Practical Considerations for Resonant Near Field Wireless Power Transfer over Common Ground

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***Abstract*— Wireless power transfer (WPT) schemes need to be both efficient and practical. When the receiver is hovering close to the charging region the alignment requirements for high efficiency should not be so stringent that a practical system cannot be built. Experimental results for the basic scheme show that when two identical helical antennas are placed on opposite sides of a ground plane strong coupling is possible in the near field when the axes of the antennas are aligned. Starting with these experimental findings this paper explores, through simulation and analysis, a range of important variations of the basic scheme that allow efficient and practical power transfer.**

Keywords—resonant wireless power transfer; wireless charging; electric vehicle; drones; unmanned aerial vehicle; helical antennas; ground planes.

I. INTRODUCTION

The ability of an electric vehicle (EV) or an unmanned aerial vehicle (UAV) to get wirelessly charged while hovering close to the charging zone is of practical importance. Previously obtained experimental results [1-2] have shown that two identical small high-Q antennas can transfer power efficiently in the near field when sharing a common or connected ground plane (efficiencies over 50 % have been measured at greater than 2 meters for 18 MHz). New experimental data shows strong coupling is achieved when the transmitter and receiver are sitting on opposite sides of a shared ground plane (greater than 70% for when receiver is placed 30 cm above the ground plane at 16 MHz). Fig. 1 illustrates the strong coupling that can be achieved in one such configuration [3] in terms of current

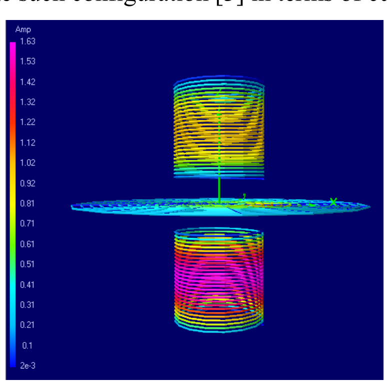

Figure 1. Source and receiver on opposite sides of ground plane showing coupled current amplitude.

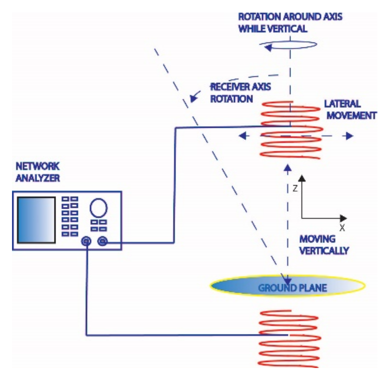

Figure 2. Scheme for studying lateral and rotational variations.

magnitudes. While distances of approximately 30 cm are still practical for the charging of multirotor UAV or EV, maintaining ideal alignment and distances of separation may not always be possible.

This paper starts by looking at experimental and simulation data for when receiver and transmitter are placed on opposite sides of the ground plane. Comments on the practical efficacy of such a system by examining what happens to the transfer efficiencies for lateral and rotational displacement configurations (Fig. 2) away from the case in which the axes of both transmitter and receiver are in perfect alignment. The next section examines and comments on what happens during perfect alignment. Lateral and rotational variations of the perfect alignment case are then studied through simulation and analysis before summarizing comments on some aspects of practicality of these this WPT scheme.

II. THE PERFECT ALIGNMENT CASE AND ITS VARIATIONS

When the receiver is placed at different elevations above the ground (see Fig. 2) with its axis in perfect alignment with the transmitting antenna, measured data and simulated (using 4Nec2) results indicate high transfer efficiencies (Fig. 3) are possible. It should be noted that the measured results are based on the highest S21 in each case and the frequencies are slightly different (and close to 16 MHz). Also, for the aligned setup it was found that receiver rotation around its helical axis does not appreciably change power coupling efficiency. This means that the feed points of the antennas do not have to align vertically

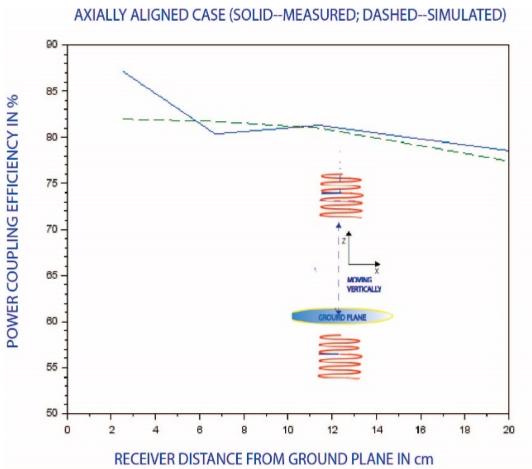

Figure 3. WPT efficiency VS receiver height above ground plane

and this is good news from a practical point of view.

A. *Impact of Lateral Variations:*

Lateral variations studies were conducted through simulation by moving the receiver in the x-direction, keeping z fixed (Fig. 2). Results of these simulations (Fig. 4) show that for a fixed height (z) above the ground plane lateral displacements up to 7 cm can be tolerated without appreciable loss in coupling. This is an interesting result since the antenna distances are increasing with increasing displacement, illustrating the importance of near field polarization to the coupling process. Such tolerance to a small amount of lateral displacement makes this scheme more robust and makes it more practical as a WPT system.

B. *Impact of Rotational Variations:*

It is important to study the impact of transfer efficiency on the case for the receiving antenna when its axis is inclined at different angles to the transmitting antenna while maintaining a constant radius from the center of the ground plane (Fig. 4).

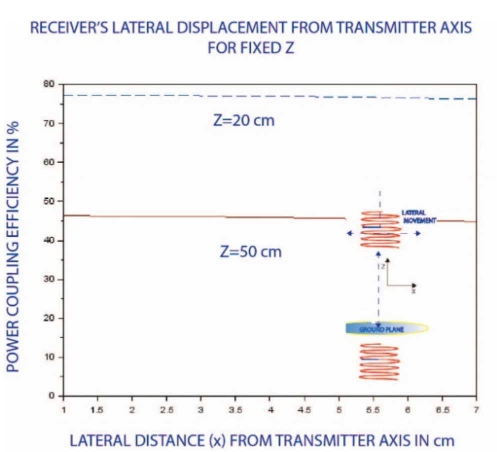

Figure 4. WPT efficiency VS lateral displacement

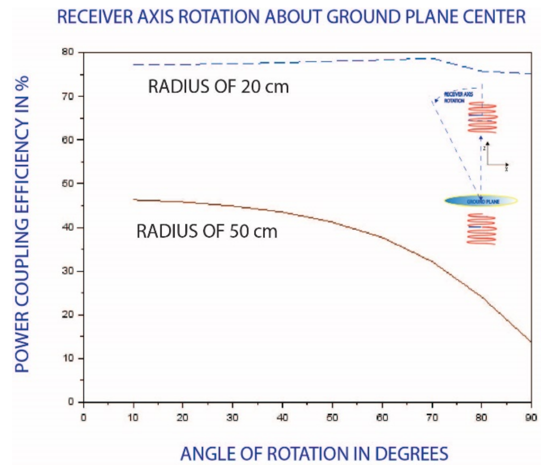

Figure 5. WPT efficiency VS angle of rotation

Simulations were run radii of 20 cm and 50 cm for inclination angles ranging from 10 to 90 degrees. In both cases for angles that vary from 0 to 30 degrees, WPT transfer efficiencies remain mostly unchanged. Following the 30-degree mark, the 20 cm case increases first and decreases gradually. In the 50 cm case only a gradual decrease is seen. Both the exception and the difference in rates of decrease may, be attributed to the difference in proximity to the finite ground plane in the 20 cm case. Both curves demonstrate a tolerance for a range of axial inclination suggesting practicality.

III. Summary

An efficient scheme for WPT was introduced through experimentation, simulation, and analysis. Measurements show that almost 80% efficiency is retained for vertical displacements of up to 20 cm. Simulation also shows that the scheme is a robust one and can tolerate a range of alignment variation from the ideal configuration, both laterally and rotationally.

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References

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