Extending Range of Wireless Power Transfer Using a Novel Intermediate Passive Loop with Coils

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***Abstract*—Wireless power transfer (WPT) suffers from limited range of separation between transmitter and receiver coils. We propose a novel method of using an intermediate passive wireless loop with multiple coils that allows large separation of WPT transmitter and receiver coils. Proof-of-concept results are presented using commercial Qi WPT systems where the transmitter and receiver coils were separated by 10 inches, while still providing almost identical voltage and current outputs.**

I. Introduction

Wireless power transfer (WPT) is a mechanism of transferring power without wired connection from transmitter to receiver. WPT is useful to power electronic devices where interconnecting wires are not possible, hazardous, or inconvenient. Inductive coupling is one of the most common type of WPT. This technique uses low frequency near field non-radiative wireless in the range of kHz to MHz. Thus, this technique has very low dosimetry related risks, and is considered safe for human proximity [1]. For this reason, this technique is suitable in consumer electronics and wearable devices.

WPT is a loosely coupled power transfer system as substantial amount of magnetic flux leaks. However, this technique became quite popular due to practicality where the transmitter and receiver are disjointed devices. For instance, many smartphones now support Qi charging based on this technique [2]. Other applications are wireless body worn sensors and medical implants that can be charged wirelessly [1], [3]. Electric car power delivery is also being researched to utilize WPT, instead of currently used plug-in technique [4].

Commonly WPT uses planar spiral coil (PSC) design for primary transmitter (Tx) coil and secondary receiver (Rx) coil [5]. This allows the transmitter and receiver to have thin profiles. However, as the magnetic flux is concentrated at the center of the Tx coil, to minimize leakage flux, the Rx coil needs to be placed coaxially at close vicinity. The magnetic flux declines with the cube of the distance and power transfer decreases at square of this rate (60 dB per decade), thus the Tx and Rx coils are typically placed within less than 1 inch separation. Many research groups are investigating approaches to resolve these limitations using multiple transmitter coils, larger coil sizes, or ferromagnetic materials [2], [6].

In this paper, we describe a novel method for extending WPT range by using an intermediate passive (battery-less) wireless loop circuit with multiple coils connected in series. In this proof-of-concept work, we demonstrate the feasibility with 2 coils in the loop. As a WPT system, we used Qi charging devices, however the proposed concept is not limited to Qi.

II. Experimental Setup

The conceptual diagrams are given in Fig. 1. The traditional setup for WPT composes of a Tx coil and a Rx coil placed on top of each other (Fig. 1a). In this work, we used two commercial Qi wireless charging systems: one from GeekFun (Model: EK1854) and the other from AdaFruit (Model: 2162).

Our proposed method uses an intermediate passive (battery-less) loop with series connected coils (Fig. 1b). For proof-of-concept, the loop was prepared with a 26 gauge magnetic wire and contained two coils in series at the ends. One of the coils, Loop coil 1 (LC1), is placed on the Tx coil (GeekFun Qi system) and another coil, Loop coil 2 (LC2), is placed on the Rx coil. The experimental setup is shown in Fig. 2. For load resistance, a breadboard setup is used for Rx load circuit, where a nominal load resistor is connected in series with a shunt resistor (1% of nominal load resistor). The output voltage is monitored across both of these resistances using a Keysight oscilloscope (Model: KT-DSOX1204G-InfiniiVision). The voltage across the shunt resistor (captured via the same oscilloscope) is used to calculate current through the load. The total load resistance is the sum of the nominal load resistance and the series shunt resistance.

Data are collected for the following 3 setups. Setup A and Setup B are for commercial Qi system from GeekFun and AdaFruit, respectively, where Tx and Rx coils are placed on top of each other. Setup C is for the extended range (Fig. 2) where Tx and Rx coils are separated by 10 inches so that power do not normally flow from Tx coil to Rx coil. Then the intermediate loop with 2 coils is placed such that one of the loop-coil (LC1) is on the Tx coil and the other loop-coil (LC2) is on the Rx coil.

III. Experimental Results

Fig. 3 shows the output voltages and currents for various load resistances for the 3 setups. The voltage and current of the Setup C follows closely to the other setups, although Tx and Rx coils were separated by a significant distance. In this case, the number of turns in both loop coils were 11 and the coils shapes were similar to that of Tx and Rx coils.

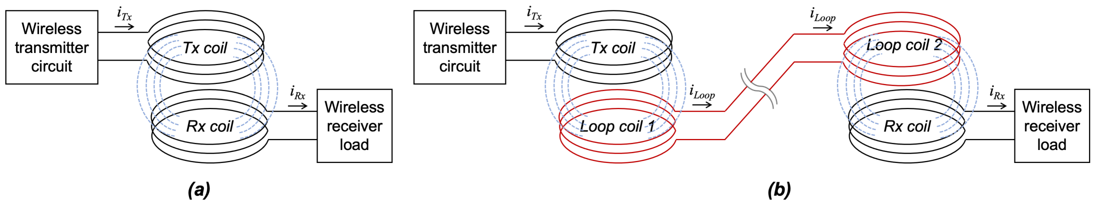

Fig. 1. Conceptual diagrams of current vs proposed WPT extension methods: (a) current WPT setup where Tx and Rx coils are placed on top of each other, and (b) WPT range extension with the proposed intermediate passive wireless loop coils (LC1 and LC2) allowing a large separation of Tx and Rx coils.

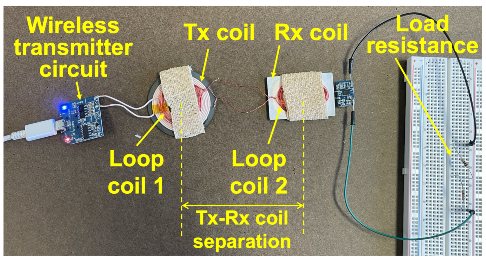

Fig. 2. Experimental setup for the proposed loop with two coils (LC1 and LC2) with a commercial Qi transmitter (Tx) and receiver (Rx) coils.

Although this proof-of-concept demonstrate feasibility of the proposed loop-coils for extending range of WPT, this can be further optimized. For instance, when the number of turns in LC1 is changed from 11 to 8 turns, the output current becomes almost identical to that of the other setups (Fig. 4).

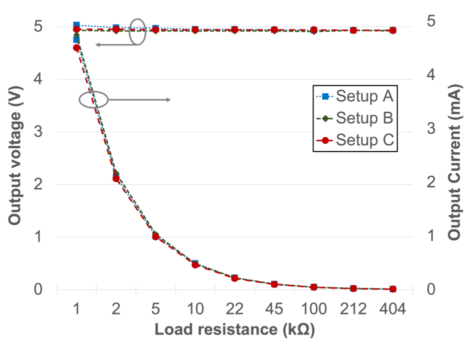

Fig. 3. Output voltages and currents for 3 setups: (A) GeekFun Tx over Rx coil, (B) AdaFruit Tx over Rx coil, and (C) TX coil 10 inches apart from Rx coil using the loop-coils (LC1 = 11 turns, LC2 = 11 turns).

IV. Discussion

In this work, we demonstrate the concept with 2 coils in the loop for the range extension. Either of the coils can arbitrarily be placed on the Tx or Rx coils. Furthermore, the loop can have more than 2 coils in series, where one or more coils can be on one or more Tx coils, one or more coils can be on one or more Rx coils, and the remaining coils can be unused.

WPT can use either resonant or non-resonant configuration for inductive coils. Similarly, for the loop coils, either of these approaches can be taken. In this paper, we present non-resonant configuration without any tuning capacitor. This is

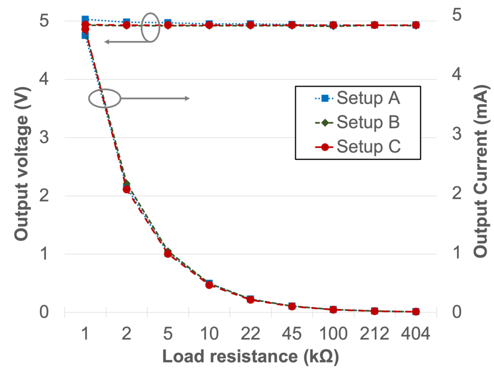

Fig. 4. Output voltages and currents for 3 setups: (A) GeekFun Tx over Rx coil, (B) AdaFruit Tx over Rx coil, and (C) TX coil 10 inches apart from Rx coil using the loop-coils (LC1 = 8 turns, LC2 = 11 turns).

simpler, albeit does not provide resonant coupling. Power transfer efficiency might be improved with using a tuning capacitor at each loop-coil providing resonant coupling.

V. Conclusion

A novel method for extending range of WPT is proposed using an intermediate passive wireless loop-coils. We demonstrated almost identical output voltage and current for Qi WPT system where the Tx and Rx coils are separated by 10 inches. This method can be applicable for powering wireless consumer electronics, wearables, medical implants, or electric vehicles.

Acknowledgement

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References

[1] T. Sun, X. Xie, and Z. Wang, "Wireless Power Transfer for Medical Microsystems", *Springer Science*, 2013.

[2] S. M. Kim, I. K. Cho, S. W. Kim, J. I. Moon, and H. J. Lee, "A qi-compatible wireless charging pocket for smartphone", *IEEE Wireless Power Transfer Conference*, pp. 387-390, 2020.

[3] R. Mahajan, B. I. Morshed, and G. M. Bidelman, "BRAINsens: Body-worn Reconfigurable Architecture of Integrated Network Sensors", *Journal of Medical Systems*, vol. 42, no. 185, pp. 1-14, Oct. 2018.

[4] P. Marks, "Wireless charging for electric vehicles hits the road", *New Scientist*, Jan. 2014.

[5] B. Noroozi, and B. I. Morshed, "PSC Optimization of 13.56 MHz Resistive Wireless Analog Passive Sensors", *IEEE Trans Microwave Theory and Techniques*, vol. 65, no. 9, pp. 3548–3555, Sep. 2017.

[6] J. Jadidian and D. Katabi, "Magnetic MIMO: How to charge your phone in your pocket", *Proceedings of the Annual International Conference on Mobile Computing and Networking, MOBICOM*, pp. 495–506, 2014.