

# Continuous wireless power transfer from road to vehicle

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**By using air to lift a receiver connected to the underside of a car from the road, and keeping it close to it, wireless power transfer can be made a viable option for removing the range limitation and long recharge times today's electric vehicles suffer from. A receiver of roughly 200 mm times 100 mm can deliver 30 kW continuously to a car with an efficiency of up to almost 87 %.**

Most cars today are powered by gasoline, but the world's oil reserves are decreasing rapidly and within a near future, there will be no oil left. In addition to this, people are getting more aware of environmental issues and the pollution caused by internal combustion engines is a major concern.

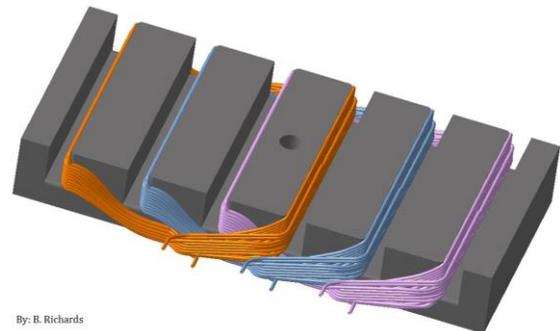
Using electric vehicles is an option that has all the possibilities for making it possible to keep the personal and comfortable way of transportation mankind has gotten used to thanks to the gasoline engine. However despite the fact that electric vehicles have been around since the late 19<sup>th</sup> century, they still suffer from the same limitations, short range and long charging times.

Even with fast charging the limited range remains a problem and to avoid having to use an unpractical amount of batteries, the best option would be to deliver power from the road to the vehicle while it is driving.

There are two different ways to accomplish this; conductive power transfer, through contact, and wireless (inductive or capacitive) power transfer, without contact. Both have advantages and disadvantages and in the case of wireless (inductive) power transfer the

advantages are that barriers such as water, ice and snow do not reduce the effectiveness of the transfer and that the source can be placed under the road to avoid unnecessary wear. The main disadvantage is that the bigger the air gap between road and receiver is, the less efficient the transfer is. <sup>1</sup>

The way inductive power transfer is done is by having coils (electromagnets) in both the road and the receiver unit in a three-phase configuration as shown in Figure 1. By running an alternating current through the coils in the road, a magnetic field is induced, like for permanent magnet. However as the current is alternating, the magnetic field varies in strength and direction, which the field from a permanent magnet does not.



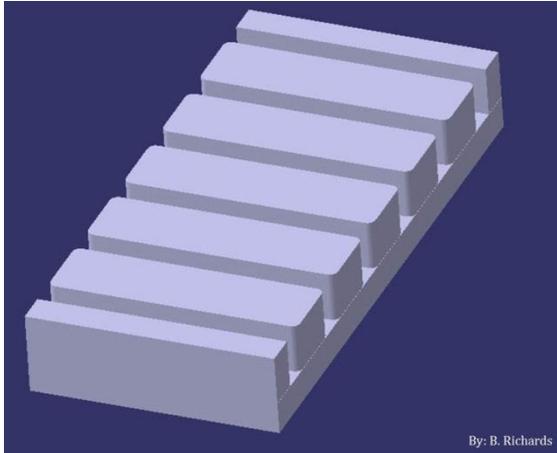
By: B. Richards

**Figure 1:** Three-phase configuration of the coils in the core.

Some of the induced magnetic field will pass through the coils in the receiver, and when this happens it will induce a voltage in them. When the coils are connected to a circuit a current starts to flow through it and power is delivered to the motor and battery.

To increase the power transfer, cores are used (see Figure 2) with the coils to increase and focus the magnetic field so that more of it

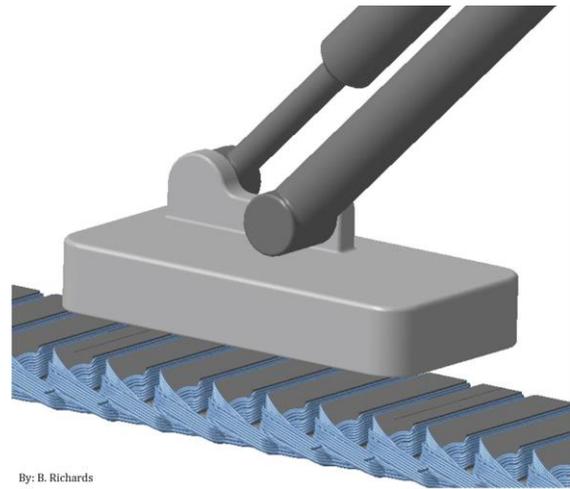
travels through the receiver coils. These cores are usually made from ferrite or a nickel-iron alloy which are well suited for such an application.



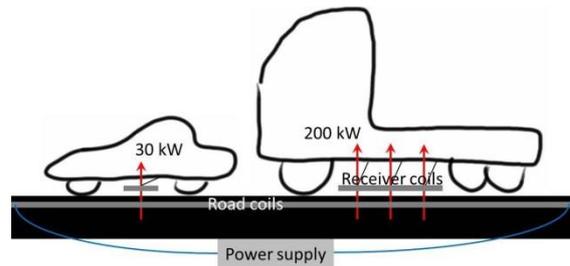
**Figure 2:** 3D illustration of the core placed under the car.

The induced voltage is proportional to the current and frequency in the road side coils, and to avoid having to use large currents to compensate for the air gap, a high frequency is used instead. The proportional relationship would mean that the higher the frequency, the more power is transferred, but the losses also increase with the frequency. So at a certain point the efficiency will start to suffer from an increased frequency. For these applications the frequency needs to be in the order of 10 kHz to be able to transfer enough power.

The performed tests show that with a core about 200 mm long and 100 mm wide with three coils placed in it, 30 kW can be transferred continuously (see principle in Figure 4). This is enough for both running the engine and charging the batteries, enabling the vehicle to drive indefinitely or until the batteries run out when driving on a road which is not electrified. The system as a whole is shown in Figure 3 below.



**Figure 3:** Rode side configuration and receiver in casing suspended from the vehicle.



**Figure 4:** Principle of the inductive power transfer system.

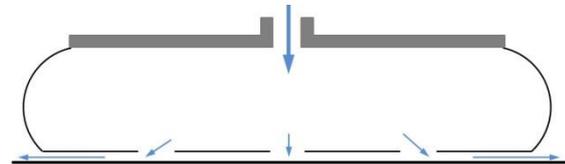
For a lorry the power requirements are much larger, about 200 kW, which means that six core configurations of the car version are needed. When two or more of these cores are joined together, the power each deliver increases so that the sum is closer to 200 than 180 kW.

To make the power transfer as efficient as possible, the air gap is still the most important parameter and for the cores to be as small as desired, the air gap has to be relatively small.

Having it placed directly under the chassis is not enough, so instead it has to be lowered closer to the road. The problem then is to keep the receiver at the determined height and a way to solve this is air bearing, meaning air is pumped under the unit to separated it from the road.

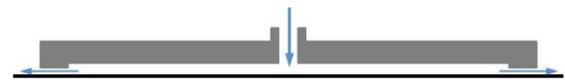
The easiest way to understand how this would work is to look at a hovercraft. By inflating a

flexible skirt attached to the hull, and allowing air to escape from the underside, lift will be generated, see Figure 5. However this solution require a lot of air per mass unit and for high weight and small size application such as this it is not practical.



**Figure 5:** Cross-sectional view of a hovercraft.

There are versions of this solution which are better suited for lifting heavy objects with limited surface. Rigid and complaint air bearing (Figure 6 and Figure 7) are both used in the industry to enable moving heavy objects by hand, and these could be adapted to work for this as well.



**Figure 6:** Cross-sectional view of rigid air bearing system.



**Figure 7:** Cross-sectional view of complaint air bearing system.

As for the road itself; a highway in Sweden has a wearing course of about 45 mm and to protect the cores and coils they would have to be placed just under this layer. As asphalt has about the same magnetic properties as air, it will not decrease the power transfer.

Using the complaint air bearing system the air gap is assumed to total up to 75 mm, which is still relatively large. However with 20 kHz current at less than 300 A, the requirements are met with an efficiency of 70 %.

Imagining an unconventional road design in which the coils can be placed level with the road surface and with rigid air bearing the air gap is assumed to be reduced to 30 mm. Both

the current and the frequency can then be reduced to less than 150 A and 10 kHz respectively and still transfer the 30 kW. Because of the smaller air gap and reduced losses from the current and frequency, the efficiency becomes almost 87 %.

What these results mean is that if this system was implemented in all the highways and all vehicles were electrical equipped with a receiver, there would be no need for gasoline as fuel. Because vehicles will get power continuously while driving, long journeys will no longer be a problem and in cities charging can be done while parked, meaning the two biggest weaknesses are dealt with.

However there is still one problem which cannot be excluded and must be solved for this to be worthwhile; the production of the energy required to power all vehicles. Supplying all vehicles with electrical power means that the power production must be expanded, and to make sure this solution is better for the environment than gasoline engines, the energy must be renewable.

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<sup>i</sup> A. Svensson, "Inductive Power Transfer – Vehicular Application" M.S. thesis, LTH, Lund University, 2013. Full work available from: <http://www.iea.lth.se/publications/pubmsc.html>