Theoretical Consideration of Current Trend and Direction of Development of Wireless Power Transmission Technology

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ABSTRACT

Wireless power transmission technology is widely used in various areas of our lives, including phone charging and automobile Wireless charging, and its role is increasing.

In this paper, based on the comprehensive consideration of the wireless power transmission technology currently being studied in the world, the scientific and technical problems to be solved in this field are described.

1. Introduction

Wireless power transmission technology refers to a technology that can transmit power without using an electric line. It's incredible to send power without electricity, but we already have wireless technology. If such a wireless power transmission technology is realized, the attention is focused because the ripple effect is very large. If we can deliver more than a few tens of W of power wirelessly, the model of IT technology is expected to change drastically. Especially in the case of the portable IT machine, which is the core of the wireless communication technology, communication is freely performed wirelessly through the network such as mobile communication and wireless LAN. However, since a charged battery is used for the power supply of the machine, the interest of the wireless power source device will increase. Various wireless power transmission technologies have been developed so far, but they have not been practical use except for some non-contact inductive coupling methods.

Figure 1. Use in wireless charging field

For example, in the past, researches on using microwaves such as 5.8GHz to transmit large power of several tens of W or more have been conducted, but they are not actively used due to their effects on the human body. However, the non-radiated high power wireless transmission technology proposed by Marin Soljacic has become a promising technology since it is announced that high power transmission of 60W is realized at a distance of 2m using a 10MHz carrier.

2. Technology trend of wireless power transmission

The wireless power transmission technology that wirelessly transfers electric energy to a machine that requires power is already used in the 1800s as an electric motor or transformer using an electromagnetic induction principle. After that, a method of transmitting electric energy by radiating electromagnetic waves such as radio waves and lasers was also attempted.

Wireless shavers that we commonly use are charged with electromagnetic induction principles.

These different types of energy transmission methods are classified as shown in Table 1 based on the transmission distance.

Figure 2 shows the transmission distance, output and application fields for various wireless power transfer methods.

The magnetic induction method is applied to applications requiring relatively high output at distances of less than 1 cm, and the radiation method using an antenna is applied when a relatively small output is required at a distance of 10 m or more.

Table 1. Major functional changes related to 3GPP A-GNSS

	Contactless transmission (magnetic induction)	Near field transmission (Radiative)	Near field transmission (Magnetic resonance)	Long-range transmission (electromagnetic waves)
Transmission	A few mm	A few m-around	A few m-	Several kilometers
frequency	125 kHz, 13.56	Tens of MHz	Within 10 MHz	GHz (5.8 GHz)
Transmission	Number W	Tens of mW	Tens of W	N / A (high power)
Technology	Maturity	developing	developing	N / A
standardization	Establishment of	N / A	Under	N / A
Module / System	Low price	N / A	High price	N / A
Miniaturization	possible	N / A	Miniaturization	N / A
Human Hazard	none	has exist	Claim no	has exist
Field of Use	Traffic Card	RFID electronic	Dozens of	Space development
problem	Short	Human Hazard	Transceiving	Human Hazard

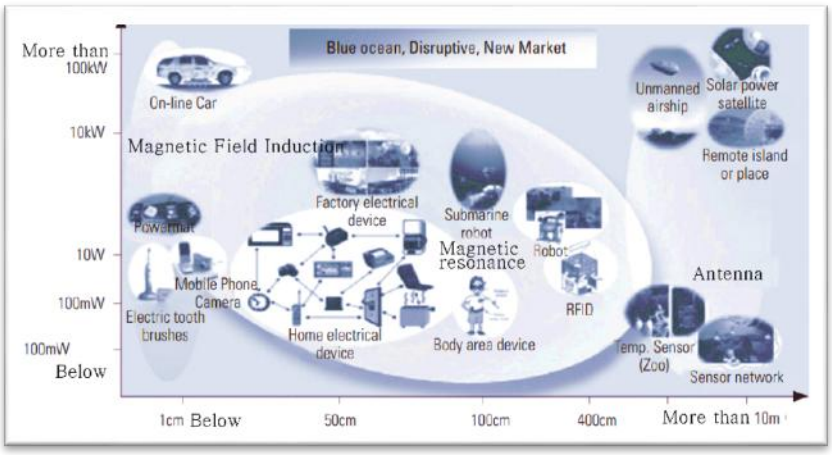

Figure 2. Transmission distance, output and application fields by various wireless power transmission methods

2.1 Long-range transmission technology (electromagnetic waves)

Electromagnetic wave method is a technology that transmits high power energy by using a high frequency of several GHz at a long distance, and it is expected to take a lot of time until practical use due to technical limitations. The electromagnetic wave method is generally used in long distances over several km with direction to specific target points, and it was used for the research of NASA's 'Sun Power Satellite (SPS)' project and Canada's SHARP project in the 1960s.

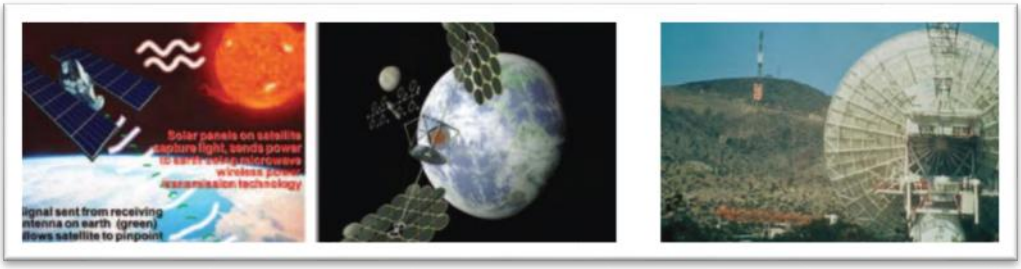

Figure 3. Long-range transmission technology by electromagnetic wave

The SPS project is to generate power through solar cells from satellites orbiting the earth and transmit it in the form of radio waves to the ground. The SHARP project is to radiate energy from the microwave antenna array on the ground in high frequency. Received by rectenna (rectifying antenna) installed in the rear of the plane is to be converted into DC power. However, electromagnetic waves require very large transmit/receive antennas, and because the power transmitted by wireless is absorbed in the air or disturbed by moisture, it is very inefficient and cannot be supplied with power.

2.2 Near Field Transmission Technology (Radiative)

Near field transmission technology that delivers energy within a few meters is a method of delivering a relatively small output based on electromagnetic radiation. (Powercast LLC) has introduced a technology that can wirelessly deliver power to low-power electronics such as radio receivers, RFID, and edible medical equipment using RF radiofrequency. These techniques have a drawback that the charging time is quite long in the case of machines requiring relatively high power because of the omnidirectional nature which is characteristic of electromagnetic radiation. To solve this problem, increasing the output of the transmitter causes environmental factors that harm the human body. Therefore, it is not appropriate as a wireless power transmission method for a wide range of applications.

2.3 Contactless transmission technology (magnetic induction)

The magnetic induction method is a method of charging the battery for generating an induced current in the two coils which are in contact with each other by several mm. It applies to small machines below 3W and shows an efficiency of 60 ~ 90%, but the distance between charger receiver is very short, several mm, heat generation is high, and charging efficiency varies greatly depending on the charging location.

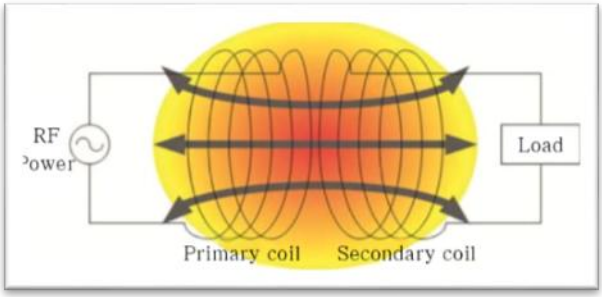

Figure 4. Magnetic Induction Wireless Power Transmission

2.4 Near Field Transmission Technology (Magnetic Resonance)

Magnetic resonance method is a technology that uses the attenuated wave coupling phenomenon in which electromagnetic waves move from one medium to another through the near field when two media resonate at the same frequency.

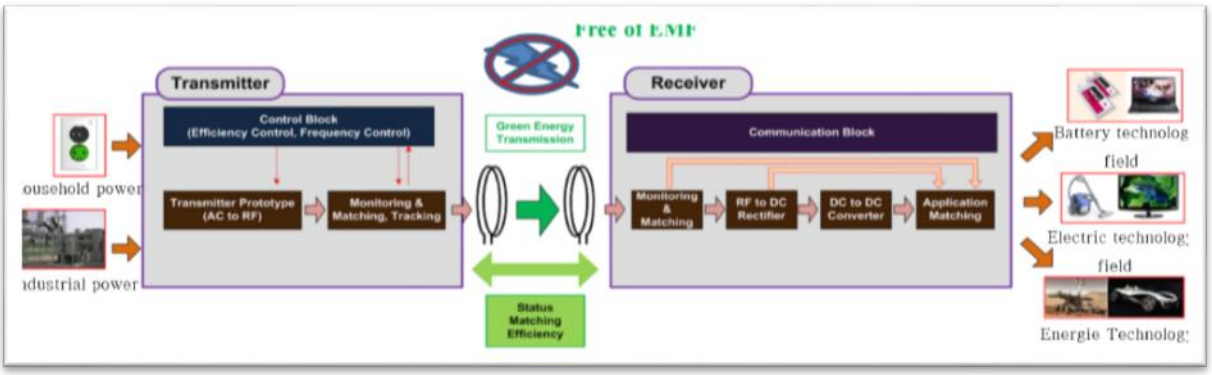

Figure 5. Magnetic resonance wirelesses power transmission core technology

Unlike conventional long-range electromagnetic radiation, this technology utilizes a concentrated field effect by transmitting at a short distance compared to the frequency/wave which is used and matches the resonant frequency of the transmitter/receiver in addition to the conventional magnetic induction. 'Nonradioactive mid-range energy transfer' is realized. The new wireless

transmission technology can deliver energy at greater efficiency than electromagnetic radiation at greater distances than conventional electromagnetic induction. At present, this technology is in the early stages of development, and the size of the wheel for transmitting/receiving wireless power is still very large, with a radius of 50cm. Therefore, there is necessary to have a technique for reducing the size of the transmission and reception wheel while maintaining resonance. In particular, for high-efficiency power transmission, it is basic to make the coupling of the transmission and reception wheels fat together with the resonance condition. When installed in the home or office, a point where the coupling is very weak is generated. Thus, techniques for improving this also become necessary. Also, when the types and sizes of machines used vary, it is very difficult to satisfy the entire resonance condition with a single power supply. Therefore, technology development is also required to overcome this.

3. Development Trend

In June 2007, MIT announced that it has succeeded in researching wirelessly supplying the level of power needed to run a portable PC, although the transmission range is limited. The system used by MIT's demonstration experiments consisted of a power source and a 60W bulb that was not physically connected, and the experiment was part of a research project called WiTricity (Wireless Electricity). WiTricity technology sees the time of practical use for 3 ~ 5 years and plans to transfer technology to the company for practical use. When WiTricity is installed in most household appliances, it can be powered from WiTricity without batteries.

The Intel Company is working on three types of technology to transfer power wirelessly. WISP technology that transmits power wirelessly based on WARP technology that acquires energy by radio waves in the surrounding environment such as TV radio waves, and RFID technology of UHF band and third transmit large power of several tens of W wirelessly at a distance of several meters. WREL technology. In the case of WREL technology, Intel has published a study using MIT's resonant wireless power transfer technology. Intel has installed a technology that can safely and efficiently deliver power wirelessly to portable computers, allowing the battery to be charged by approaching a few tens of centimeters away from the transmitting resonator.

-One of the companies has developed a power transmission system that enables high-efficiency, solid-state power transmission, with small pieces capable of transmitting/receiving quantity with a module size that fits into a mobile phone. The maximum efficiency of this product is 70%, which is very high and 2.5W of power transmission is possible. The company has begun developing a contactless rapid charging system that can shorten the charging time. This system combines a high-efficiency transmission wheel with a 70% power transmission efficiency and a lithium-ion secondary battery that can be rapidly charged, allowing a non-contact and short-term charging.

The transmission power is about 15W, and mainly the charging of the handset is used. Device ID certification is also installed to prevent false charging of products with different charging voltages. Besides, the installation of metal detection prevents accidents due to overheating by installing a function to stop transmission when other materials fall into the charger and increase safety.

At the University of One Country has developed synthetic resin boards that can transmit power without contact. Since it has a function of detecting the position of the object placed on the plate, power can be selectively related only to an object placed on the plate. The power that can be taken by the machine is up to 29.3W, the power transmission efficiency is up to 62.3%, the plate size is about A4, the thickness is 1mm, and the weight is 50g. The range of power supply can be extended by flattening this power transmission board.

Electromagnetic induction was used as the power transmission method, and when the object is brought close to the power transmission plate, the induction of the position detection coil is changed by magnetic coupling with the coil of the object, and the change amount is used for the position detection. Electric power is supplied to the coil for power supply at the position where it reads into the semiconductor triploid element connected to the coil and detected the change of induction. The power transmission plate was fabricated using organic superconductor technology, MEMS technology, and printing technology, and consisted of stacked layers of power supply coil plate, MEMS switch plate, position detection coil plate, and organic TFT plate.

One research institute has developed a proprietary wireless charging technology that can charge a handset or a portable computer without a charger. This technology connects the power to PCs and TVs in your home, allowing you to charge machines (phones, handhelds, etc.) within 1m without electricity. Figure 6

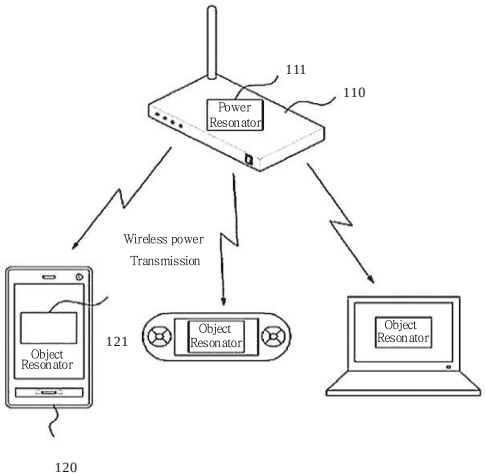

Figure 6. Proprietary wireless charging technology

This technique used a technique called near-field magnetic resonance to charge batteries at a long distance. This method is to adjust the resonance frequency of the same MHz band in which coils are installed in different machines. For example, if the resonant frequency of the intelligent handset is 10 MHz, the resonant frequency of the power supply to the electric power is also set to 10 MHz, and several machines can be charged at the same time.

One research institute has developed a technology that can wirelessly charge multiple facilities such as an intelligent handset and a portable computer with one charger.

The wireless charging method developed by the research institute is a magnetic resonance method, and since the power is transmitted using the resonance frequency of the magnetic field, the charging distance is longer than that of the magnetic induction type which is only 30cm maximum. Also, to minimize the impact on peripheral devices and energy loss, the power from the power resonator is intended to be concentrated in the charger system. The power not transmitted to the machine to be charged is intended to be stored and reused using the charging module, minimizing the impact on the waste energy and peripheral equipment. Also, the world's lightest 3D glasses with wireless charging have been developed.

4. Application Products

Most users want the charging of the equipment being used to be simpler and more convenient using wireless power transmission technology than charging by electric wire. The various applications using wireless power transfer technology are briefly described here.

Figure 7. Various application products using wireless power transmission technology

4.1 Car Wireless Charging

Research on applying wireless charging to automobiles since 2011

Figure 8. Car wireless charging

• Plugless, Momentum Dynamic, HEVO wireless charging system applied test

• Plugless currently sells EV wireless charging system

- ✓ Type: Magnetic induction, Power: 7.2kW max, Transmission distance: 10cm
- ✓ Resonator (cm2): 56x47 (TX), 84x41 (RX)

• Momentum Dynamic is currently piloting a wireless charging system at Google headquarters.

- ✓ Type: Magnetic induction, Power: 3.3kW (Maximum 200kW possible)

• HEVO is also currently piloting the wireless charging system at Google headquarters.

- ✓ Type: Magnetic induction, Power: 1.5kW

4.2. Electric bicycle, drone wireless charging system

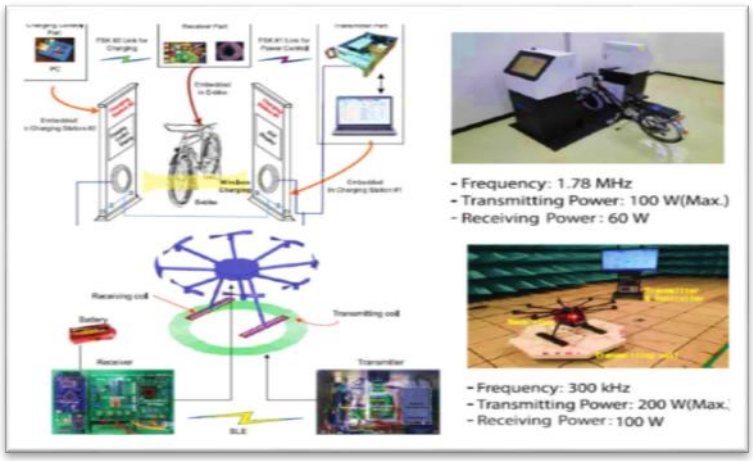

Figure 9. Electric bicycle, drone wireless charging system

4.3. 3D Wireless Charging System (E-Cup)

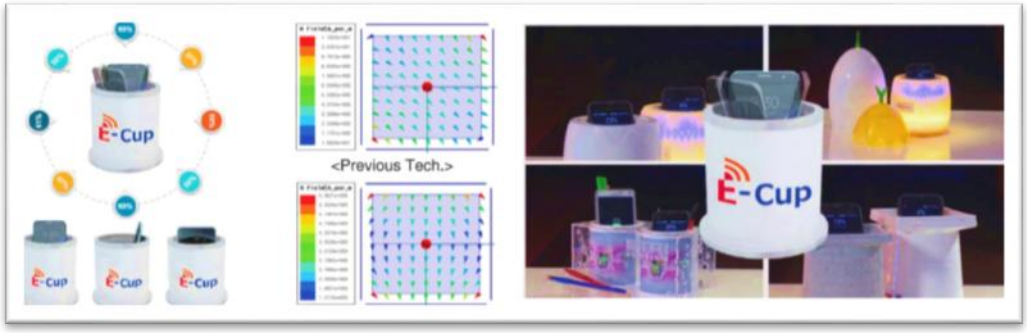

Figure 10. 3D Wireless Charging System (E-Cup)

5. Conclusion

Wireless power transmission technology is a cutting-edge technology with a very high ripple effect, changing the model of technology.

As described in the text, wireless power transmission technology is composed of contactless transmission (magnetic induction), near field transmission (radial), near field transmission (magnetic resonance), and long-range transmission (electromagnetic wave).

A comprehensive summary of the current technology is as follows.

First, there are physical limits that limit the diameter-to-diameter transmission distance and degrees of freedom.

Second, there are problems of efficiency and frequency change caused by distance, load change.

Third, it can only be served in the limited space where the transmitter is present.

Fourth, the user's attention is attracted, but the user has not yet satisfied in terms of convenience and efficiency.

Therefore, if the utilization effect of wireless power transmission technology is higher and this technology is widely used in various sectors of the people's economy, it is important to raise the advantages of every method and overcome the disadvantages to develop a practical and reasonable wireless power transmission technology.

From this point of view, the resolution of the following scientific and technical content is an important issue.

First, 3D radio energy transmission technology for high degree of freedom should be established.

Second, a new concept of transmission and reception circuit technology and automatic freedom matching should be realized to establish the transmission frequency and efficiency.

Third, magnetic field strength, distributed control, and non-radiated resonance technology must be realized to extend the transmission distance and overcome the interference problem.

Fourth, the service area should be extended by the transfer of energy between machines.

If more advanced wireless power transmission technology is developed and actively used on the basis where such scientific and technical problems are solved, the electric wires are removed in almost all branches of the economy and life, and household appliances and machines are located along the length of the electric wire. I think that if we can move and use freely in the territory where electric energy is transmitted without being determined separately, a great change will occur in our lives.

It is hoped that if the scientists and technicians in this branch work together to make further improvements in current wireless power transmission technology. Further achievements will occur in this branch.

6. References

[1] Z. M. Zhao, Y. M. Zhang, K. N. Chen. New progress of magnetically-coupled resonant wireless power transfer technology [J]. Proceedings of the Csee, 2013, 33(3):1-13.

[2] In-Soo Suh, Jedok Kim. Electric vehicle on-road dynamic charging system with wireless power transfer technology[C]// Electric Machines & Drives Conference (IEMDC), 2013 IEEE International. IEEE, 2013.

[3] K. Song, C. Zhu, Y. Li. Wireless power transfer technology for electric vehicle dynamic charging using multi-parallel primary coils[J]. Proceedings of the Csee, 2015, 35(17):4445-4453.

[4] Hao Jiang,, Junmin Zhang,, Di Lan,. A Low-Frequency Versatile Wireless Power Transfer Technology for Biomedical Implants [J]. IEEE Transactions on Biomedical Circuits & Systems, 7(4):526-535.

[5] Samanta S, Rathore A K. Wireless power transfer technology using full-bridge current-fed topology for medium power applications [J]. 2016, 9(9):1903-1913.

[6] COST Action IC1301 Team, Nuno Borges Carvalho, Apostolos Georgiadis. Europe and the Future for WPT : European Contributions to Wireless Power Transfer Technology[J]. IEEE Microwave Magazine, 2017, 18(4):56-87.

[7] K. Ota, H. Mizutani, R. Ishikawa. Bi-directional wireless power transfer technology for wireless sensor/power networks[C]// Antennas and Propagation in Wireless Communications (APWC), 2013 IEEE-APS Topical Conference on. IEEE, 2013.

[8] T. Campi, F. Dionisi, S. Cruciani. Magnetic field levels in drones equipped with Wireless Power Transfer technology[C]// 2016 Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC). IEEE, 2016.

[9] Liu, Xun. Qi Standard Wireless Power Transfer Technology Development Toward Spatial Freedom [J]. IEEE Circuits & Systems Magazine, 15(2):32-39.

[10] K. N. Mude, M. T. Outeiro, A. Carvalho. In-motion wireless power transfer: Technology, infrastructure, challenges and market scenario[C]// 2017 IEEE International Conference on Industrial Technology (ICIT). IEEE, 2017.

[11] Ya-Feng Deng, Quan-Lai Li, Jian Li. STUDY ON MINIATURIZATION ELECTROMAGNETIC RESONANT WIRELESS POWER TRANSFER TECHNOLOGY *[C]// 2015 International Conference on Material Engineering and Mechanical Engineering (MEME2015). 2016.

[12] Byung Chan Kim, Seong-Min Kim, Jung-Ick Moon. Shielding for reduction of magnetic field strength from docent robot being charged by wireless power transfer technology[C]// 2015 IEEE Global Electromagnetic Compatibility Conference (GEMCCON). IEEE, 2015.

[13] Tanik, Murat M. EDITORIAL WIRELESS POWER TRANSFER TECHNOLOGY AND EV APPLICATION [J]. 2011, 15(3):1-2.

[14] Xia, Qingfeng, Yan, Longyang. Application of wireless power transfer technologies and intermittent energy harvesting for wireless sensors in rotating machines[J]. Wireless Power Transfer, 3(02):93-104.

[15] Francesco Carobolante. Resonant wireless power transfer technology & integration roadmap[C]// 2015 IEEE Custom Integrated Circuits Conference - CICC 2015. IEEE, 2015.