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Performance Of Cognitive Wireless Charger For Near-Field Wireless Charging

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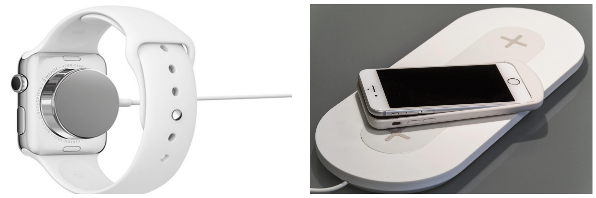
***Abstract*—Wireless charging provides a convenient way to charge various mobile and IoT devices. Prior work in state-of-the-art wireless charging systems operates at a frequency controlled by explicit networking from the power-receiving devices and is designed for the environment when the participating devices are perfectly aligned with each other. The need for the finer control due to the devices' misalignment is increasing in near-field and pseudo-tightly coupled charging applications, as more charging pads, are being deployed in the public domains and serving heterogeneous clients. Because inductive-coupled charging applications are sensitive to the placement and alignment variations between the power-transmitting and the power-receiving coils, we design and build Cognitive Wireless Charger (CWC). CWC adaptively controls the operating frequency in real time using implicit feedback for optimal power transfer operations. This demo is to supplement our paper about CWC [1]. In this demo, we showcase the impact on power transfer performance caused by the variations in the placement and alignment between the charging coils of power transmitter and power receiver and demonstrate the performance improvement provided by CWC.**

I. INTRODUCTION

Since early 20th century, wireless power transfer is enabled between physically separate inductor coils using the electromagnetic (EM) field coupling. Generating an alternating current (AC) in the transmitter's inductor coil produces a magnetic flux around the coil. When the receiver inductor coil is placed close to the transmitter coil, it consequently generates AC in the receiver circuit and the induced power can be used to power electronic components or charge the battery. Recent developments in power transfer envision the wireless experience when the devices are getting charged so that customers can do so without the inconvenience of wired charging cables. Personal charging pads are customized and tightly aligned to the customers personal device receiving the power; hence there are very limited fluctuations across different charging sessions in the receivers coil with respect to the transmitters coil. Public domains (such as restaurants and airports) are also deploying public charging pads so that the customers can charge their devices on the go; such public charging infrastructure introduces a necessity to embrace greater variations in the transmitter-receiver charging dynamics. As they are designed for near-distance wireless charging, we call them pseudo-tightly coupled regions and provide a representative example in Figure 1.



(a) Tightly coupled (b) Pseudo-tightly coupled

Fig. 1. Pictures depicting tightly coupled and *pseudo-tightly* coupled transfer

We introduce the Cognitive Wireless Charger (CWC) system which incorporates intelligence sensible to such fluctuations and improves the wireless power transfer performance. We focused and designed our prototype CWC to be compatible to the Qi standard [2], currently the most widely adopted standard for mobile devices and operating in the 110-205 kHz frequency range and distance in the order of centimeters. Like the power control networking for charging status sharing, our novel contribution is not to bootstrap the power transfer but to make the ongoing power transfer more efficient during the charging process. This demo paper is to supplement the paper about CWC [1], which provides greater details about CWC and the theoretical/simulations- and prototype-based studies of the impact of devices/coils variations in power transfer. In this demonstration, we showcase the design implementation of our CWC prototype charger and demonstrate the performance of our CWC prototype by adaptively tuning the frequency in real-time for optimal power transfer performance sensitive to variations in transmitter-receiver coil alignments.

II. COGNITIVE WIRELESS CHARGER

Our work is inspired by *Cognitive Radio* technology in wireless networking and the software-defined radio tools that facilitate its implementation, by sharing the networks spectrum resource incorporating flexible and adaptive control in its communications parameter (e.g. center frequency and bandwidth). It is inherently required to avoid the primary users operations at all times and with no aid from the primary user. Similarly, our CWC prototype transmitter does not rely on the networking from the receiver but rather uses

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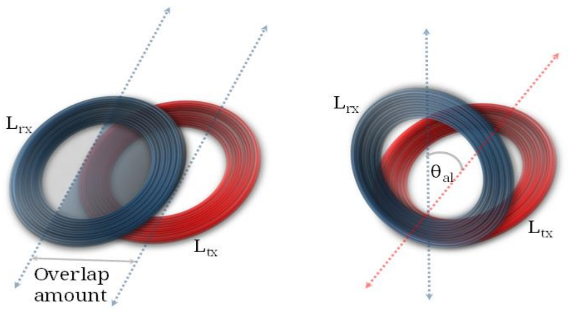

Fig. 2. Coil misalignment metrics: (a) Overlap and (b) Alignment angle

sensing (based on the signal measured across its own coils) for frequency control. In contrast to other prior work that changes the power transmitters hardware configurations [3], we focus on the software-defined parameter (*frequency*) for maximizing the power transfer; implementing control at the software level enables greater programmability, flexibility and provides finer granularity for adapting to varying placements and heterogeneous clients. CWC's use of sensing (with no explicit networking) for power transfer optimization is novel to the best of our knowledge, and we verify its effectiveness from theoretical relations and simulations described in our paper [1]. CWC thus inherently bypasses the compatibility issues that can arise from having heterogeneous clients.

III. PERFORMANCE OF COGNITIVE WIRELESS CHARGER

We compare our CWC prototype's steady-state performance with a *baseline* performance, operating at the fixed resonance frequency (which is oblivious to the transmitter-receiver alignment). Figure 2 illustrates the metrics of coil misalignment by the measured alignment angle and the amount of overlap. Here, we measure the effect of the misalignments in distance (D), orientation/angle (θ_{al}) and overlap amount (X) between the transmitter coil and the receiver coil without the regulator. Results are obtained by using the setting corresponding to: D=0.5cm, θ_{al}=0^o and X=100% (the perfectly aligned setting). Figure 3 (a), (b) and (c) shows the results as the misalignments in D, θ_{al} and X respectively, vary. The maximum gain of CWC over the baseline is approximately x1.63 when the coils are best aligned. As the misalignment increases (and the coupling strength consequentially decreases), CWC converges to the baseline, which is the optimal operating frequency in a loosely-coupled region. When our CWC prototype is turned off, the wireless charging has comparable performance to the commercial-grade Qi wireless chargers. When the CWC prototype is enabled, we are able to achieve significant improvement of power transfer over modern wireless chargers.

IV. DEMONSTRATION

This demo using our wireless charging prototype is designed to serve two purposes. First, we demonstrate the impact of device placements and alignments on power transfer performance, motiving the charging control. We introduce CWC, describing the design and implementation of the system. Second, relative to the baseline (which is the typical practice in Qi wireless charging of fixing the frequency to be the resonant frequency), we show the performance gains achieved by CWC by adaptively tuning the frequency in real-time for optimal power transfer performance.

ACKNOWLEDGMENT

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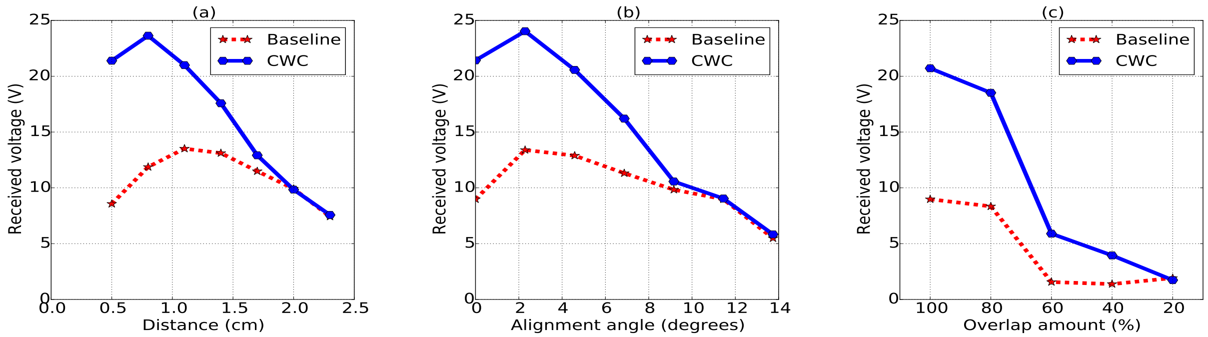

Fig. 3. CWC and the baseline performances for coil misalignments (a)$\vec{D}, \theta_{al}, X$; (b)$D, \vec{\theta_{al}}, X$; (c)$D, \theta_{al}, \vec{X}$