SAVONIA

Application and promotion of wireless charging technology

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Bachelor's Thesis

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SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS**
Abstract

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Abstract

The aim of this thesis is to study wireless charging technology and analyze the application and promotion of each technology. This technology is based on Faraday's electromagnetic in 1830s. It is not a new technology but it is developing high speed nowadays.

This thesis introduces four mainstream types of wireless charging technology and three mainstream standards, and analyzes their features and development status.

Wireless charging technology has been applied to some products, such as electric toothbrushes, electric shavers and cordless phones. Now its application field has been expanded to smart phone field and vehicle field. In future, wireless charging technology will be applied to the daily life gradually.

Lastly this thesis gives several feasible suggestions on how to promote wireless charging technology.

All in all, the final aim is to let more people know wireless charging technology and accept it.

Keywords
Wireless charging technology, electromagnetic induction, application, promotion.

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ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
MIT	Massachusetts Institute of Technology
TI	Texas Instruments
ENIAC	Electronic Numerical Integrator And Calculator

1 INTRODUCTION

Wireless charging technology, which belongs to wireless energy transmission technology, means just transmitting electrical energy from a power source to a battery or a load without any conductors like wires (WIKIPEDIA, 2014). It is different than traditional charging type, without wires' constraint, charging becoming easier and more flexible.

With the development of science and technology, there is a continuous improvement of the living standard. It means that more electronic devices contact people. The development trend of electronic devices is smaller and mobile, just like from phone to mobile-phone, from computer to laptop to pad, etc. So the batteries become a necessary part of electronic devices gradually. The low battery is a common problem with the most people. We have to charge every day.

Abandoning the electric wires to charge is many people's dream, and also the target that engineers have been working on. To compare with traditional charging type, wireless charging has many great advantages. Without wires limitations, the operation of charging is easier and faster. For some precision equipment, no charging sockets can be tighter. Thus it prolongs equipment's life. At sometimes, wires are dangerous in some places. It is possible to short circuit when old wires touch together. In some humid areas, like bathroom, wireless charging is safer because of no risk of electric leakage from charging plugs. (Li 2011, 3.)

In fact, wireless charging technology is non-contact charging technology, and not a recent technology. Some electric toothbrushes and cordless phones have been using this technology to charge already. But the technology has been very immature. Low efficiency, high heat, large radiation, and poor security limited its development. In a long period of time, this technology was in the bottleneck. (Li 2011, 3 - 4.)

Until 2007, a team of Massachusetts Institute of Technology used its experimental wireless charging machine to power a 60 W light bulb at a two meters distance (Hadley 2007). Wireless charging technology was in focus of international attention again. After that, it has been in the rapid development. A large number of applications of wireless charging technology have been created.

Wireless charging technology is a new revolutionary charging technology for us now. It will play an important role in the electronic world. To promote it, there are some problems. High cost, poor efficiency, short distance, customers' usage habit, and confusion about security are waiting us to solve. It is still not a very mature technology today, but it has a bright future. (Li 2011, 5.) The final aim of this thesis is to let more people know wireless charging technology and accept it.

2 TECHNOLOGY DESCRIPTION

2.1 Technology background

Early in 1831, Michael Faraday discovered that changes in the surrounding magnetic field can generate a current in the wire. Then in the 1890s, Nikola Tesla, the inventor of the modern AC (Alternating Current) electricity supply system, put forward the concept of wireless power transmission and demonstrated the possibility of intercontinental wireless power transfer. (Culbertson.)

Unfortunately, research in this area delayed about one century. The biggest obstacle is the transmission efficiency is too low and dangerous. Electromagnetic radiation is only suitable for transmission of information but not suitable for transmission of energy at that time, because the energy of non-directional radiation will be wasted in useless space. Some people envisaged using directional electromagnetic radiation, such as lasers, but it is too difficult to control and extremely dangerous. (Culbertson.)

Nowadays, the transmission efficiency of wireless charging technology can be achieved 80 to 90 percent (Battery University). Wireless charging technology is developed rapidly today.

2.1.1 Advantages

Wireless charging technology has many great advantages compared to traditional charging type.

- Convenience

  Just imagining it, all wires, patch boards and chargers disappear. People never waste time to look for patch boards and suitable chargers, and are never exhausted by clearing up the tangled wires. All devices can move freely during charging. There is no need to go out with chargers (Jing 2013, 7).

- One transmitter to more receivers

  A charging transmitter can charge more devices within the scope of work. Wherever at home, office or street, the wireless charging is available for all devices, provided that the standard is the same for these devices (Jing 2013, 7).

- Continuity
  For moving devices, it is not necessary to stop to charge. Wireless charging can be used anytime. It ensures a steady stream of energy supply. (Jing 2013, 7.)

- Durability
  Without charging sockets, the structure of devices can be tighter to reduce the corrosion of air and water (Culbertson).

- Security
  Without external wires, sockets and plugs, it completely avoids the risk of electric leakage and short circuit (Jing 2013, 7).

Some of the above advantages have been proven just in theory. Although they have not been fully achieved yet, we expect engineers to improve this technology and achieve the above advantages as early as possible.

2.1.2 Disadvantages

Wireless charging technology is still not a very mature technology today, and there are some disadvantages we must face.

- Short distance
  Now wireless charging technology is only suitable for short distance charging. The problem that the long distance causes low efficiency has not been solved. (Culbertson.)

- Low efficiency
  Without conductors to charge, energy is difficult to control. There will always be some energy waste in radiation and heat (Battery University).

- Low power
  Not only the low efficiency but also the defects of technology lead to low power. It means that we have to spend more time to charge (Battery University). It is not good news for customers.

- Expensive.
  At current stage on market, the cost of the wireless charging application is generally higher than traditional charging application. Because it is fresh for market, complex structure also involves a number of patent fees.

- Customers' psychology
  Most people have spent a lifetime to use wires to charge. It's hard to change the habit of customers unless there is a huge advantage. Like mobile phones, wireless charging distance is shorter than the length of normal charging wires now. Its efficiency is also lower than traditional charging. So, nobody wants to pay much more money to a wireless charger of mobile phone.

Finally, the above disadvantages are temporary. With the development of technology, all problems can be solved in the future.

2.2 List of events in development history

1. Michael Faraday discovered electromagnetic induction in 1831 (Bueche & Jerde 1995, 608).

2. Nikola Tesla put forward the concept of wireless power transmission in the 1890s (Culbertson).

3. MIT team successfully powered a 60 W light bulb at a more than two meters distance in 2007 (Hadley 2007).

4. Wireless power consortium has been established in 2008. It has established the Qi standard (WPC).

5. Nokia presented an innovative smartphone named "Lumia 920" with a built-in wireless charging system in 2012 (Tilbey 2012).

2.3 Technology methods and theory

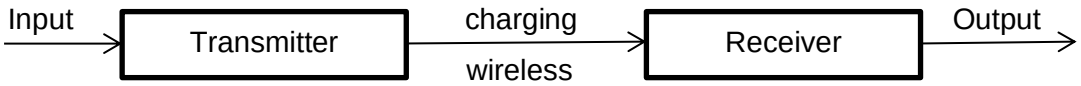


FIGURE 1. Flow chart of wireless charging technology (Jing 2013, 11)

Figure 1 shows the basic theory of wireless charging technology. First, input power changes to wireless power through transmitter, then transmitting to receiver wirelessly, finally changes to valid output power from receiver.

At current stage on market, there are four mainstream types of wireless charging technology. This part is focused on magnetic induction, the widely used method at current stage.

2.3.1 Magnetic induction

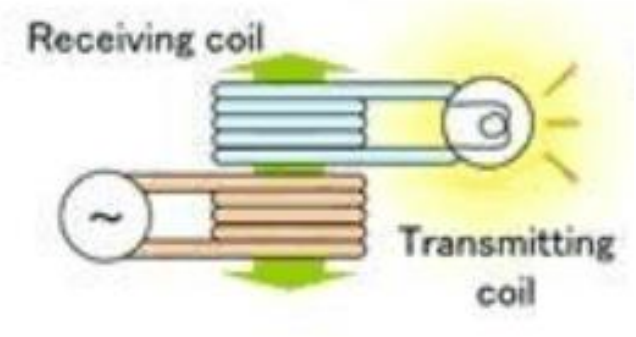


FIGURE 2. Operation of magnetic induction method (Xinlueh 2012)

This method is based on Electromagnetic induction. As Figure 2 shows, it is like a simple open cored transformer including primary and secondary coils and some other electronics. A varying current in the primary coil can produce a varying magnetic field, and then, an induced current in secondary coil is generated from a varying magnetic field. The flux is coupled into the secondary coil which induces a voltage, current flows. The primary coil works as a transmitter and it is built into a charger pad. The secondary coil works as a receiver and it is built into a part of a load or a battery of a device. When the receiver is positioned on the transmitter, magnetic coupling occurs during the transmitter is driven. The power can be transmitted to a load wirelessly. (Bueche & Jerde 1995, 609.)

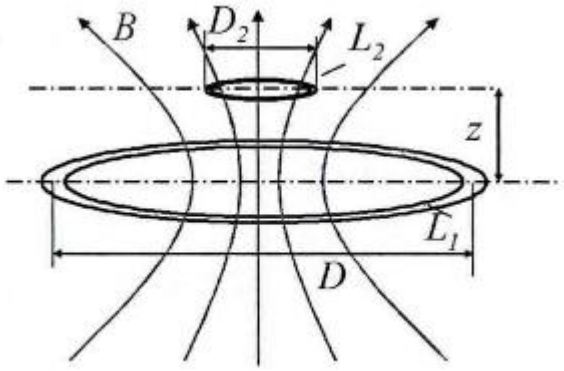


FIGURE 3. Principle of magnetic induction method (Zhu 2012, 6)

The transmission efficiency depends on coefficient of coupling and quality factor of coils. From Figure 3, the coefficient of coupling is not only related to the distance (z) and size (D) of coils, but also shape and angle of coils. To shorten the distance or increase size can raise coefficient thus improving transmission efficiency. (Zhu 2012, 6 - 7.)

The Qi standard of Wireless Power Consortium is based on this technology. Now many manufacturers are interested in it and present a lot of products. Here is a chip product related to magnetic induction of TI (Texas Instruments) Company.

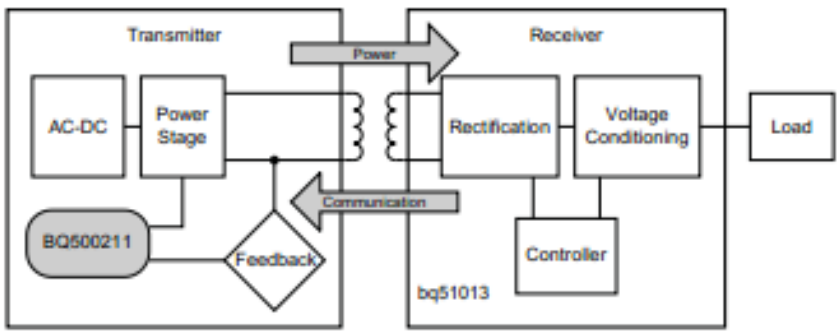


FIGURE 4. Principle of operation of wireless charging system of TI (TI 2012)

Figure 4 shows two parts of this system, a transmitter and a receiver. The transmitter converts AC power to a pulse signal with a period of variation, so that the primary coil generates a changing magnetic field. Due to the coupling effect, the varying current is induced in the secondary coil, and then the current is through the voltage conditioning to control and regulate. Finally, the voltage of output is accepted to the load. (TI 2012.)

These loads may be working in the mobile phone, or the battery, or a plurality of loads simultaneously. There is a communication control unit of receiver, the change of the load can be fed back to the transmitter, especially in the case of no load, and the transmitter does not perform any form of energy into the work, so that save energy, but also greatly reducing the electromagnetic interference to the surrounding environment. (TI 2012.)

2.3.2 Magnetic resonance

This method is based on the sound's resonance. The arrangement of the tuning forks with the same vibration frequency, and if one sounds by vibration, others also sound by resonance. The coils with the same vibration frequency in a magnetic field can also transmit power from one to others. (Xinlueh 2012.)

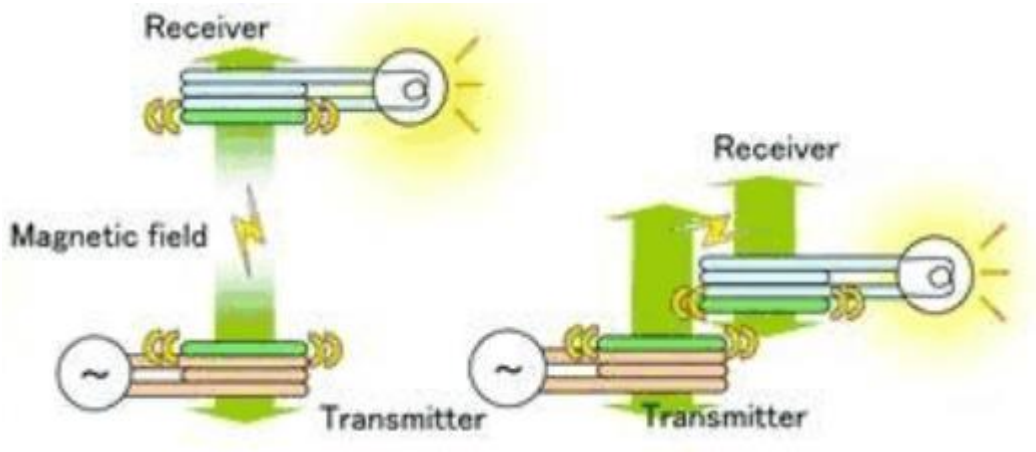


FIGURE 5. Operation of resonance method (Xinlueh 2012)

Figure 5 shows some differences between magnetic induction method and magnetic resonance method. To compare with magnetic induction method, magnetic resonance can extend the transmitting distance. It is different from magnetic induction method so it is unnecessary to take the coils completely consistent (Xinlueh 2012).

IMAGE 1. MIT (Massachusetts Institute of Technology) team experimentally demonstrated wireless power transfer (Karalis 2007)

Image 1 shows MIT team which used magnetic resonance method to power a 60 W light bulb from a power source at a more than two meters distance without any physical connection in 2007. They called this concept as “WiTricity”. (Hadley 2007.)

Magnetic resonance method can provide a longer charging distance than other methods. Because of resonance’s feature, it just transmits power to the objects which have the same frequency, and it does not influence other objects almost. (Hadley 2007.)

2.3.3 Radio wave reception

Radio waves, also called electromagnetic waves, are a familiar thing to people. They are the important foundation of the broadcast, TV and modern communications. The radio wave can not only transmit information, but it can also transmit energy.

The theory of the radio wave reception charger is similar to the crystal radio. The system is consisting of a radio transmitter and a radio receiver. The crystal radio is a very simple radio receiver that was popular in the early 20th century. It receives information and power from radio waves without charging or a battery. (Li 2011, 10.)

Powercast Company has developed this method and its product can provide continuous wireless charging at a maximum distance of 12 to 15 meters for one or more low-power electronic devices. Powercast’s technology system is consisting of two parts,

the transmitter called “Powercaster” and the receiver called “Powerharvester”. The transmitter is plugged in a working power, and the receivers are embedded in electronic devices. The receivers can receive power from transmitter by radio waves, and then convert to DC(Direct Current) power to electronic devices. The conversion efficiency is as high as 70% in some scenarios. (Li 2011, 11.)

2.3.4 Capacitive coupling

This method is to apply an alternating voltage across the capacitor at a plate, so that the energy transfers to the opposing plate.

Murata’s capacitive coupling wireless charging technology utilizes the induced field generated by coupling the two asymmetric dipoles in the vertical direction to transmit electricity (Murata).

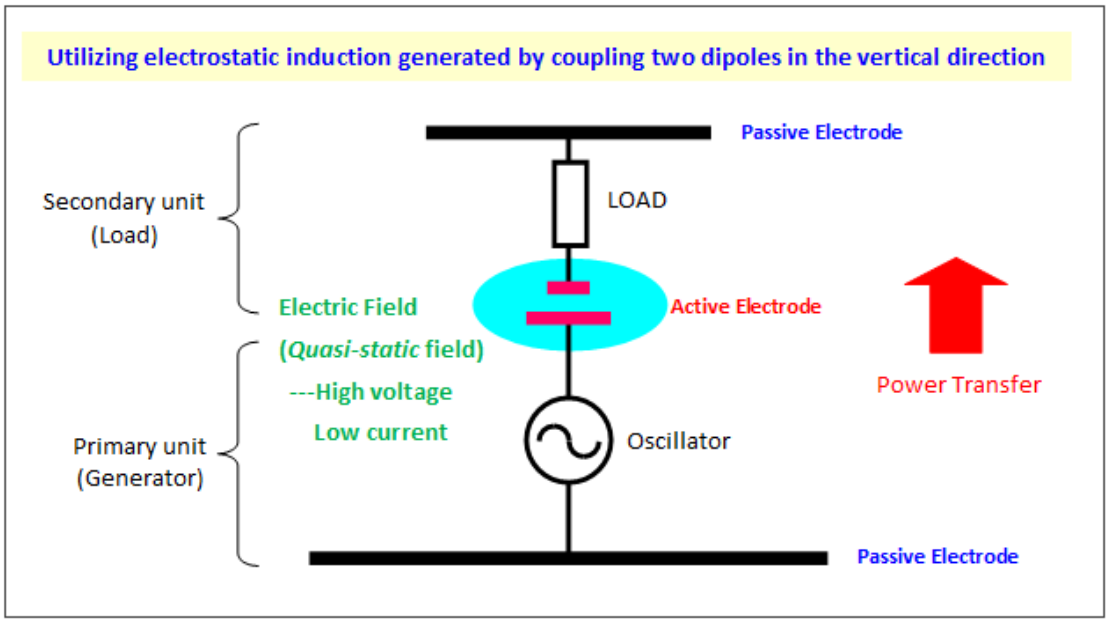


FIGURE 6. Principle of Murata’s capacitive coupling wireless charging technology (Murata)

Figure 6 shows the electric field. Quasi-static field generated by two active electrodes transmits power from the generator to load. The feature of this Murata’s capacitive coupling method is asymmetric dipoles. There are two sets of electrodes and Murata calls them as “passive electrode” and “active electrode”. The passive electrodes play a major role in the grounding. System is a combination of these electrodes to transmit power. (Murata.)

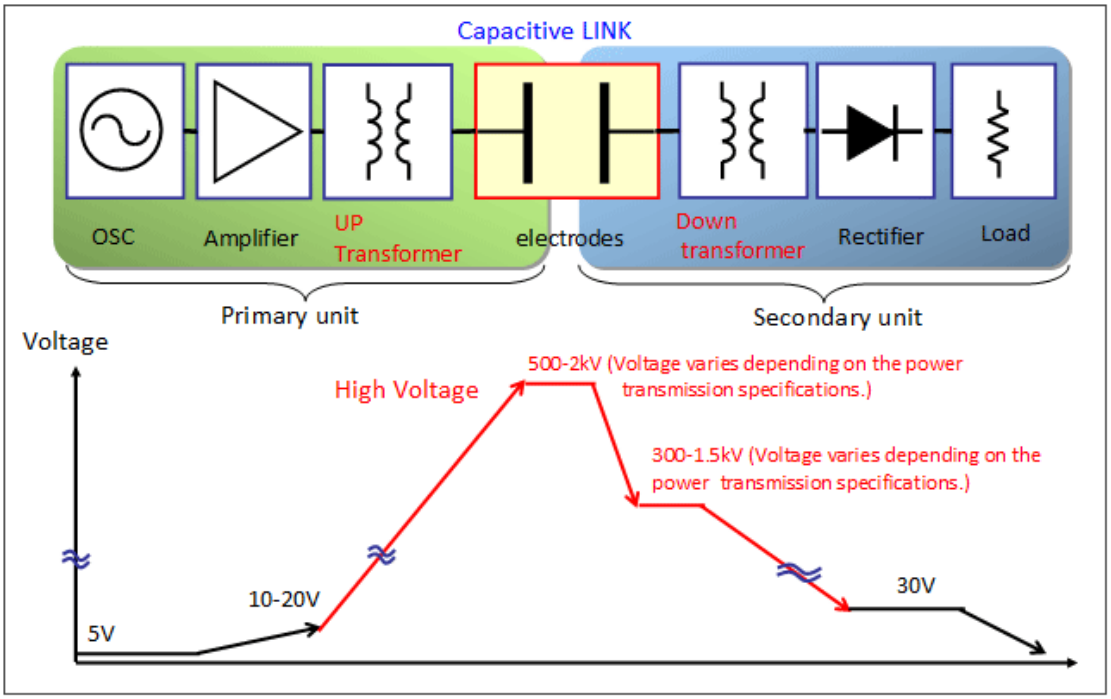


FIGURE 7. Block diagram/Transition of voltage (Murata)

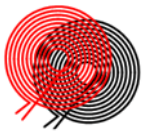
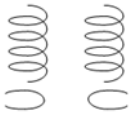
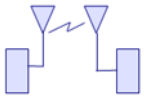
Figure 7 shows the voltage is slightly increased from amplifier, then sharply increased to high voltage about 500 - 2 kV through up transformer. Power transmission is with that high voltage. After down transformer and rectifier's adjustment, voltage is controlled under to 30 V for loads.

There are three main advantages of capacitive coupling method (Murata):

- Free positioning of devices on charging pad.
- Electrodes are thin.
- Temperature of electrodes does not continue to rise.

2.3.5 Conclusion

TABLE 1. Comparison of four wireless charging methods (Jing 2013, 4; Xinlueh 2012; Murata)

Method	Magnetic induction	Magnetic resonance	Radio wave reception	Capacitive coupling
Overview	Induced current from a magnetic field between opposing coils	Similar to magnetic induction by resonance coils	Power is generated from radio waves	Capacitive coupling from opposing plane electrodes
Image				
Power	Less than several hundred kW	Less than several kW	Less than several W	About 10 W
Distance	Several centimetres	Several metres	More than 10 m	Several centimetres
Strengths	High efficiency High power	High efficiency High power Long distance	Long distance	Less heating High efficiency
Limits	Short distance	Big size	Low efficiency Low power	Short distance

1. As Table 1 shows, each method has different characteristics. So there is not an absolute best method. Each method is suitable for different application fields.

2. Magnetic induction method is the most popular way on market now. The most wireless charging phones use this method.

3. Resonance method has the greatest potential in the future. The distance and power are suitable for vehicles. But it is difficult to reduce its size now. Currently this method can provide a 60 W power between 2 m distance from coils of 50 cm radius (Hadley 2007).

4. Radio wave reception method is only suitable for low power devices. It is too difficult to control radio wave's direction. Power loss is too huge.

5. The most important problem is security. The radiation out of wireless charging system is harmless to human body, but the radiation in the system is still large. Because current wireless charging products is based on tightly coupled technology. So the charging distance is too short to put anything in. However, with the development of technology, charging distance is extended. To ensure safety in somebody or some electronic devices between the transmitter and the receiver is important. (Jing 2013, 13.)

3 APPLICATION

3.1 Technology standards

Establishment of technology standard is beneficial to build a wireless charging ecosystem. But confirming a uniform standard too early is a limit of development. At this time, three standards are competing on market. And market will choose the best one in the future.

3.1.1 Qi

The Qi standard is the first global standard of wireless charging technology that was published in August 2009. It is created and maintained by the Wireless Power Consortium. The Qi standard is based on magnetic induction method of wireless charging technology. The idea of Qi is to set up a universal wireless charging way. The different devices which are certified by the Wireless Power Consortium and with the Qi logo can work pairing with all Qi chargers. The first product with the Qi standard appeared in September 2009. There are more than 590 kinds of products with the Qi standard in September 2014. (WPC.)

The typical product of Qi is smart phones like Nokia Lumia 920 and Google Nexus 4. These products can be charged on any Qi chargers without any accessories.

Wireless Power Consortium
Since being founded in 2008 by eight members, the Wireless Power Consortium has steadily grown to over 200 members including a lot of sets of industries like semiconductors, components, batteries, mobile phones and consumer electronics. The Wireless Power Consortium published the Qi standard in August 2009. (WPC.)

3.1.2 PMA

The PMA standard is established by the Power Matters Alliance in 2012. This standard is based on magnetic induction method as the same to the Qi standard. The significant difference is that the Qi standard’s power frequency is 100 to 205 kHz but the PMA standard’s is 277 to 357 kHz. (Culbertson; PMA.)

The Duracell Powermat Company has presented some products with the PMA standard including charging cases for some popular mobile phones. The charging cases are like power receivers. The phones with those cases can be charged on all PMA chargers. As a supporter of PMA standard, Starbucks will install PMA chargers under the coffee tables with Duracell Powermat. (Jing 2013, 5.)

Power Matters Alliance

The Power Matters Alliance is a global industry organization being founded by Procter&Gamble and Powermat Technologies in March 2012. Membership has grown rapidly. There are more than 100 members today, including AT&T and Starbucks. (PMA.)

3.1.3 Rezence

The Rezence standard is built by the Alliance for Wireless Power in January 2013. This standard is based on magnetic resonance method. The Rezence is a portmanteau word of “resonant” and “essence”. And it is the only standard with magnetic resonance method. (A4WP.)

Alliance for Wireless Power

The Alliance for Wireless Power is a not-for-profit organization being founded in early 2012. The members are over 110 in 2014. They expand their application range than other two standards including some high power products like electric vehicles. Because this alliance was not established so long ago, there are few its products on market. (A4WP.)

3.1.4 Conclusion

TABLE 2. Comparison of competing standards for wireless charging technology (Culbertson; WPC; PMA; A4WP)

Standard	Qi	PMA	Rezence
History	5 years	2 years	1.5 years
Union	Wireless Power Consortium	Power Matters Alliance	Alliance for Wireless Power
Technique	Magnetic induction	Magnetic induction	Magnetic resonance
Distance	4 cm	4 cm	Several inches or more
Free Positioning of Devices on Pad	No (Yes, using arrays of transmitter coils)	No (Yes, using arrays of transmitter coils)	Yes
Charges Multiple Devices	No (Yes, with multiple transmitters)	No (Yes, with multiple transmitters)	Yes
Power Frequency	100 to 205 kHz	277 to 357 kHz	6.78 MHz
Communication Frequency	100 to 205 kHz	277 to 357 kHz	2.4 GHz
Receiver Power	Up to 5 W (now), up to 120 W (coming)	Up to 5 W (now)	3.5 W, 6.5 W
Target Charging Applications	Smart phones	Smart phones	Electric vehicles
Member Count	200+	100+	110+
Founders	Various	Powermat, Proctor& Gamble	Qualcomm, Samsung, Powermat
Key Supporters	Nokia, HTC, Sony	AT&T, Starbucks	WiTricity, Intel

1. Table 2 shows comparison of these three standards. Qi is the earliest standard around the world and it owns the largest number of members. A lot of applications with Qi standard is on market. At current stage, Qi is the leading standard in wireless charging world.

2. PMA standard's strength is its strong supporters on the marketing of the USA. PMA applications can be popularized rapidly through AT&T and Starbucks in the USA.

3. The Rezence standard is a new standard of the new type technology - magnetic resonance. The advantages of magnetic resonance help Rezence to have a bright future.

4. Because magnetic induction and magnetic resonance have different advantages, more multi-mode devices are coming. In February 2014, Power Matters Alliance and Alliance for Wireless Power make a decision to join in cooperation (PMA). It means the multi-mode devices of PMA or Rezence standard will support the other one. It is beneficial to establish a global wireless charging ecosystem and industry consolidation.

3.2 Application fields

This part introduces four application fields. Wireless charging technology displays different advantages in different fields. Now on market, portable products are the most wide application field.

3.2.1 Portable product

With the development of technology, electronic products will be smaller and lighter. For example, in 1945, the ENIAC (Electronic Numerical Integrator And Calculator) was the first electronic programmable computer built in the University of Pennsylvania, the USA. The weight of the computer was about 30 tons. Nowadays, the most of computers become portable products. The iPad Air designed by Apple Company in 2013 weighs only 0.45 kg. It can be carried as a book. Emergence of portable products led to people's lives more convenient. In the future, there will be more portable products available. (Techil Warehouse 2004; Apple.)

Continuous power supply is a major limit of portable products. Now the solution is to install a battery with a wire charging in a fixed power outlet. But the battery capacity is not unlimited. And the battery with big capacity is usually heavy to limit flexibility. People like to use small and light portable products that cause battery capacity to

decrease and charging frequency to increase. So people spend much time and resource on charging with a wire. A convenient charging type without wires can help people save huge resource.

The aim of wireless charging technology for portable products is to change the charging type. Traveling will be more convenient without charging wires. They do not have to carry an extra bag of many kinds of wires. Just putting portable products on a wireless charger to charging can also save a lot of time. In some places, wireless charging is a more secure way to people. It is dangerous to use a hairdryer in a humid bathroom after a shower. Charging wires in humid air are prone to accidents.

Nowadays, wireless charging technology has been applied in some smart phones and other portable products. Portable products become the fastest growing application field of wireless charging technology.

3.2.2 Household appliance

The household appliances need continuous power supplies that connect to a fixed power outlet. In a house, power outlets are usually in the walls, fixed from construction. So the household appliances can be only placed in a limited area of the power outlets. Less power outlets lead to insufficient power supply. More power outlets lead to the house to look not beautiful.

The conception of wireless charging technology for household appliances is to build a wireless charging transmitter in a house. Because one transmitter can supply more receivers, one transmitter is enough for a house. It does not influence house beauty. There is no limit to place household appliances. People can place household appliances anywhere in house and move them flexibly.

3.2.3 Implantable medical device

There are a lot of implantable medical devices, in general divided into two types. One is passive type, including bone and joint substitutes, artificial heart valves and so on. The other is active type, including implantable cardiac pacemakers, and implantable nerve stimulators and so on. (Han 2007.)

The active types of implantable medical devices need power to operation and passive types do not. Wireless charging technology is applied to active types. Traditional active implantable medical devices are using disposable batteries or wires through skin to provide power. (Han 2007.)

The implantable medical device is implanted in body. In order to beauty and convenience, wireless charging is the best way to charge. Nobody likes a wire emerging from body skin. For security reasons, wire's junction will cause bad influence on sealing.

3.2.4 Vehicle

At current stage on market, the most vehicles run with fossil fuels. The extensive utilization of fossil fuels has worsened our living environment. Meanwhile, because the fossil fuels will be depleted in the future, the new energy vehicles represented by electric vehicles is one of the direction of the automotive industry. But there are two problems with electric vehicles now. One is the lack of battery endurance, the other is charging inconvenience. The wireless charging technology is likely to help people solve these two problems to some extent. Although wireless charging technology cannot raise directly the upper limit of battery endurance, a lot of wireless charging stations can strengthen endurance indirectly. Even if wireless charging is not more convenient than refueling at a gas station, but more than wired charging.

At this stage, because of the limit of battery technology, charging time is much more than refueling time. To build wireless charging stations in the parking lots is a good choice to solve the problem of charging time. When the vehicles stopped in the charging space, the system will automatically charge vehicles until fully charged. Charging during the free parking time can save charging time indirectly. It is also more secure than wired charging at open parking lots in bad weather. There is no risk of broken wires' leakage with rain.

The primary conception is to install wireless chargers for every parking space, then with the development of technology, just to install one wireless charger for a parking lot. It will be very convenient for electric vehicles. The final conception is to install wireless chargers under the roads, directly to provide power for electric vehicles without batteries.

3.3 Application products

This part introduces three typical products on the market now. The first one is based on low level technology in the early days. The second one is a popular smart phone based on Qi standard. The third one is an accessory for smart phones based on PMA standard. They are both successful in each field.

3.3.1 Oral-B rechargeable toothbrush

The Oral-B rechargeable toothbrush is a mature product of wireless charging technology on the market. It uses the magnetic induction method to charge wirelessly. The coils are built in a toothbrush and a base like a transmitter and a receiver. A toothbrush and a base combine to a transformer when they close to each other.

The wireless charging technology of toothbrushes is easier than other products. Because the charging power of electric toothbrushes is not high and the charging distance is not long. The low power of wireless charging does not cause any problems of energy waste or a large quantity of heat. The base is designed to be like a ring to fix toothbrush. It looks like the toothbrush setting at the base. This form is more like a transmitter. The first coils in the base and the second coils in toothbrush's tail can be in a plane. (Liszewski 2009.)

The electric toothbrushes show the great advantage of wireless charging technology that it is safer than traditional charging type. The completely sealed toothbrushes and bases ensure water cannot get in. So it also avoids any problems of electric leakage and short circuit.

3.3.2 Nokia Lumia 920 smartphone

Nokia Company has announced a number of smartphones with wireless charging technology of Qi standard. The typical product is Lumia 920 announced in September 2012. (Tilbey 2012.)

IMAGE 2. Lumia 920 smart phone and some supporting wireless chargers (Tilbey 2012)

On the market, there are many so-called wireless charging phones. The most of them need to add the charging accessories like cases or shells. But the Lumia 920 is different than them. A wireless charging receiver is built in Lumia 920's body. So it can be charged directly on any wireless chargers with Qi standard. This design enables the charging process easier. (Tilbey 2012.)

Wireless charging technology is a design highlight of Lumia 920, but this feature is not very popular on the market. Like Image 2 shows, the supporting wireless charger is a little expensive and it is bigger than traditional charger. The distance and efficiency of wireless charging are hard to satisfy customers. Tests showed the Lumia 920 can be charged wirelessly with the maximum about a 2 cm distance and about 70% efficiency (Shyam 2012; Litchfield 2013).

These limits are temporary that cannot influence people's enthusiasm of the wireless charging technology. This is also the power of technology development.

3.3.3 PowerKiss charging ring

PowerKiss Company is from Finland and is located in Helsinki. Its concept is a novelty that is to add design elements into products. PowerKiss is devoted to put wireless charging transmitters into household furniture and public facilities like tables and chairs. It removes customers' criticism about the big size of wireless charging transmitters. A lot of public transmitters make a convenient charging environment for people. There are already some transmitters in Helsinki Vantaa Airport and some in McDonald'ses. (PowerKiss.)

The wireless charging ring is main product of PowerKiss. It is a wireless charging accessory for smart phones. The outlook of the charging ring is stylish and special. It is easy to engage customers' attention in first time. People can buy it or free borrow it in public which located supporting transmitters. Various charging rings with different plug can support the most of mobile phones.

In May 2013, PowerKiss has cooperated with Powermat and joined the Power Matters Alliance. The charging rings can operate with any chargers of PMA standard based on magnetic induction method (PMA).

4 PROMOTION

Nowadays, people need to adapt the quick pace of life because the high technology is developing. The high technology gives the convenience to people, some high-technology products are entering into modern life.

In the application fields, wireless charging technology is already applied in a small scope of portable products like smart phones. Other application fields are almost stopped in the theory; they are not applied in the most people's life yet.

With the development of smart phone, more functions are loaded to it. People use smart phones not only making calls, but also surfing the internet, taking photos, and watching videos. It increases electricity consumption and charging demand. A large number of smart phones and frequently charging times make a good market to wireless charging technology. So this chapter will focus on portable products, especially on smart phones.

4.1 Development tendency

In 2013, there were 21 million devices with wireless charging receiver sold and only 5 million wireless chargers. It is a small part of all but it cannot deny its wonderful future. According to source from IHS, Figure 8 shows the world market for wireless power from 2011 to 2023. It predicts the revenues will increase to several billions in several years. (Sanderson 2014, 1.)

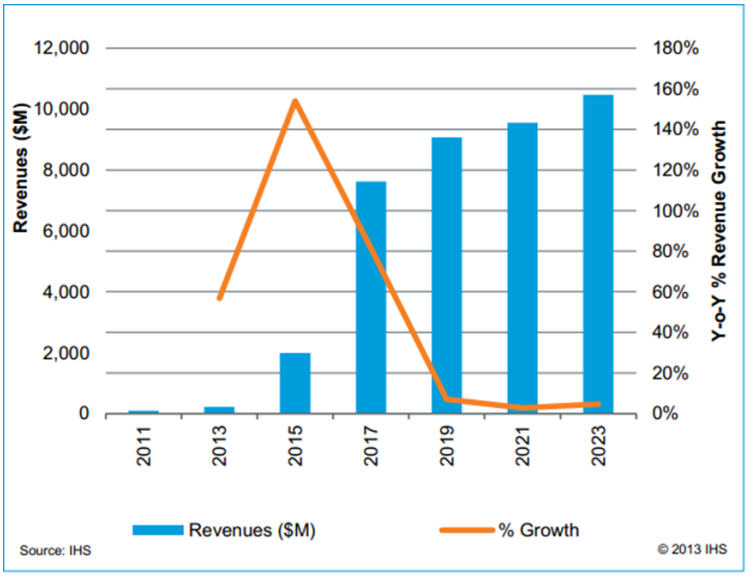


FIGURE 8. The world market for wireless power (Sanderson 2014, 2)

IHS considered that one of the biggest disadvantages is wireless charging distance is too short based on tightly coupled technology. It limits the devices to move freedom. Some companies already announced to certify some loosely coupled projects in 2014. It is good news to extend wireless charging distance. So, IHS predicts the wireless charging market will grow rapidly from 2015. (Sanderson 2014, 1.)

In 2019, the revenues will increase to $9 billion with an important part of smart phones. Smart phones manufactories increasingly are start to build wireless charging receivers directly in their products. Meanwhile, development of uniform standards also benefits the widespread adoption. While wireless charging is a special function for a high end smart phone now, it is expected to become a necessary function for a normal phone. (Sanderson 2014, 1.)

4.2 Quality development

There are many quality weaknesses of wireless charging technology. The purpose of this part is improving these quality weaknesses. The performance is the key point.

4.2.1 Outlook

The wireless charging system includes the transmitter and the receiver. Receivers can be built in smart phones directly or other accessories like cases. Nowadays, the size and weight of these smart phones or accessories are similar to normal products. The transmitters for smart phones are usually bigger and heavier than normal chargers, even than smart phones themself.

In order to carry transmitters conveniently, the outlook target is reducing the size and weight of transmitters. The wireless charging system's structure is more complex, and therefore it is difficult to achieve this target in a short time. Since it is so, hiding transmitters in some other appliances can achieve this target indirectly.

The Inter Company is developing a kind of wireless charging technology and they are building transmitters in computers for smart phones. Some vehicle manufacturers are also interested in building transmitters in vehicles. They are good ways to hide the disadvantages of transmitters' outlook. (Mick 2012.)

Starbucks has put some transmitters under the coffee tables in the USA (PMA). Widely installing wireless transmitters in public places is a good promotion of wireless charging technology.

4.2.2 Performance

There are five things concerning wireless charging phones' performance.

- Transfer efficiency

This transfer efficiency means the wireless charging receiver's ratio of output power and input power. Now the transfer efficiency of magnetic induction method is usually from 50% to 80%. Some products which have more than 70% transfer efficiency generally are accepted by customers. It involves not only the hardware design and materials, but also software design. Good software design can adjust circuit parameter to improve transfer efficiency. (Jing 2013, 13 - 14.)

- Operating temperature

Now on the market, the power of wireless charging phones is about 5 W. The charging operating temperature is usually controlled to about 40 degrees centigrade with 70% transfer efficiency. It does not affect phones' operation. Low transfer efficiency may cause high temperature, because a part of loss of power transfers to heat energy. High operating temperature is harmful to electronic devices. So, controlling operating temperature is important to wireless charging technology. (Jing 2013, 14.)

- Charging distance

Now on the market, the rated charging distance of wireless charging phones based on magnetic induction method is usually from 3 mm to 7 mm. The best charging distance is from 3 mm to 5 mm. This distance can provide a stable 5 W power for phones. Charging power is rapidly dropping down over the rated charging distance. The bigger size of coils can provide more power and distance, but it is not suitable for mobile phones. The current charging distance is too short to satisfy customers. Engineers need to improve charging distance carefully, ensuring that rated power does not drop and product's size does not increase. (Jing 2013, 14.)

- Quality of separating magnetic piece

The power frequency of Qi and PMA standard is in the range of 50 to 500 kHz. The radiation of this frequency is harmless to the human body. But it affects electronic devices operation. The batteries and other electronic components absorb radiation energy to rise the temperature. High temperature may cause devices breakdown and damage to people. Thus the separating magnetic piece is being a necessary part of wireless charging phones. Good quality of separating magnetic piece includes small size, durable ability, and separating radiation efficiently. At present the ferrite material has relatively good quality to produce separating magnetic pieces but high price. (Jing 2013, 14.)

- Standby power and working life

Standby power is related with the design of hardware and software, and material of components. It is important to some wireless charging transmitters which need to be on standby for long time. At the same output power, the better products' standby power is smaller. Smaller standby power not only saves energy, but also to extend working life. (Jing 2013, 14.)

4.2.3 Cost

At current stage on the market, for smart phones, the cost of wireless charger is more than traditional charger. The high price is a limit of customers' urge to buy.

The ratio *R* of cost of wireless charger *C1* and traditional charger *C2* is described by the formula

$$R = C1 / C2 \quad (4.1)$$

Now on the market, *C1* is more expensive than *C2*. So *R* is more than 1 now. The target is decreasing *R*. Under the same condition of charging distance *L*, *C1* is the cost of the transmitter and receiver, *C2* is the cost of the plug and wire. *L* also is the length of wire. *R* also is described by the formula

$$R = C1 / (C3 + LW) \quad (4.2)$$

Where *C3* is the cost of plug and *W* is the cost of wire per unit length.

From the formula 4.2, decreasing *C1* and increasing *L* can decrease *R*. The strength of *C1* is none of cost of wires. If the distance of wireless charging is long enough, *C1* will be obviously cheaper than *C2*.

4.3 Sales development

The purpose of this part is to analyze how to attract more customers to buy wireless charging smart phones.

4.3.1 Marketing situation

In 2013, 1.8 billion mobile phones are sold globally, and more than 50% are smart phones. It is the first time that smart phones win traditional mobile phones. Also the number is increasing continually. (MNW.) Most people charge their smart phones every day or once every two days because of smart phones' large electricity consumption. It is an enormous marketing.

Wireless charging technology began as commercial production in 2010 and rapidly developed from 2011. Because it is a new technology, customers need time to compare it and traditional charging type. In fact, only 1% of all smart phones market was with wireless charging function during 2011. According to source from iSuppli, until 2013, the sales of wireless chargers was $180 million. The most part was from the smart phone field. (Jing 2013, 15.)

The company which is a designer cooperates with manufacturer to produce the new product - the smart phone - which can charge wirelessly. First, the company will introduce these high technology products through the advertisement; the advertisement should emphasize the characteristic and advantage of the product to searching the potential customers, and then the company can build some place which can show the new product, people can try them there, they can know more information - especially the advantage of the product. This promotion can help people study more and arouse their demand.

4.3.2 Customer scope

- Potential customers

The potential customers are students. The high technology products always attract students. Young students are willing to accept new things, but they don't have jobs, so they cannot afford the product with high price. With the time flying, the technology will improve further and the cost of product will decrease, the price of the product will become cheaper. At that time, some of the students have ability to purchase the smart phones which can charge wirelessly in the future.

- Target group

The target group is business people. They usually use smart phones because of their busy work, so the electric quantity is easy to run off. The wireless charging smart phones are suitable for them if they go to other unfamiliar places for business and forget to take their charger when busy with work. If they have the wireless charging smart phones, they can charge in any places which have power supply in public area. They are high income people and they have enough money to buy the new technology products at first time.

4.3.3 Sales promotion

- Producers

The producers include designers and manufacturers. As the designers, they should consider improving the appearance of products. As the manufacturers, they should consider reducing the cost of production. The main objective of these two roles is earning more money and gaining more profit.

Otherwise, they should understand something about product characteristics, which are quality, brand, image, package and service; improving quality, building a good brand and image, designing a suitable package and doing a good service are very important and necessary. Another thing is product range that should be explicit. Wireless charge smart phone is a high technology product now. Finally, the producers should establish the plan for product development. According to product life cycle, they should be continuously innovative to give more life on the product. (Bradley 1995, 111 - 117.)

- Dealers

The dealers mean the sellers who sell the products to wholesalers or individual. They can plan a price strategy according to price policy. They are pricing the products like 199 euro. It always looks like cheaper than 200 euros, and it is called psychology of pricing. Sometimes the company should grasp the opportunity to make the discount decisions, for example, before festivals or introduction of new product company can give some discount to customers. By the way, the terms of payment are also important. Cash, card or pay through the internet are necessary channel.

On the other hand, the dealers should consider the place, more specifically. They should scheme the distribution channels that they can know how the products will be sold. The second one is logistics, from ordering to storage and then to deliveries. These whole processes should be known. Also important thing of place is external and internal accessibility. The external accessibility means the sales area's location, the internal accessibility means inside the shops, how to put the product reasonably and so on. (Bradley 1995, 840 - 843.)

As a dealer, a good skill of personal selling is the key to success. Through the communication process, sellers can show a large amount of information to the buyers and they can know the real thought of customers, and introduce the suitable products to the customers quickly. It is a face to face communication so it is easy to make the product close to customers and finally give a power to customers to purchase. (Bradley 1995, 844.)

In the selling process, the seller can give the gifts or test products to the customer in the appropriate situation. On the one hand, it can build or keep a good relationship with the customer, on the other hand, the gifts or test products are marking the brand of company, and it is easy to build the product impression.

- Sponsors

The sponsors are also useful role as cooperators. The manager of company can bring the wireless charging smart phones to take part in the technology shows which is organized by sponsors; sometimes the sponsors can support the product launch for the new product. The purpose is to let more people know and want to purchase the new product.

The company relates with the suitable sponsors in order to build the public relations. It is powerful alliances for achieving a win-win strategy.

4.4 Future expectation

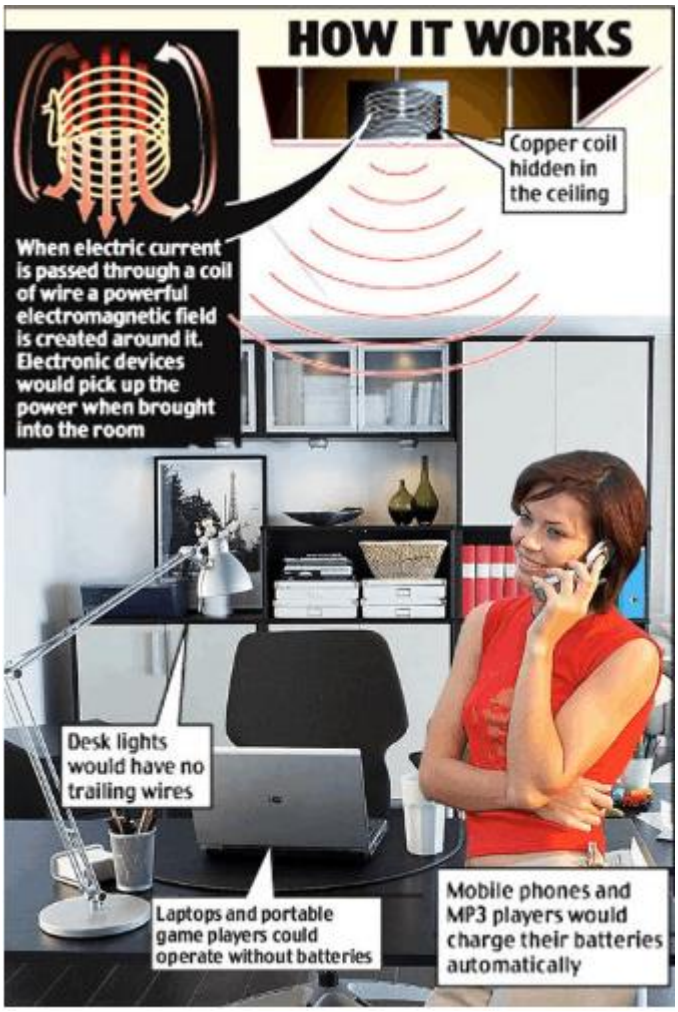


IMAGE 3. Wireless charging system in future (Xinlueh 2012)

As Image 3 shows, one of the future expectation is establishing an indoor wireless charging system. Using wireless charging technology is like Wi-Fi. There is only one wireless charging transmitter for a house. Every device in the house can be charged wirelessly.

The other expectation is establishing an outdoor wireless charging ecosystem. A large number of transmitters will be installed under every road. All vehicles and devices on the road can be charged at any time. The electric motors of vehicles can get power directly from transmitters without batteries. It will also save resources of producing batteries.

Of course, it may look like unachievable. But nothing is impossible unless unexpected. With the development of technology, the charging process will be easy like breath.

5 CONCLUSION

I had a chance to charge my smart phone wirelessly by a sponsor's accessory in Helsinki Vantaa Airport last year. This experience shocked my heart powerfully. From that time, I devoted myself to study wireless charging technology and present it to more people. It is also the original motivation for me to achieve this thesis.

Nowadays, electricity plays a very important role in people's daily life. Traditional charging type limits flexibility of electric devices in some respects. It costs a lot of resources to produce wires. The research of wireless charging technology is a way to promote progress of mankind.

In my opinion, this thesis refers to many fields I have studied like electricity, magnetism, and industrial business management. In this thesis, Chapter 1 is a brief introduction of the technology. Chapter 2 introduces some background information, and all methods for wireless charging technology are explained.

Chapter 3 is related to application and all standards and some products are introduced. Qi standard is the most popular standard. Portable product is the key point of application field. There are many portable products with Qi standard on the market now. Chapter 4 is focusing on promotion to wireless charging smart phones. It is important to improve performance. Meanwhile, good sales promotion is also important to further expand the market.

Wireless charging technology is a revolutionary innovation with the ability to change the world. Its excellent charm attracts many companies to improve it. Actually, it is still in the initial stage at this time. From my point of view, standardization is the most important problem in the future. It requires the government's support. Uniform standard means one wireless charger can charge all devices. For customers, it saves money to buy more chargers. For producers, it reduces cost of every steps of industry chain. For countries, it is beneficial to resource saving and environment protecting.

In 1940s, the computer was bigger than a truck in the initial stage, and at that time few people trusted it can be improved to a book's size in less than 100 years. In 1980s, mobile phones were in the initial stage, people also doubted its performance and security at that time. There are always some weaknesses of a new technology like the darkness before the dawn. But nothing is too fantastic to come true, only if it complies with the laws of nature.

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