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# Research Progress on the Impact of Coil Offset on Power in Wireless Charging and Countermeasures

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**Abstract.** Wireless charging, as an important technology, is constantly being applied in people's lives. However, there is still the problem that coil offset affects power transmission. Currently, solutions such as multi-coil array adaptive compensation are adopted, which to a certain extent increase the transmitted power and reduce energy loss, providing more application fields for wireless power transmission technology. Based on the development of wireless charging technology, this paper sorts out the principles of wireless power transmission and some studies on coil offset from 2010 to 2025. At present, the research on the problem of coil offset still has limitations in terms of single research scenario, theoretical model deviation from reality, and imbalance between demand and cost.

**Keywords:** Wireless Charging; Wireless Power Transmission; Coil Offset Technology; Transmission Power.

## 1. Introduction

With the rapid innovation and development of technology, more and more people are beginning to use electronic devices such as mobile phones, drones and electric vehicles. The rise of these devices has brought many opportunities for wireless power transmission. Wireless power transmission can carry out electrical energy transmission without the connection of transmission lines, which improves the safety and convenience of charging and thus is widely applied.

In 1831, Michael Faraday discovered the phenomenon of electromagnetic induction, laying the theoretical foundation for the transmission of wireless power. In 1891, Nikola Tesla achieved short-distance wireless power transmission through Tesla coils, but failed to solve the problem of coil alignment [1].

In 2007, the WiTricity experimental team used magnetic coupling resonance technology for the first time to light a 60-watt light bulb at a distance of 2 meters [1]. In 2010, the Wireless Power Alliance released the Qi1.0 standard, which uses electromagnetic induction technology to generate an alternating magnetic field of 110-205kHz through the primary coil, and the receiving circuit is rectified and filtered to charge the battery [3]. In 2014, the Academy of Korean Sciences demonstrated a new long-distance wireless power supply technology and developed a dipole coil resonance system, which provides a wider range of wireless sensing areas and can transmit up to 5 meters, which is a great improvement compared to the past [4]. In 2025, researchers will make breakthroughs in materials science. Electromagnetic metamaterials are embedded around the transmitting coil to enhance magnetic field aggregation, which effectively improves the efficiency of lateral offset [5].

At present, wireless charging technology inevitably has the problem of coil offset in every aspect, and coil offset will lead to a significant decrease in transmission efficiency, which restricts the development of wireless charging technology. In response to the above problems, this paper sorts out the existing coil offset technology.

## 2. Overview of Wireless Power Transmission Technology

Wireless charging technology has developed into many categories based on different ways of power transmission. The more common ones include electromagnetic induction type, magnetic coupling resonant type and microwave type. This chapter will introduce the advantages and disadvantages of these three types of transmission methods as well as their working principles.

The advantages and disadvantages of wireless charging technology are mainly reflected in aspects such as energy transmission distance, transmission efficiency, coil offset resistance, complexity of circuit structure, and construction cost. The advantages and disadvantages of various transmission methods of wireless charging technology are shown in Table 1.

**Table 1.** Advantages and disadvantages of the three power transmission methods

| Transmission Mode | Advantages | Disadvantages |
|---|---|---|
| Electromagnetic induction type | High charging efficiency at close range | Short charging distance |
| | The technology is relatively mature | The coil has poor anti-offset characteristics |
| | Low cost and simple structure | |
| Magnetic coupling resonant type | Relatively high charging efficiency | Resonant frequency mismatch reduces efficiency |
| | The transmission distance is relatively long | The cost is high and the structure is complex |
| | Good anti-offset characteristics | |
| Microwave type | Long charging distance | The more severe the energy diffusion over long distances |
| | Not affected by direct occlusion | High cost and extremely high structural complexity |

The principle of electromagnetic induction wireless charging is based on Faraday's law of electromagnetic induction. It generates an induced electromotive force in the receiving coil through an alternating magnetic field. The workflow diagram is shown in Figure 1.

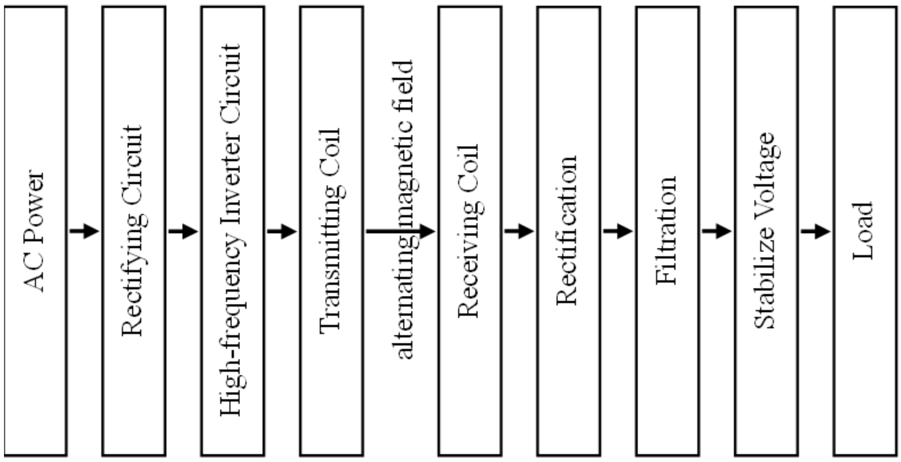


**Figure 1.** Workflow diagram of electromagnetic induction wireless charging system

The principle of magnetically coupled resonant wireless charging is based on electromagnetic resonance coupling. The transmitter coil and receiving coil form strong coupling at the same resonant frequency, and high-energy transmission is achieved through the near-field magnetic field [7]. The workflow diagram is shown in Figure 2.

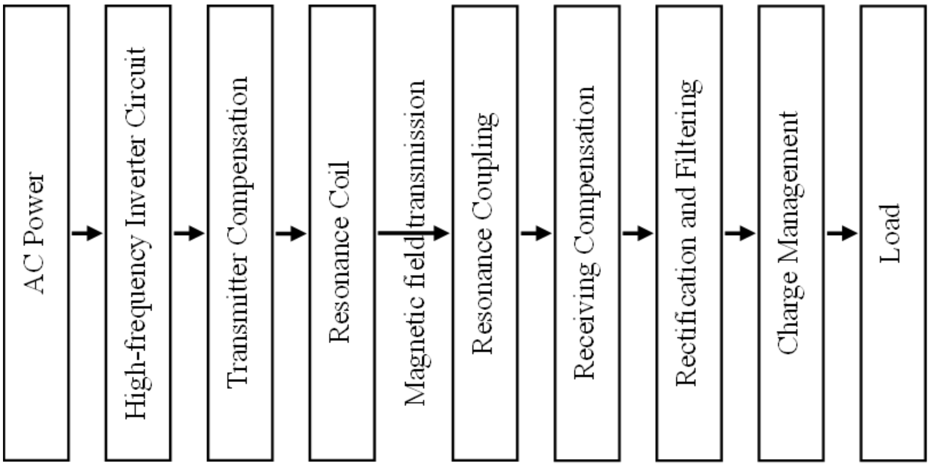


**Figure 2.** Workflow diagram of electromagnetic induction wireless charging system

The principle of microwave wireless charging is to utilize the directional radiation characteristics of electromagnetic waves in the microwave frequency band. Through the transmitting antenna, electrical energy is converted into microwaves, and at the receiving end, microwaves are converted into electrical energy through the receiving antenna, and then rectified and converted into direct current [8]. The workflow diagram is shown in Figure 3.

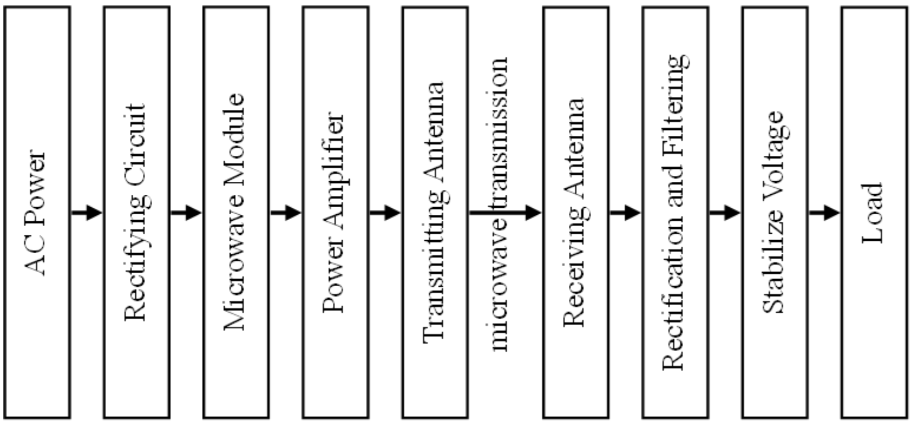


**Figure 3.** Workflow diagram of electromagnetic induction wireless charging system

## 3. The main applications of coil anti-offset technology

Wireless charging technology was strictly limited by distance in its early development stage. When the center position of the coil deviated or the distance was large, the power would drop significantly. To address this issue, people have stabilized the transmission power through innovative dynamic control algorithms for coil structures and other improvements in materials and other aspects. Coil anti-offset technology is closely related to wireless charging technologies in many fields. This chapter will discuss the applications of coil anti-offset technology in various aspects.

In terms of wireless charging for wearable devices and mobile devices, some chargers adopt the Qi2.0 standard, which utilizes magnetic absorption and self-coordination technology to reduce the offset caused by oscillation during the movement of charging devices and lower the energy loss resulting from the offset.

In the field of wireless charging for electric vehicles, Yang Yang et al. proposed a biorthogonal DD type coil magnetic coupling structure, which not only enhances the anti-offset capability of the wireless charging system through the coupling and complementarity between coils, but also is compatible with both static and dynamic wireless charging scenarios [9].

In terms of wireless charging of drones, Chen Wanqi connects three sets of circular coils with the same current direction in series as transmitting coils to improve the anti-offset capability, and adopts a receiving coil with a horizontal spiral structure to achieve the co-type and modularization of the system. At the same time, thin and light nanocrystalline strips are selected instead of traditional cores, which reduces the weight of the receiving end and reduces the energy consumption of UAVs [10].

In the field of industrial automation, the introduction of wireless charging is mainly aimed at reducing the downtime of machinery and ensuring its automatic charging. Li Zhizhong et al. proposed a diagonal cross-solenoid magnetic coupler. Through magnetic simulation verification, theoretical analysis and experimental verification, it was proved that this structure can effectively enhance the multi-directional anti-offset capability of the wireless charging system [11].

The essence of the coil anti-shift technology of wireless charging is to break through the space requirements of precise alignment, so that the transmitter of wireless charging can actively adapt to the receiver. The application of this technology has penetrated from electronic devices to industry, medical and transportation, and has continued to evolve to bring convenience to people.

## 4. Coil structure optimization

Under the condition of a fixed transmission distance, changes in the relative positions of the transmitting coil and the receiving coil will cause lateral offset of the coil, thereby affecting the transmission efficiency of the entire system. When the coils of energy transmission are not aligned, it will affect the mutual inductance between the coils, and the larger the displacement between the coils, the smaller the value of the mutual induction, resulting in a significant reduction in the overall transmission power and efficiency. The research on improving the anti-offset characteristics of the system mainly focuses on the resonant compensation topology, control strategy and coil structure, among which the design of the coil structure is a very important research direction. This chapter will analyze the influence of some existing coil structure designs on the anti-offset characteristics of wireless charging and the development process of related technologies.

### 4.1. Development of multi-coil array structure

As an effective solution to enhance the anti-offset characteristics of wireless power transmission, the multi-coil array mainly arranges multiple coils in a specific pattern and uses the superposition of the magnetic fields of the coils to expand the effective charging area, thereby reducing the power fluctuation caused by the offset of the receiving coil position.

To verify that multi-transmitter coils can effectively enhance the anti-offset capability of coils during wireless power transmission, Huang Meiling used circuit theory to model and analyze single-transmitter single-receive and multi-transmitter single-receive wireless charging systems. Then, she designed and built the hardware circuits. Through the comparison of the two, she verified the feasibility of the theory and simulation results, and confirmed the effectiveness of multi-transmitter coils in enhancing the anti-offset capability of wireless power transmission system coils [12].

In 2012, Keishi Miwa et al. from Japan proposed the idea of transmitting coil arrays, using a 1×3 coil array, which expanded the effective energy transfer area of the coil in the x-axis direction and improved the alignment fault tolerance of the coil in the system, but there is still a significant efficiency attenuation in the y-axis direction. Then in 2013, they proposed a 2×2 array, which improved the anti-offset ability of the coil in the x-axis and y-axis directions, and further expanded the energy receiving area on the original basis, so that the receiving coil had a greater degree of freedom in space, and realized the improvement of the anti-offset ability in all directions within the plane. When the receiving coil moves in the plane, the system can transmit energy by activating coils at different positions, which nearly doubles the energy receiving area compared to the 1×3 coil structure, but the magnetic field interference between the coils will cause the efficiency fluctuation in the edge area of the coil [6].

In 2014, S. Abdollah Mirbozorgi et al. improved the original 2×2 matrix and adopted a parallel multi-coil array structure based on syntony. They used printed circuit boards to make coil units and optimized them in terms of volume and weight. This design utilized the resonant coupling between coils to counteract the interference of magnetic fields, keeping the efficiency fluctuation within a small range. However, the parallel connection method imposed extremely high requirements on the consistency of coil parameters [6].

In 2015, Farid Jolani et al. connected the 2×2 array units independently, so that the coils of the four arrays resonated uniformly, making the magnetic field distribution in space more uniform. Through testing, the transmission efficiency of some areas above the plane can reach more than 60%, but there are also some areas where the transmission efficiency fluctuates greatly [6].

In 2018, Yeran Liu et al. of Southwest Jiaotong University used a double-stacked DD coil array, which can generate a magnetic field without dead points compared to traditional coils that will have energy blank areas at the intersection of magnetic fields.

At the same time, they also proposed an optimized current control method, which can dynamically adjust the direction and proportion of the transmitting current when the receiving coil moves above. However, this rectangular array can only improve the stability and transmission efficiency in the x-axis direction, and has limited optimization in the y-axis direction [6].

In conclusion, the existing technology has proved that the multi-coil array structure is effective in enhancing the anti-offset capability of the coils in radio power transmission technology. In response to the demands for transmission efficiency in different directions, researchers have developed various multi-coil array structures, making radio power transmission technology more practical. However, the core technology of multi-coil arrays still faces many challenges at present. Firstly, as the scale of the array continues to expand, the logical complexity of coil switching is constantly increasing, and at the same time, the hardware cost is also rising. Secondly, mutual inductance coupling among multiple transmitting coils can cause the resonant point to shift. If the distance between multiple transmitting coils is insufficient, the mutual inductance effect will cause energy to circulate within each coil, resulting in energy loss and significantly reducing the transmission efficiency and power stability.

### 4.2. Design of special-shaped coils

In the wireless power transmission system, the transmission efficiency is related to the performance of the system, and the traditional round and square coils show disadvantages in terms of anti-offset ability and space utilization in practical application scenario. To address the deficiency of traditional-shaped coils in terms of anti-offset capability, researchers have begun to explore the impact of coils of different shapes on transmission efficiency, in order to meet the performance requirements of wireless charging systems in various usage scenarios.

In order to obtain a better wireless charging coil shape and meet higher transmission efficiency, Huang Jianli established a coil model of square, octagonal, hexagonal, circular and rounded rectangle through Maxwell-3D simulation software, and obtained the magnetic field distribution around the coil. Through the simulation results, it is concluded that the self-inductance of the rectangular coil is the largest, the magnetic field distribution of the circular coil is the most uniform, the quality factor of the regular hexagon and regular octagon is the highest, and the rounded rectangle combines the advantages of various shapes and has a more balanced performance in all aspects. Then, the rounded rectangles were divided into concentric circle rounded rectangles and rounded rectangles with the same radius for simulation tests. It was concluded that, under the condition of ensuring that the self-inductance meets the power requirements, the concentric circle rounded rectangle matrix should be given priority [6].

It is not only the shape of the coil that affects the transmission efficiency of radio energy, but also the magnetic flux density produced by different radii, which also affects the transmission efficiency of the magnetic field, and the optimal radius value is related to the transmission distance. To quantify the relationship between the optimal radius of the transmitting coil and the transmission distance, and to obtain the optimal radius, Wang Hong et al. first analyzed the spatial magnetic field of the system, confirmed the existence of the optimal radius value, and then explored the relationship between the optimal radius value and the transmission distance. Based on the results, they designed a conical helical transmitting coil structure with the radius value of each turn being the optimal value. Finally, after simulation verification, the optimized conical coil structure, compared with the traditional coil, not only successfully reduced the leakage magnetic flux but also decreased the consumables by 34.3% and increased the mutual inductance value by 140.16%, thereby enhancing the transmission performance of the system [14]. This structure of the coil can also be applied to enhance the anti-offset capability of the coil. The optimal radius values required for different transmission positions can be calculated and stacked and fixed in the system space. When the receiving end device offsets in the direction perpendicular to the coil during the charging process, the charging efficiency can be maximized by activating coils of different radii.

Yang Yang et al. proposed an optimized design of a movable spherical transmitter coil, by establishing a mathematical model of mutual inductance calculation, comparing the change rate of mutual inductance of 9 coil windings, first simulating it with Maxwell, selecting the optimal coil structure, and then using Matlab to simulate the topology of the wireless transmission system. At the end, an experimental platform was built, and the actual results were compared with the theoretical calculated values and simulation results to verify the feasibility of the idea [15]. By constructing a three-dimensional transmitting coil structure, omnidirectional magnetic field coverage was achieved, taking into account the possibility of angular offset of the receiving equipment, but it could not effectively eliminate the influence of horizontal offset.

In conclusion, the design of irregular-shaped coils has demonstrated unique advantages and broad application prospects in the field of radio power transmission. Through in-depth analysis of the requirements of different application scenarios, researchers have developed a variety of targeted irregular coil structures, effectively enhancing the anti-offset capability and transmission efficiency of the wireless power transmission system. With the continuous deepening of research, the design of irregular-shaped coils is expected to be applied in more fields and bring new breakthroughs to the development of radio power transmission technology.

## 5. Views and Prospects

The future development potential of wireless charging technology is huge. It overcomes the limitations of wired charging on the charging range, offers greater flexibility, and enables devices to charge while in operation, ensuring longer battery life for the devices. This further liberates human labor and saves time. The optimized design for the impact of wireless charging coil offset on power has enhanced transmission efficiency, reduced energy loss caused by magnetic flux leakage during wireless charging, further improved the practicality of wireless charging technology, ensured the efficiency and safety of energy transmission, and also improved the user experience, accelerating the popularization of the technology. This paper reviews the development of anti-offset technology for radio power transmission coils from 2010 to 2025, and confirms from both theoretical and practical levels that the structural optimization of coils can effectively enhance the anti-offset capability. However, there are still some problems: firstly, the offset scenario is complex, and it is difficult to accurately model and predict the wireless charging scenario. Secondly, there are some obvious problems in the existing technologies, taking multi-coil array as an example, although this technology can expand the coupling range, it requires complex coil switching logic and control algorithms, but increases the volume, cost and energy consumption.

In the future, the coil structure can continue to be explored and optimized. While ensuring the system's anti-offset capability, the integration degree of the system can be enhanced to reduce costs. In terms of integration with other technologies, such as electric vehicles, the alignment accuracy of the charging coil can be enhanced by combining more precise positioning technologies, fundamentally reducing the impact of coil offset on the system.

## References


[1] Li, X. B. (2018, November 19). The Road of Wireless Charging [EQ/OL]. Retrieved September 2, 2025.

[2] Anonymous. (2020, February 28). Application of Wireless Charging Technology in Electric Toothbrushes [EB/OL]. Retrieved September 2, 2025.

[3] PConline Pacific Technology. (2023, April 16). Infinite Future, Future Wireless: The History of Qi Wireless Charging Technology [EB/OL]. Retrieved September 2, 2025.

[4] Shandong Xiehe University, School of Computer Science. (2014, August 1). Latest Long-Distance Wireless Power Supply Can Reach Up to 5 Meters [EB/OL]. Retrieved September 2, 2025.

[5] Lee, S.-Y., Park, J.-H., Kim, D.-H., & Cho, H.-J. (2025). Metamaterial-based magnetic shielding layer for quasi-static magnetic field suppression in wireless power transfer systems. Journal of Materials Science and Technology, 226, 1 – 15.

[6] Huang, J. L. (2022). Research and Design of a Wireless Charging Array Coil System Based on Magnetic Coupling Resonance [D]. Mianyang: Southwest University of Science and Technology.

[7] Kurs, A., Karalis, A., Moffatt, R., Joannopoulos, J. D., Fisher, P., & Soljačić, M. (2007). Wireless power transfer via strongly coupled magnetic resonances. Science, 317 (5834), 83 – 86.

[8] Brown, W. C. (1964). The history of wireless power transmission. Solar Energy, 56 (1), 3 – 21.

[9] Yang, Y., Zhang, Z., Xu, B., et al. (2025). Research on DDDQ-type magnetic coupling structure of wireless charging system for electric vehicles. Automotive Engineering, 47 (06), 1007 – 1021.

[10] Chen, W. Q. (2023). Research on lightweight wireless charging system for unmanned aerial vehicles (UAVs) [D]. Harbin: Harbin Institute of Technology.

[11] Li, Z. Z., Zhang, Y. D., Yu, S. S., & Zhang, G. D. (2025). A hybrid wireless power transfer system with high misalignment tolerance using diagonal crossed solenoid magnetic coupler. Chinese Journal of Electrical Engineering, 11 (1), 138 – 150.

[12] Huang, M. L. (2022). Research on wireless charging system for inspection robots based on multi-coil coupling [D]. Hangzhou: Zhejiang University of Science and Technology.

[13] Kim, S., Lee, J., & Park, J. (2020). Design to minimize coupling coefficient between transmitter coils based on deep learning for wireless power transfer with multi-transmitter. IEEE Transactions on Industrial Electronics, 68 (1), 733 – 742.

[14] Wang, H., Jing, F. S., & Li, Y. (2021). Optimization of conical coil WPT system based on optimal transmission radius. Electric Drive, 51 (24), 1 – 6.

[15] Yang, Y., Chen, W., Dai, L., Wang, R., & Houran, M. A. (2018). An optimization design of the moving ball-shaped coil used for wireless charging, 1 – 4.