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Foreign Object Detection for Wireless Power Transfer

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Abstract

This paper presents foreign object detection (FOD) methods for MHz wireless power transfer (WPT) systems. Unlike current FOD implementations, the presented methods can operate without requiring a feedback loop from the wireless power receiver to the transmitter. This allows complete decoupling of the transmitter and receiver and therefore reduces the design complexity and cost of the system. The developed FOD methods were implemented on a 13.56 MHz WPT and experimental results are presented showing successful detection of a wide range of objects regardless of the loading condition of the system.

1 Introduction

WPT technology allows powering electronic devices without a physical connections. This feature can be convenient and in certain cases even necessary. However, the safety of WPT should also be considered. There are two major safety concerns related to WPT systems: the specific absorption rate (SAR) and the inductive heating effects of the generated magnetic and electric fields. The SAR of typical low-power WPT systems, according to CST human body simulation, meet the ICNIRP 1998 standard [1] (e.g. a CST simulation we performed showed that 15cm away from the WPT system, SAR is 0.23 mW compare to 12 mW maximum localised SAR from ICNIRP 1998). However, the inductive heating of foreign objects can be a significant problem. Consequently, FOD implementation is required to limit the temperature rise of any foreign objects by the either reducing the transmitted power and disabling the WPT system until the foreign objects are removed.

Table 1 presents the experimental results of inductive heating of common objects on two different types of WPT systems, a commercial Qi standard Class D based wireless charger which operates at 120kHz, and a 13.56 MHz WPT system using the load-independent Class EF inverter [2] developed by our group, the Wireless Power Lab at Imperial College London. While most metallic objects can heat up quickly on low-frequency Qi chargers (figure 1), their temperature barely increases on the MHz frequency WPT system. However, objects that contain thin metal structures, e.g. a compact disc, can heat up when exposed to a MHz magnetic field. These phenomenons indicate the necessity of including FOD systems in WPT systems for commercial use notwithstanding the frequency of operation.

Table 1. Temperature rise (°C) of foreign objects in 30 seconds with kHz and MHz WPT systems

	Coin	Keys	Compact Disc
kHz WPT	25	23	0
MHz WPT	1	0	12

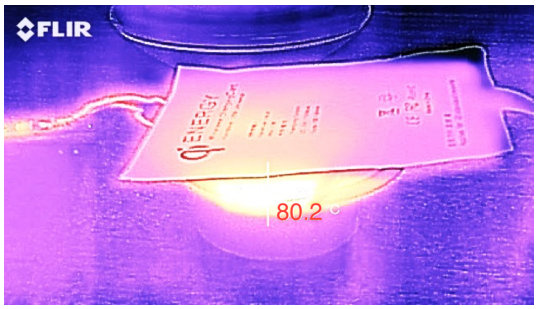

Figure 1. Inductive heating of a coin on a Qi wireless charger

Various FOD methods for WPT have been developed. The one developed by Texas Instruments (TI), uses a technique known as Power Loss Accounting (PLA) [3], and the Wireless Power Consortium (WPC) uses a technique known as Power Loss Detection (PLD) [4]. The PLA solution by TI calculates the difference in power between the transmitter and the receiver. If the difference is sustained at a power greater than 700 mW (the defined threshold), then the device assumes that a foreign object is absorbing power and shuts down the system. The PLD solution provided by the WPC uses regression analysis to find relationships between parameters, and uses these to estimate the power, and like the PLA solution compares these values to determine the presence of a foreign object. Both of these solutions fundamentally use a difference of efficiency to evaluate if a foreign object is present. Limitations exist for these techniques, especially if the foreign object and the receiving circuit are both loaded from the transmitter at the same time.

This paper presents the design and development of a FOD

method that can work without the requirement of communication between the transmitter and the receiver, and independent of the loading condition of the WPT systems.

2 WPT Device and Equipment Setup

A WPT system using a load-independent Class EF inverter will be used for the experiment, simulation, and the development of the FOD in the system we propose. The inverter maintains zero-voltage switching and inherently regulates the current's amplitude and phase as long as the receiver is tuned to 13.56 MHz, i.e. reflecting a resistive load. The drain voltage of the switching transistor on the inverter and the current of the transmitting coil were measured using a Lecroy HD4096 oscilloscope.

3 Drain Waveform FOD Method

The FOD method we present works by recognising the signal response patterns of foreign objects. A tuned wireless receiver would behave as a resistive load of the transmitter, however, foreign objects are not tuned to the wireless transmitter so they could behave as either capacitive or inductive load. This difference between the wireless receiver and foreign objects could thus cause a different response to the drain waveform of the wireless transmitter. Figure 2 shows the waveform changes when foreign objects are present in proximity to the WPT system. This FOD method therefore, detects the change of the drain waveform to determine whether foreign objects exist or not.

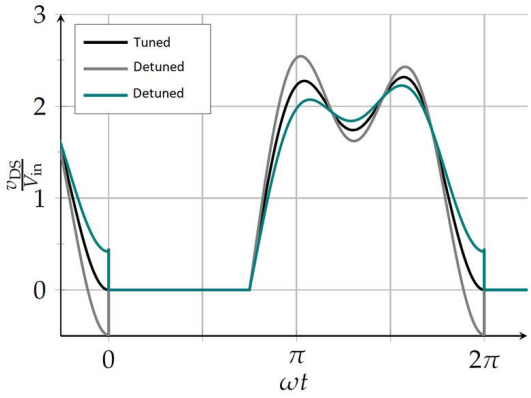

Figure 2. Drain waveform response to foreign objects

4 Sense Coil Phase Detection Method

An additional possible FOD method that detects foreign objects using an extra sense coil has also been investigated. A tuned wireless receiver can only draw the maximum amount of power at the tuned frequency (resonance frequency), and decreases rapidly as frequency changes. However, foreign objects are not tuned to any specific frequency, and therefore they still absorb energy from the WPT systems when the operating frequency changes (not significantly, as the impedance of the foreign objects can also vary with frequency). Therefore, by placing an extra coil (sense coil) near the transmitting coil, and driving it at a slight different frequency and monitoring the power transmitted from the sense coil, it is possible to detect foreign objects.

The sensor coil however, can also load the WPT system, and the additional circuit required to drive the sense coil could also increase the cost of implementation. A further improvement to this method could be using the original transmitting coil as the sense coil. The inverter could be modified to drive this coil at a different frequency regularly to detect foreign objects. This method is yet to be finalised and more experiment will be conducted to verify it.

5 Conclusion

This paper presents the design and development of FOD methods that work without communication between transmitter and receiver, and regardless of the loading condition of the WPT system.

6 Acknowledgements

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