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Analysis of Wireless Power Transfer Systems for Microcontroller-Based Systems

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Abstract— **This paper discusses wireless power transfer technologies for low-power devices such as Internet of Things (IoT) sensors, medical implants, and portable electronics. The main transmission methods are covered, including inductive coupling, resonant inductive coupling, radio frequency, and ultrasonic transmission. Particular attention is paid to resonant inductive power transfer at frequencies of 100–300 kHz with a range of up to 2 meters, which is the most promising for compact devices. Examples of implementations, such as WiTricity and Powercast, are given, as well as calculations of the transmission efficiency.**

Keywords— ***Wireless Power Transfer, Iot, Resonant Inductive Coupling, Medical Implants, Radio Frequency Transmission, Ultrasonic Transmission, Energy Efficiency, 5G, Safety, Standards.***

I. Introduction

The issue of wireless energy transmission is a hot topic given the rapid development of the Internet of Things (IOT), 5G networks, portable electronics and autonomous sensor systems. These technologies are being actively implemented in such industries as medicine, industrial monitoring, ecology and agricultural technology. In all these cases, the most important requirements are compactness, energy independence and the ability to operate in remote or hard-to-reach places without frequent maintenance.

One of the strategically important tasks is to provide energy to small-sized measuring probes, which consume low power within 5 W, via wireless channels. The use of wires in such systems limits mobility and complicates installation. At the same time, traditional batteries add weight, require regular recharging or replacement, and create an environmental burden when disposed of.

Wireless energy transmission not only reduces the weight of devices and increases their mobility, but also significantly simplifies their design and maintenance, especially when installed in sealed, sterile or aggressive environments. In medicine, this opens the way to the creation of fully implantable devices that do not require surgical replacement of the power source [1], [2], [3].

II. History of the Development of Wireless Power Transmission

The idea of wireless energy transmission dates back to the work of Nikola Tesla in the late 19th century. In 1899, Tesla conducted experiments at the Wardenclyffe Tower, where he attempted to transmit energy through the air over long distances. Although the project failed, it marked the beginning of research in this area [2] .

Later, in the mid-20th century, technologies for transmitting microwave energy over short distances were developed. In 1964, William Brown first demonstrated the possibility of transmitting energy using microwaves, successfully powering an unmanned helicopter at a distance of several meters. Since then, two main directions of wireless energy transmission have developed: inductive and radio frequency methods.

III. Characteristics and Features of Wireless Power Transmission

Wireless energy transmission can be accomplished in several ways:

- Inductive coupling - used for short distances (millimeters - centimeters);
- Resonant inductive coupling - allows to increase the working distance up to meters;
- Radio frequency transmission - provides long range but requires complex radiating systems;
- Optical transmission - uses lasers, applicable for specialized tasks;
- Ultrasonic transmission is a promising method for transmitting energy through human tissue.

The most promising method for small-sized probes is resonant inductive energy transfer at frequencies of 100–300 kHz with a range of up to 2 meters.

IV. Examples of Implementation of Wireless Energy Transmission Systems

- WiTricity Prototype: 60W power transmission over 2m using resonant coils.
- Powercast PCC110: RF charging for low power sensors (~1mW at 1m).

- uBeam : Ultrasonic energy transmission up to 3m, aimed at mobile devices.

Brief calculation:

To transmit 2 W at 1.5 m with an efficiency of 30%, it is necessary to transmit:

P before=2 / 0.3≈6.7 W

A frequency of about 200 kHz is selected, coils with a diameter of 30–50 cm, 10–20 turns, and a capacitor capacity of about 100–500 nF to adjust the resonance.

V. Prospects for the development of wireless energy transmission technologies

Interest is expected to grow in the following areas:

- Intelligent implantable devices powered by an external field;
- Ultrasonic energy transfer for biomedical applications;
- Development of long-range resonant inductive systems;
- Application of magnetic and acoustic metamaterials to enhance focusing;
- Creation of wireless charging networks for premises and medical institutions.

The development of adaptive focusing technologies based on phased array coils or acoustic emitters will increase the safety and efficiency of energy transmission.

TABLE I.
ASSIFICATION OF WIRELESS POWER TRANSMISSION BY RANGE (BASED ON ITU DOCUMENTS)

Energy Transfer Zone	Range	Operating frequency range	Application
Near (contact)	2-10 mm	100 kHz – 30 MHz	Wireless charging for smartphones, watches, medical implants
Average	0.1–2 m	6.78 MHz; 13.56 MHz; 27.12 MHz (etc.)	Charging wearable devices, IoT probes, sensor networks
Far	Up to kilometers	915 MHz; 2.45 GHz; 5.8 GHz	Power transmission for UAVs, remote sensors, specialized power systems

Brief explanations:

- Short-range transmission is often used in strong magnetic coupling mode (inductive transmission).
- Medium transmission involves the use of magnetic resonance or electromagnetic waves, while providing mobility.
- Long-distance transmission requires strict compliance with electromagnetic compatibility standards and sanitary restrictions.

VI. Prospects of use

1. Future Technologies: With the development of 5G and the increasing demand for IoT devices, there is a need to efficiently and securely transmit power over longer distances. This will open up new opportunities for wireless power systems in areas such as automation, smart homes and industry.
2. Medical field: Wireless power will be actively used for medical implants such as pacemakers and neurostimulators, which will operate without the need to change batteries. The use of ultrasonic or resonant wireless transmission in medicine also has great prospects, especially in wireless charging of small devices.
3. Space Technologies: In the future, wireless energy transmission technologies can be adapted for use in space, where traditional methods of energy transmission (wires) are not applicable due to the lack of wired connections. The development of long-range wireless energy sources will make it possible to power spacecraft and equipment on other planets.
4. Sustainability and Safety: As wireless power transmission becomes more popular, safety standards such as radiation and electromagnetic compatibility restrictions remain an important consideration. Developing new technologies that meet these standards will be important for the widespread adoption of wireless power.

Thus, wireless energy transmission not only has many current applications, but also huge potential for the future. Continued research and development in this area promises revolutionary changes in a number of industries, from medicine to automation of industrial processes.

VII. Conclusions

Wireless power transmission continues to grow rapidly, especially with advances in the Internet of Things (IoT), medical technology, and autonomous devices. For small systems such as measurement probes, efficiency and portability are especially important. Using wireless power in the 100 kHz to 2.45 GHz frequency range is a realistic and efficient way to solve power problems in the 1–2 meter range.

Technologies such as resonant induction and phased array coils can provide the necessary parameters for transmitting power over such distances while minimizing losses and providing the necessary mobility. However, to successfully implement these technologies in small devices, many factors must be considered, including specific frequency ranges, safety, and regulatory compliance.

References

[1] ICNIRP Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). https://www.icnirp.org/

[2] IEEE C95.1-2019: IEEE Standard for Safety Levels with Respect to Human Exposure to Electric , Magnetic , and Electromagnetic Fields . https://standards.ieee.org/

[3] International Telecommunication Union (ITU) Recommendations on Wireless Power Transfer . https://www.itu.int

[4] FDA Regulation Guidelines for Diagnostic Ultrasound Devices . https://www.fda.gov

[5] Kurs , A., Karalis , A., Moffatt , R. et al . Wireless Power Transfer via Strongly Coupled Magnetic Resonances . *Science* , 317(5834), 83–86, 2007.

[6] International Telecommunication Union (ITU) - Reports ITU-R SM.2303-2 and ITU-T Q.3949, " Systems for Wireless Power Transmission (WPT)"

[7] Sample , A.P., Meyer , D.A., & Smith , J.R. Analysis , Experimental Results , and Range Adaptation of Magnetically Coupled Resonators for Wireless Power Transfer . *IEEE Transactions on Industrial Electronics* , 58(2), 544–554, 2011.