INTERNATIONAL JOURNAL OF COMPUTING, SCIENCE AND NEW TECHNOLOGIES (IJCSNT)
VOL. 6 NO. 1 JANUARY 2025

DEVELOPMENT AND PERFORMANCE EVALUATION OF A WIRELESS POWER TRANSMISSION MODULE

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Abstract

This study presents the development and performance evaluation of a wireless power transmission module based on electromagnetic induction principles. The system comprises of a transmitter unit, designed to enable efficient contactless energy transfer for low-power portable applications. The transmitter module is powered by a 220 V AC mains supply, which generates a 48 kHz oscillation circuit. The oscillator generates a high-frequency square wave signal that drives a transmitting coil, producing an alternating electromagnetic field for wireless energy transfer. Performance evaluation was conducted in terms of output voltage stability, transmission efficiency, operating frequency characteristics, and load response. Experimental results demonstrate reliable power transfer, low acoustic noise operation, and satisfactory efficiency for short-range wireless charging applications. The developed module provides a practical and scalable solution for compact wireless power systems.

Keywords/Phrases: Wireless, Transmitter, Oscillator, Electromagnetic induction, Frequency.

1.0 Introduction

The development and performance evaluation of a wireless power transmission module is situated within the broader domain of Wireless Power Transfer (WPT), a field that seeks to eliminate physical electrical interconnections between power sources and loads. Wireless power transmission refers to the transfer of electrical energy from a source to an electrical load without the use of conductive cables (Agbinya, 2022). This concept, first experimentally explored by Nikola Tesla in the late nineteenth century, has evolved from theoretical demonstrations to practical short-range applications in modern electronic systems. Conventional power delivery relies heavily on copper conductors and direct plug-in charging mechanisms. While effective, wired systems present limitations including mechanical wear, safety risks, limited mobility, and cable clutter. Wireless transmission offers a viable alternative in scenarios where rapid, continuous, or safe energy transfer is required without physical connectors. By transmitting energy through an electromagnetic field across an air gap, wireless systems improve convenience, reliability, and system flexibility.

Recent technological advancements in power electronics, high-frequency switching circuits, and integrated control systems have accelerated the commercialization of wireless charging technologies. Since 2014, major consumer electronics manufacturers such as Samsung, Apple, and Huawei have incorporated wireless charging capabilities into smartphones and portable devices (Liang, Zhao, Yuan, Chen, Zhang, Huang, Zhang, 2019). This shift reflects growing consumer demand for cable-free solutions, similar to trends observed in wireless communication technologies such as Wi-Fi and Bluetooth-enabled devices. The fundamental operating principle of most short-range wireless power systems is electromagnetic induction. In inductive coupling, a time-varying current flowing through a primary (transmitter) coil generates a magnetic field. When a secondary (receiver) coil is positioned within this magnetic field, an electromotive force is induced, allowing power to be transferred across the air gap (Donnevert, 2020). System performance depends on parameters such as operating frequency, coil alignment, coupling coefficient, switching topology, and load conditions.

Although commercial wireless chargers are available, many systems remain limited by efficiency losses, restricted transmission distance, thermal constraints, and cost considerations. Consequently, there is ongoing research aimed at improving energy transfer efficiency, enhancing voltage regulation, minimizing electromagnetic interference, and ensuring safe operation for users and the environment. This study therefore focuses on the development and performance evaluation of a wireless power transmission module designed for short-range, low-power applications. The work involves the design of a high-frequency transmitter stage, inductive coupling interface, rectification and voltage regulation circuits, and systematic performance testing under varying load conditions. The outcome contributes to the advancement of efficient, compact, and economically viable wireless power solutions for modern electronic devices.

2.0 Wireless Power Transfer

The theoretical foundation of wireless power transmission is based on electromagnetic induction and resonant circuit theory. When an alternating current (AC) flows through a transmitting coil, it generates a time-varying magnetic field. If a receiving coil is placed within this magnetic field, an electromotive force (EMF) is induced according to Faraday's law of induction. The induced AC voltage is then rectified, filtered, and regulated to provide a stable DC output suitable for powering or charging electronic devices.

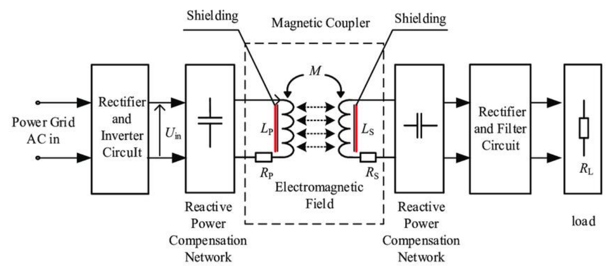

Figure 1: Block diagram of an inductive coupled circuit (Arkeholt, 2018).

2.1 Review of Related works

The reviewed literature collectively highlights major advancements and considerations in wireless power transfer (WPT) and contactless charging technologies. Mehdi Kiani and colleagues (2012) optimized inductive link designs, demonstrating that a 3-coil system achieves superior power delivered to the load (PDL) with comparable power transfer efficiency (PTE) to 4-coil systems, particularly at moderate coupling distances. Hai Jiang et al. (2012) focused on safety concerns in high-power wireless charging for electric vehicles (EVs), addressing electromagnetic exposure, electrical shock, and fire hazards using Hazard Based Safety Engineering principles. Babji Bommana et al. (2023) examined EV charging standards, infrastructure, and protocols, comparing on-board and off-board systems, bidirectional and unidirectional power flow, and various charging levels. Arunmozhi Manimuthu et al. (2021) explored the integration of contactless technologies with IoT, big data, and cloud infrastructures for smart city applications, emphasizing system design and emergency management. Finally, Siqi Bai (2023) provided a comprehensive review of WPT methods for EVs—including inductive, capacitive, microwave, and laser approaches—discussing their principles, advantages, limitations, and future challenges such as coil optimization, safety, and standardization.

3.0 Methodology

This work incorporates relevant theoretical models, design phases, and both qualitative and quantitative evaluation techniques to ensure system efficiency, reliability, and maintainability. After reviewing various software development life cycle models, the Waterfall model is selected due to its structured and sequential nature, which provides clear documentation and systematic project execution. The development process followed five key stages: requirement analysis and specification, involving feasibility study and documentation of system needs; design phase, where schematic diagrams and subsystem models were developed; implementation and unit testing, including simulation and functional verification of the system; integration and system testing, ensuring proper interaction among subsystems; and finally, operation and maintenance, where charging capacity and overall system efficiency were evaluated to confirm that the design objectives were achieved.

3.1 System Design

Although several wireless power transmission methods exist such as microwave and laser-based techniques, this work adopts the inductive coupling method due to its practical efficiency, reliability, and suitability for short-range applications. While microwave and laser systems can achieve higher directional efficiency, significant energy losses occur during reconversion to electrical power at the receiving end, reducing overall system effectiveness. In contrast, inductive coupling offers a stable and achievable efficiency range of approximately 75–85% with current technology, making it more appropriate for compact consumer charging systems. A comprehensive process involving system analysis, modeling, design, implementation, testing, verification, and operation was conducted. In operation, the transmitter is activated when a light-emitting diode (LED) indicates that the receiver has been properly positioned on the charging platform, enabling magnetic coupling, followed by rectification and regulated DC delivery to the mobile device.

3.1.1 Block Diagram

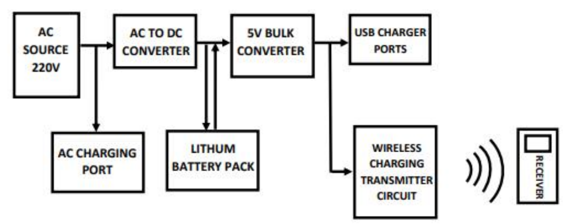

Figure 2: Block Diagram of a wireless power transmitter

3.1.2 Flowchart

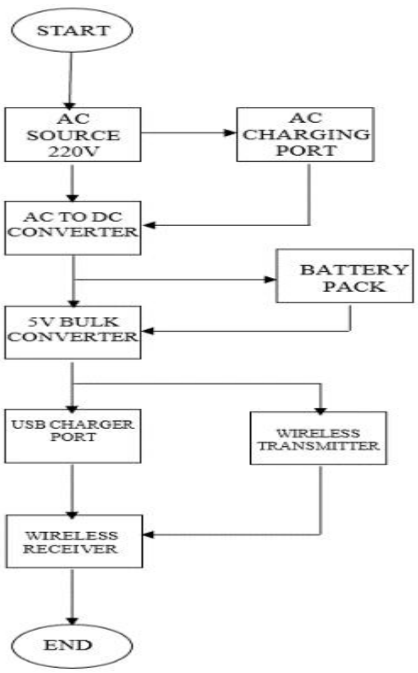

Figure 3: Flowchart Diagram

3.2 Transmitter

The transmitter operates on the principles of electromagnetic induction. Inductive charging also Known as (wireless charging or cordless charging) is a type of wireless charging that uses an electromagnetic field to transfer energy between two objects using electromagnetic induction which is the production of electricity across a magnetic field. Inductive charging is usually done with a charging station or inductive pad (transmitter). Energy is sent through this transmitter which in turn delivers this energy to a receiver wirelessly which then utilizes this energy to charge batteries or run electronic devices. Induction chargers use an induction coil to create an alternating electromagnetic field from within a charging base, and a second induction coil (receiver) in the portable device takes the power from the Electromagnetic field and converts it back into electric current to charge batteries. The two coils in proximity combine to form an electrical transformer. It should be noted that the greater the distance between the two coils the lower the power received. Although greater distances between transmitter and receiver can be achieved using resonant inductive coupling, this work adapts the inductive coupling method of wireless power transfer. Also, the transmitter is interfaced with an SG3525 oscillator which is a 16-pin IC and the IC is configured in astable mode to generate constant clock pulses. The clock pulse which is the oscillating frequency was chosen to be as high as 48 kHz since the energy transfer is through an air core and also above the audible frequency range. A square waveform was also chosen based on its simplicity of generation.

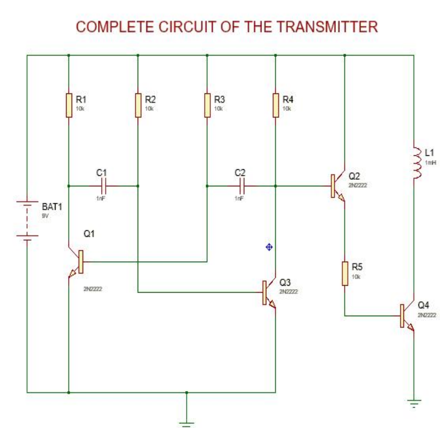

Figure 4: Circuit diagram of the transmitter

TX voltage, V	TX current, A	TX Power W	RX Power W	Efficiency %
14.5	0.77	11.16	6.81	61.02
14.5	0.85	12.32	7.86	63.8
14.5	1.18	17.11	11.01	64.35
14.5	1.39	20.15	13.78	68.39
14.5	1.50	21.75	15.88	73.01
14.5	1.63	23.63	17.85	75.54
14.5	1.75	25.37	19.96	78.68
14.5	1.97	28.56	23.51	82.32

Table 1: Custom 30W WPT table system efficiency measurement data.

4.0 Result Analysis

Based on the system requirements and design analysis, the wireless charging device operates using electromagnetic induction with resonant coupling for efficient power transfer. The system incorporates two power supplies integrated through a control circuitry that manages operation. When energized, the transmitter coil radiates an electromagnetic field whose intensity and range depend on the coil diameter and number of turns. A nearby receiver coil couples with this field, enabling wireless energy transfer. The induced alternating current is then rectified and regulated to a stable 5 V DC output suitable for charging mobile devices.

4.1 Tests and Measurements

Several tests were done to check the operations of the system since efficiency is an important part of the system's operation, corresponding measurementswere carried out. The measurement data is presented in Table 1 and the efficiency curve is shown in Figure 5.

The test was carried out using Array 3711A programmable DC electronic load. TX voltage is the voltage supplied to the transmitter module and RX power is the total power that sinks in the load on a constant current mode.

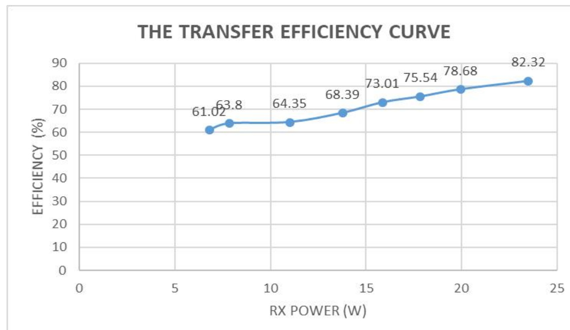

Figure 5: Graph to measure the transfer efficiency curve

As can be seen from the graph the efficiency rises drastically but exceeds 70% only after ~2.25 W. In addition, the maximum achieved distance is 5 mm through different materials including linoleum, carpet and rubber and Perspex which was eventually the material we used for our covering. The system was proven to be working as expected. However, a strict limitation to maximum of 5 W power output, tight alignment of the coils and too short range (only up to 1 cm) were the main drawbacks. They prevented the system from being "truly wireless" and provide a considerable advantage over traditional wires.

4.2.1 Charging Capacity Evaluation

This evaluation was carried out using a wireless earbud at the receiver end with a power rating of 250mAH.

Table 2: Charging Capacity Evaluation using a 250mAH wireless earbuds

RX Power W	Time Taken to charge from 0% - 25% Minutes	Time Taken to charge from 0% - 50% Minutes	Time Taken to charge from 0%-75% Minutes	Time Taken to charge from 0%-100% Minutes
6.81	7 mins 10 Sec	14 Mins 15 Sec	20 Mins 30 Sec	27 Mins 24 Sec
7.86	6 Mins 57 Sec	11 Mins 26 Sec	17 Mins 3 Sec	23 Mins 40 Sec
11.01	6 Mins 10 Sec	11 Mins 1 Sec	16 Mins 50 Sec	23 Mins 2 Sec
13.78	5 Mins 43 Sec	10 Mins 40 Sec	16 Mins 10 Sec	22 Mins 50 Sec
15.88	5 Mins 2 Sec	10 Mins 20 Sec	15 Mins 30 Sec	21 Mins 45 Sec
17.85	4 Mins 45 Sec	9 Mins 1 Sec	14 Mins 30 Sec	21 Mins 3 Sec
19.96	4 Mins 10 Sec	8 Mins 40 Sec	12 Mins 2 Sec	18 Mins 45 Sec
23.51	3 Mins 1 Sec	7 Mins 50 Sec	11 Mins 45 Sec	18 Mins 3 Sec

It was observed that as the Receiving Power increases the charging time decreases.

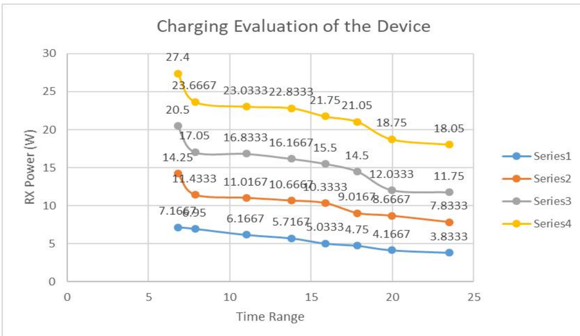

Figure 6: Graph for the Charging Capacity Evaluation

5.0 Conclusion

The global shift toward renewable energy highlights the urgent need to expand and improve energy supply systems to sustain technological advancement. To meet growing demand, innovative solutions such as wireless power transfer (WPT) must be explored as viable alternatives for efficient energy distribution. Although WPT presents technical challenges, it offers a promising and potentially practical approach if adequate research, collaboration, and investment are pursued. Transmitting electrical energy through the air, similar to Wi-Fi or radio signals, could significantly transform modern technology. Failure to develop clean and efficient energy transmission methods may hinder technological progress and contribute to long-term environmental problems, including pollution from discarded batteries.

References

Agbinya J. I. (2022). Wireless power transfer. River Publishers.

Arkeholt S. (2018). Induction in Printed Circuit Boards using Magnetic Near-Field Transmissions.

Bommana B., Siva Kumar J. S. V., Nuvvula R. S. S., Kumar P. P., Khan B., Muthusamy S., & Inapakurthi R. (2023). A comprehensive examination of the protocols, technologies, and safety requirements for electric vehicle charging infrastructure.

Bai S. (2023). Wireless power transfer technologies for electric vehicles: Principles, challenges and opportunities.

Donnevert J. (2020). Time-Varying Electric and Magnetic Fields. In Maxwell´ s Equations: From Current Density Distribution to the Radiation Field of the Hertzian Dipole (pp. 89-131).

Wiesbaden: Springer Fachmedien Wiesbaden.

Jiang H., Brazis P., Tabaddor M., & Bablo J. (2012). Safety considerations of wireless charger for electric vehicles — A review paper.

Liang Y., Zhao C. Z., Yuan H., Chen Y., Zhang W., Huang J. Q., ... & Zhang Q. (2019). A review of rechargeable batteries for portable electronic devices. InfoMat, 1(1), 6-32.

Manimuthu A., Dharshini V., Zografopoulos I., Priyan M. K., & Konstantinou C. (2021). Contactless technologies for smart cities: Big data, IoT, and cloud infrastructures.

Richard Wolfson. Essential University Physics: Volume 2 (Second Edition). Harlow: Pearson Education Limited; 2018.

Waffenschmidt E., "Wireless power for mobile devices," Telecommunications Energy Conference (INTELEC), 2018 IEEE 33rd International, vol., no., pp.1,9, 9-13 Oct. 2018.

Kiani M., Jow U.-M., & Ghovanloo M. (2012). Design and optimization of a 3-coil inductive link for efficient wireless power transmission.

