An Optimization Method of Wireless Charging of Placement

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Abstract In this paper, we propose an classification placement method of wireless charging. In a charging plate with multiple nodes, we use voltage as classification. After scanning the entire charging plate, we can know where the maximum charge voltage on the charging plate, and then classification the charging voltage. When the user is placing the device on the charging plate to find the best charging node, by using the proposed optimal classification algorithm. By using the method, user can still do the best charging range classification on the different brands of charging plates to achieve more efficient wireless charging.

Keyword Wireless Charging, Charging Range Classification, Placement

1. Introduction

1.1. Issues of Wireless Charging placement

In recent years, there are many products of wireless charging continue to publish. So there are many smartphones equipped with wireless charging module, and there are many power supplies and portable consumer electronics products have wireless charging capabilities. But many users met a problem, when the user don't put the device with wireless charging capabilities properly on the charging pad, there will be not charged or charging efficiency is poor. The reason is because the wireless charging coil module is covered in the product housings, the users may not know how to put the coil to the "sweat point" to get better efficiency. Therefore, in this paper we will proposed a method to find the optimal charging point placement.

1.2. History of Wireless Charging

In 1899, Nikola Tesla completed its first successful use of high-frequency power transmission system in Colorado, the system transmitted 100 million volts of electricity through the distance of 26 miles to lit 200 bulbs and an electric motor. [1]

In 1964, William C. Brown demonstrated a helicopter using a 2.45GHz microwave charging the helicopter in the air for more than ten hours. In 1975, Mr. Brown implemented in 2.5 GHz frequency successfully received 30 KW DC output from 450 KW transmitter over a distance of 1.6 Km in California Goldstone. And Mr. Brown also won the Pioneer Award from MIT in 1995[2] .

Today's wireless charging technology can roughly be divided into three types, the first: Magnetic Induction, second: Near Field Coupling, third: Radiation Mode. Table 1 is the comparison of the three wireless charging.

From Table 1, we can see that Magnetic Induction can get the best charging efficiency (about 70%), but the transmission distance is only several mm. The user need place the device on the charging pad to be charged. However, the Near Field Coupling methods' efficiency is not good as Magnetic Induction, but by increasing the charging distance, it will get more flexibility when using wireless charger.

In 2007, in MIT Andre Kurs et al. published "Wireless Power Transfer via Strongly Coupled Magnetic Resonances", by using self-resonant coils in a strongly coupled regime, it can demonstrated efficient non-radiative power transfer over distances up to 8 times the radius of the coils. And they were able to transfer 60 W with nearly 40% efficiency over distance in excess of 2 meters. [3]

Table 1. Comparison of three wireless charging

	Magnetic Induction	Near Field Coupling	Radiation Mode
Distance	Several mm	Less than 0.3 wavelength	Several Wavelengths
Efficiency	Maximum 70%	40~60%	Inefficient

1.3. Qi

Qi is a short distance, low power wireless inductive power transmission standard developed by Wireless Power Consortium (WPC). Its main purpose is to provide wireless charging technology for mobile phones and other portable electronic devices. Wireless charging alliance founded in December 2008 by nine companies, including Logitech, National Semiconductor, Olympus, NXP, SANYO, TI, etc. They want to be able to develop all the electronic devices are capable of compatible low-power wireless charging standard target. Currently it has more than 180 member companies.

In 2010, Qi released V1.0 version, the output power is up to 5W, the operation frequency range is in 110-205 kHz, by adjusting the operation frequency band, duty cycle or its input voltage to the power control, and it has simple communication protocol. V1.1 version is increase the foreign body detection (FOD) sensitivity and more comprehensive compatibility test. And its typical products are Apple Watch, Nokia Lumia 1520, Google Nexus 7 and SAMSUNG GALAXY S6.

2. Measurement

We used a set of wireless charging module meet the Qi Standard to do measurement. The parameters of the wireless charging are shown in Table 2. The measurement scenario is shown in Fig. 1. Initially, the left side of the transmitter coil fixed at 0 grid position, and then the receiver coil start move right from 0 gird position for each grid until to the eighth gird. The distance of each grid is 1 cm.

Through the different location of transmitter and receiver coils, we can get interesting data, when the two coils overlapping area over 3/4m, the receiver can get the maximum charging efficiency (about 0.5 Walt). When the overlapping area is only 1/2, the receiver can receive approximately 0.2 Walt. If the overlapping area is less 1/2, then the charging module is completely unable to receive energy, as shown in Table 3.

According the measurement result, we find a phenomenon. When the wireless charging coil overlapping area over 1/2, it will occur magnetic induction and generate electricity transmission. But the coils need to more than 3/4 overlapping area to meet the operating voltage 5V.

Therefore, we will design a classification method, when the receiver circuit receives more than 5V, then the module will display a green light. When the receiving voltage is higher than 3V but lower than 5V, the module will display red light. But when the receiving voltage is lower than 3V, the module will not display any light.

Table 2. Module Parameter

Input Voltage	12 V
Maximum Current	1.3 A
Receive Voltage	5 V
Receive Current	1.5 A
The outer diameter	43 mm

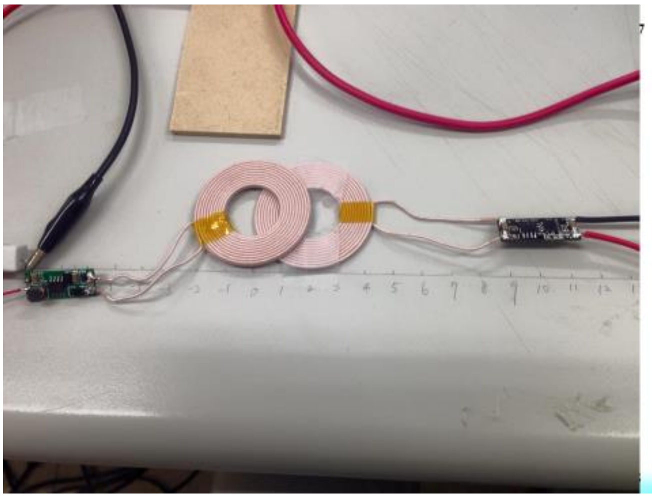

Fig. 1. The Measurement Schematic

Table 3. The Result of Measurement(Transmitter)

Distance (cm)	Vtx (Volt)	Itx (mA)	Ptx (Walt)
0	9	66	0.594
1	9	67	0.603
2	9	94	0.846
3	9	148	1.332
4	9	154	1.386
5	9	146	1.314
6	9	94	0.846
7	9	68	0.612
8	9	68	0.612

Table 4. The Result of Measurement (Receiver)

Distance (cm)	Vrx (Volt)	Irx (mA)	Prx (Walt)
0	0	0	0
1	0	0	0
2	3.16	63.2	0.2
3	5.01	100.2	0.502
4	5.01	100.2	0.502
5	5.01	100.2	0.502
6	3.15	63	0.198
7	0	0	0
8	0	0	0

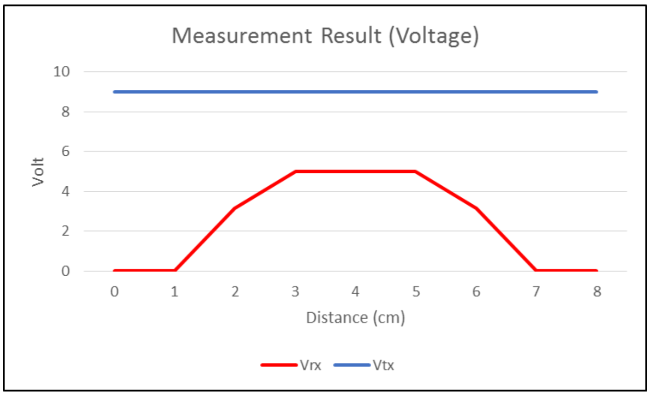

Fig. 2. Measurement Result (Voltage)

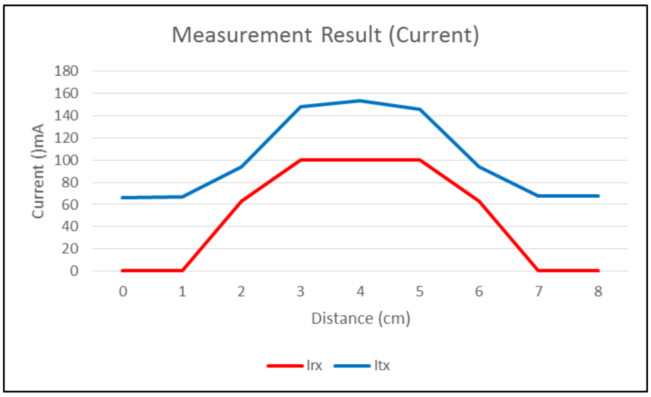

Fig. 3.Measurement Result (Current)

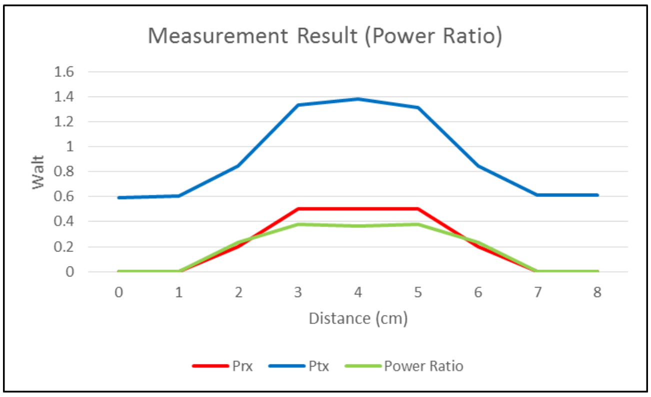

Fig. 4. Measurement Result (Power)

3. Method of Classification

We assume that there is a wireless charging pad with four charging coil, that can provide up to four user to charge, but users may probably place smart phone of poor placement or overlapping two or three coils, so can't get best charging efficiency, as shown in Fig. 5-7.

If we assume that the wireless charging module has two-way communication capability (pairing) in the following scenario. As shown in Fig. 5, if we assume that coil A and coil R can reach 68% charging efficiency (70% for the best charging efficiency) in scenario, we can see in APP shows that coil A charging efficiency up to 68%. In Fig. 6, for scenario 2 the APP may display the coil A's efficiency is 20% and Coil B's efficiency is 30%. And in Fig. 7, scenario 3 shows that the worst situation as the coil R covering three coil, the coil A's efficiency is 40%, the coil B's efficiency is 5%, and the coil C's efficiency is also 5%.

When the smart phone in the situation of overlapping multi-coil, the APP will display the current receive energy of each coil, and it will automatically determine the best efficiency coil to send the control signals to do charging, but the other coils will be determined to the noise energy to be ignored. The APP flow chart is shown in Fig. 8.

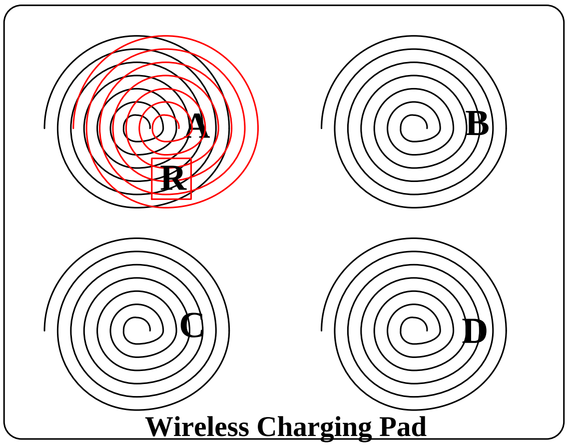

Fig. 5. Scenario 1 one-by-one coil (Good)

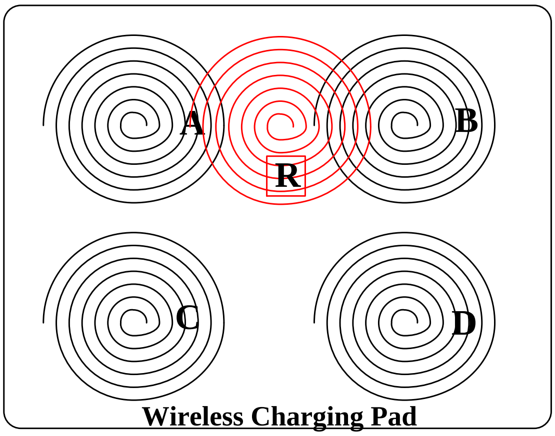

Fig. 6. Scenario 2 one-by-two coil (Worse)

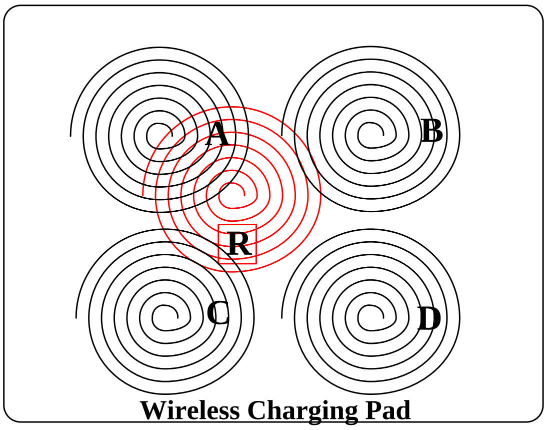

Fig. 7. Scenario 3 one-by-tree (Worst)

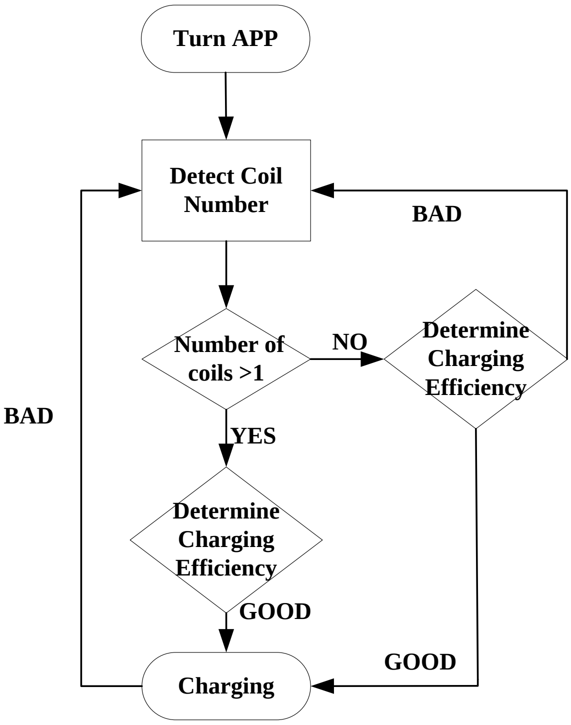

Fig. 8. The APP flow chart

4. Conclusion

In this paper, we made a simple measurement by using wireless charging module. We can found that in the poor condition of coils overlapping, there will be poor charging efficiency.

Therefore, we proposed a concept, by using NFC transmit charging command and report regularly. If the charging efficiency is poor, the APP will using NFC to send warning to smart phone. When the coil leave to the charging pad, the APP will send command to stop charging. And when the APP inducing the coil, it can connect the wireless charging module to do pairing and then do wireless charging to achieve optimum charging efficiency.

5. References

[1]Nikola Tesla, “Method of utilizing effects transmitted through natural media” United States Patent No. 468,654, Nov 5, 1901.

[2]W. C. Brown, “The Microwave-Powered Helicopter,” J. Microwave Power, vol. 1, no. 1, 1966.

[3] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljacic, “Wireless power transfer via strongly coupled magnetic resonances,” Science, vol. 317, no. 5834, pp. 83–86, Jul. 2007.