Analysis of Wireless Power Transfer (WPT) Scheme with Connected Ground Planes

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Abstract— **This paper continues further analysis of experimental results of a WPT scheme through simulation. Simulation results have increased the understanding to more fully appreciate the potential impact of this technology. Of particular interest is the configuration, where two identically constructed helical antenna-ground plane combinations that are separated by a distance within the near field of each other. While it has been shown that the system is capable of transferring power at high efficiency, simulation results have been designed to extend the understanding of the system and to allow for additional commentary on potential applications.**

Keywords—wireless power transfer; wireless charging, laptop charging; cellphone charging; energy recycling in printed circuit boards; electromagnetic interference; helical antennas; ground planes;

I. INTRODUCTION

The promise of numerous applications for wireless power transfer (WPT) systems has inspired a number of studies that show the potential of good power coupling between electromagnetically resonant antenna structures in the near field [1-2]. Experimental results [3-4] have shown that identical two high-Q helical antennas suspended over identical connected ground planes (Fig. 1) can increase their wireless power efficiency considerably (over 50% for around 2 meters separation at 18 MHz). A high efficiency and relatively large distance of separation has clear-cut implications to WPT charging technologies and potential applications such as wireless charging designs for classrooms, libraries, and desks for charging laptops, tablets, cellphones, and so forth.

The paper starts by describing the model used in conducting the simulation and its resemblance to the original experimental setup. Next, data obtained from both approaches are then compared, discussed, and explained. The impact of connecting wire length between ground planes are explored by changing connecting wire length. Finally, single source multi receiver system is studied through simulation with comments are made regarding its applicability and implication in the design of a table top charging system for mobile electronic gadgets.

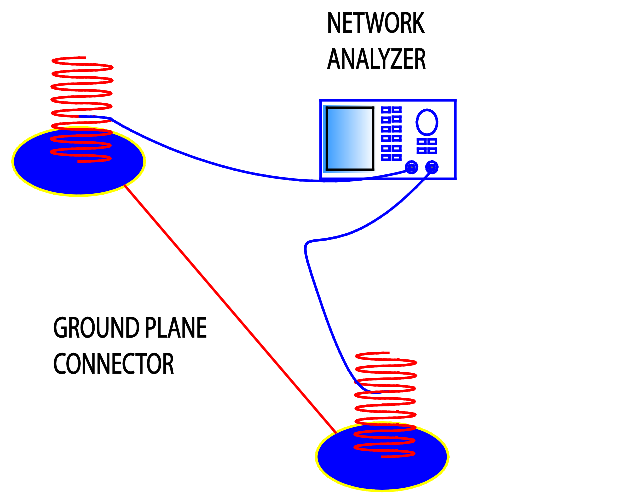

Figure 1. Schematic of experimental setup for the measurement for wireless power transfer

II. SINGLE SOURCE SINGLE OR MULTIPLE RECEIVER WPT SYTSTEMS

A. Simulation Model

The modeling was done on 4nec2 which is a well-established tool for analyzing and designing wire antenna models using a moment method approach. The 26 turn helix with a diameter 4.5 cm and height 9.5 cm was suspended above a ground plane and fed midway between the turns (about 13 turns from the bottom). The ground plane was built using a radial wire structure with several peripheral wires using the geometry builder tool. Both transmitter and receiver are identical and their ground planes are connected to the receiver ground plane using a single wire. A 50 ohm load resistance was placed in the receiver in the same location as the feed in the identical transmitter which will be referred to as port 2 while the feed point is be considered as port 1. With the exception of wire size the experimental antenna was basically the same in all respects when compared to the model.

B. Transferred power measurement scheme

Once the structure has been built in 4nec2 the input power is setup as a 100 watts and the simulation is run. The efficiency of the system is calculated by reading the power transferred to the 50 ohm load (port 2) from the feed (port 1). Based on 100 watts power transmitted, the received power in watts is the same as the percentage of power transferred or the power transfer efficiency of the system.

With the separation distance between 30-80 cm the experimental [3] and simulation efficiencies for antennas having their ground planes connected are quite close. Simulation results (Fig. 2) with and w/o connector between planes are close in the 10-30 cm range and changes drastically afterwards. Beyond this point, most of the power is carried through the connecting wire between the ground planes which act almost like a one wire transmission line between the transmitting and receiving antennas. The previous conclusion is supported by viewing near field transverse section equidistant between the antennas (Figure 3). Changing connecting wire lengths does impact WPT transfer as learned through investigation where the system was kept 30 cm apart and the connecting wire lengths were increased in steps showing decreased efficiencies for increased lengths moving from 88.3 % to 59.8 % when increasing from 22.5 cm to 52.5 cm. Simulation results presented in Fig. 2 have been kept the same as the wire lengths in used actual experimentation.

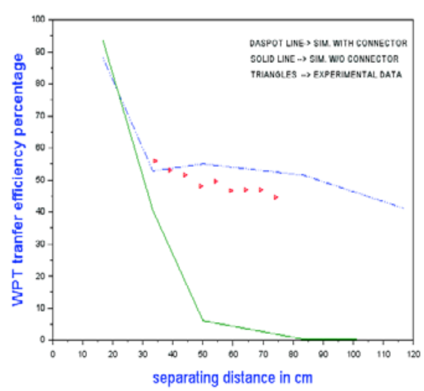

Figure 2. Comparison of experimental and simulated efficiencies

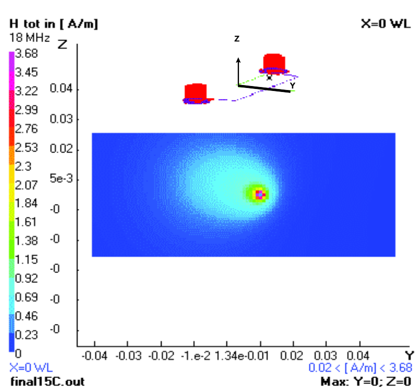

Figure 3. Magnetic near field distribution mid-way (x=0 plane) between receiver and transmitter appears to center around connecting wire.

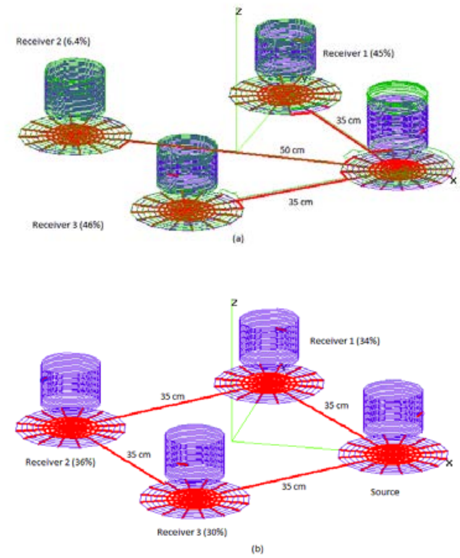

Figure 4. Two different schemes for providing wireless power from a single source to multiple receivers.

C. Single source multiple receiver system simulation

Fig. 4 shows two different schemes, (a) and (b), for running a wireless power transfer system with the source sitting at the right hand corner of a 30 cm square with identical receivers 1, 2, and 3, going anticlockwise from the source. Results summarized for brevity indicate transfer power from the source in scheme (a) for receivers 1, 2, and 3, are 45%, 6.5%, and 46% of the input. In scheme (b) power transfers in the same order are 34%, 36%, and 30% of the input respectively. In the real world scenario scheme (b) may be preferred given the ability to create a more uniform power distribution. In a table top charging scenario the receivers would be replaced by laptops, cellphones, etc.

III. SUMMARY

Experimental data from WPT scheme for a single source single receiver system been supported and extended through simulation to encompass the single source multiple receiver case. Results indicate that the scheme could provide a practical solution as a charging system for mobile electronics.

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