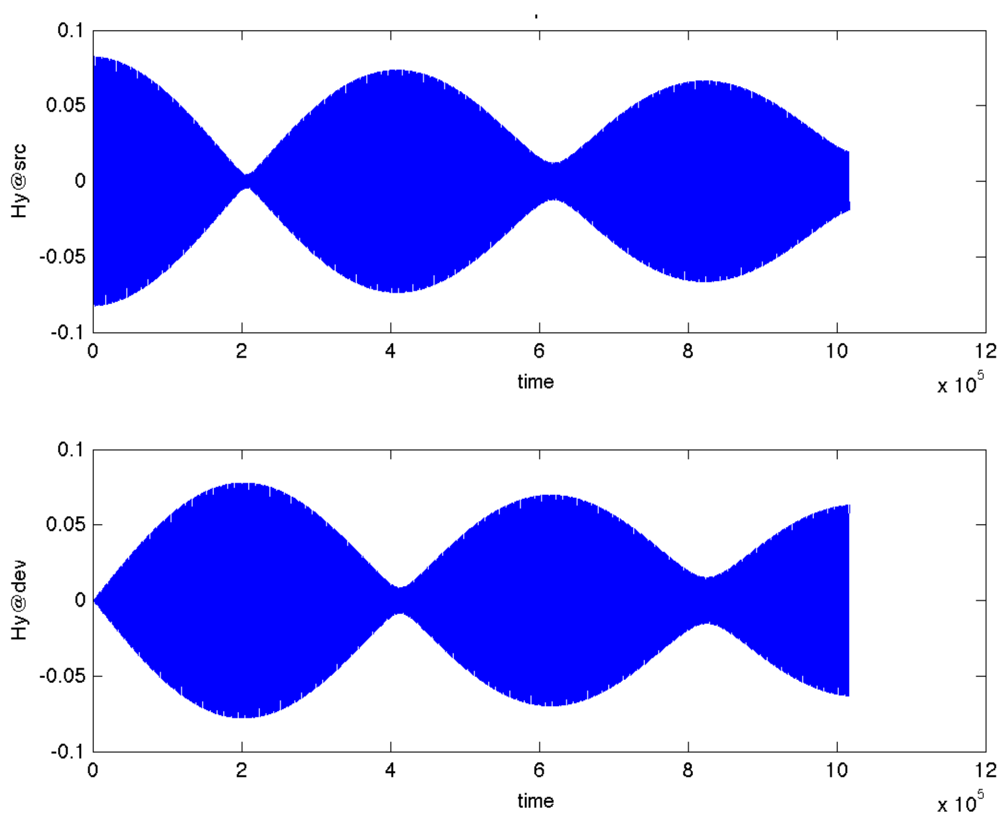

Figure 5: (Top) Time evolution of the magnetic field at the source. (Bottom) Time evolution of the magnetic field at the device. We use reduced unit in the time axis.

Progress and future plans

In the last 4 months, we have obtained our first very promising results on wireless energy transfer system. Both the dielectric disks resonators and the capacitively-loaded conduction loops system demonstrated applicable transfer efficiencies. And the transfer time is shown to be much shorter than the time scale of a moving vehicle. We will continue our efforts to optimize the system design of the resonators for better transfer efficiency and investigate the influence of the extraneous objects to the power transfer system. We also plan to set up an analytical model for better understanding the physics within.

Publications: (none)

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