A NEW INDUCTIVE POWER TRANSFER USING INTEGRATED LOW LOSS DIELECTRIC TECHNIQUE ON METAMATERIAL

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MASTER OF SCIENCE IN ELECTRONIC ENGINEERING

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**A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "A New Inductive Power Transfer Using Integrated Low Loss Dielectric Technique On Metamaterial" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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Date	:	15/08/2025

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Master of Science in Electronic Engineering.

Signature : ....

Supervisor Name : TS. DR. MOHAMAD HARRIS MISRAN

Date : 15/08/2025

DEDICATION

I would like to dedicate this entire study to Allah Almighty, the ultimate source of wisdom, patience, and inspiration, whose grace has guided me through the completion of this research. My heartfelt thanks go to my beloved parents, whose blessings and encouragement have been invaluable throughout this process. Additionally, I extend my deepest appreciation to my supervisor, Dr. Mohamad Harris bin Misran, and co-supervisor, Dr. Norbayah binti Yusop, for their invaluable guidance and support in bringing this project to fruition.

ABSTRACT

In recent times, there has been a significant surge in innovation and advancement in the field of wireless power transfer (WPT), leading to an increased demand for WPT systems that offer high power transfer efficiency (PTE) and longer transmission lengths for end users. As a result, there is an increasing need for enhanced PTE and extended transmission distance in WPT systems, to meet the needs of consumers. However, currently available WPT systems have limited PTE and transmission ranges due to their use of inductive coupling. As the distance between the transmitter and receiver coils increases, the PTE undergoes a substantial decrease when using this approach. Therefore, this work proposes a concept for inductive WPT that utilizes metamaterials (MTMs) to enhance PTE by controlling the refraction of magnetic fields. Integration MTM between the transmitting (TX) and receiving (RX) coils can improve the effectiveness and distance coverage of WPT. MTMs have qualities such as evanescent wave amplification and negative refractive index, which show potential for improving PTE. The proposed MTM structures exhibit a negative permeability characteristic, allowing them to redirect the flux towards the RX coil area. This redirection results in an increase in both the flux density and the generated current. The PTEs shows amplification with implementation of MTM. When used at a distance of 40 mm, MTM A, MTM B, and MTM C all show a notable enhancement in PTE. Specifically, there is a 32.95% increase with MTM A, 32.49% increase with MTM B, and another 20% increase with MTM C.

PEMINDAHAN KUASA ARUHAN BARU MENGGUNAKAN TEKNIK DIELEKTRIK KEHILANGAN RENDAH BERSEPADU PADA METABAHAN

ABSTRAK

Dalam masa kini, terdapat peningkatan ketara dalam inovasi dan kemajuan dalam bidang pemindahan kuasa tanpa wayar (WPT), yang membawa kepada peningkatan permintaan terhadap sistem WPT yang menawarkan kecekapan pemindahan kuasa (PTE) yang tinggi serta jarak penghantaran yang lebih jauh bagi memenuhi keperluan pengguna. Sehubungan itu, keperluan terhadap peningkatan kecekapan pemindahan kuasa dan jarak penghantaran dalam sistem WPT menjadi semakin mendesak. Namun demikian, sistem WPT sedia ada menghadapi had dari segi kecekapan dan jarak pemindahan disebabkan oleh penggunaan teknik gandingan beraruhan. Apabila jarak antara gegelung pemancar dan gegelung penerima meningkat, kecekapan pemindahan kuasa akan menurun secara ketara menggunakan kaedah ini. Oleh itu, kajian ini mencadangkan satu konsep baharu bagi sistem WPT beraruhan yang menggunakan metabahan (MTM) bagi meningkatkan kecekapan pemindahan kuasa melalui pengawalan pembiasan medan magnet. Penyepaduan struktur MTM di antara gegelung pemancar dan gegelung penerima dapat meningkatkan keberkesanan serta liputan jarak penghantaran sistem WPT. MTM memiliki ciri-ciri seperti penguatan gelombang evanesen dan indeks pembiasan negatif, yang berpotensi untuk meningkatkan kecekapan pemindahan kuasa. Struktur MTM yang dicadangkan menunjukkan ciri kebolehtelapan negatif, yang membolehkan ia mengarahkan fluks magnet ke kawasan gegelung penerima. Pengarahan semula ini menghasilkan peningkatan dalam ketumpatan fluks serta arus terhasil. Kecekapan pemindahan kuasa menunjukkan peningkatan PTE dengan penggunakaan MTM. Pada jarak 40 mm, penggunaan MTM A, MTM B dan MTM C masing-masing menunjukkan peningkatan ketara dalam PTE. Secara khusus, peningkatan sebanyak 32.95% direkodkan dengan MTM A, 32.49% dengan MTM B dan manakala peningkatan sebanyak 20% dengan MTM C.

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LIST OF ABBREVIATIONS

UHF	-	Ultrahigh Frequency
SHF	-	Superhigh Frequecy
RFID	-	Radio Frequency Identification
E-FIELD	-	Electric Field
PM	-	Perturbation Method
TE	-	Transverse Electrical
TM	-	Transverse Magnetic
AC	-	Alternating Current
CPW	-	Coplanar Waveguide
CFA	-	Complementary Folded Arm
DS-CSRR	-	Double Slit Complementary Split Ring Resonator
SSRR	-	Square Split Ring Resonator
SRR	-	Split Ring Resonator
Q-Factor	-	Quality Factor
PEC	-	Perfect Electric Conductor
EM	-	Electromagnetic
DXF	-	Drawing Exchange Format
UV	-	Ultraviolet
CST	-	Computer Simulation Technology
VNA	-	Vector Network Analyzer
DUT	-	Device Under Test
LUT	-	Liquid Under Test
SUT	-	Solid Under Test
MUT	-	Material Under Test
PSC	-	Planar Spiral Coil
WET	-	Wireless Energy Transfer
WPT	-	Wireless Power Transfer

LIST OF SYMBOLS

μm	-	Micrometre
mm	-	Millimetre
ε_r	-	Permittivity
$\varepsilon_r{}'$	-	Real Permittivity
$\varepsilon_r{}''$	-	Imaginary Permittivity
ε_o	-	Permittivity of Free Space
G	-	Gain
L	-	Inductor
C	-	Capacitor
R	-	Resistor
E	-	Electric Fields
Z_0	-	Characteristic Impedance
ε_{eff}	-	Effective Dielectric Constant
w	-	Width
l	-	Length
h	-	Height (thickness)
g	-	Gap Width
c	-	Speed of Light
L	-	Actual Length of Patch
L_{eff}	-	Effective Length
ΔL	-	Incremental Length of Patch
f_r	-	Resonant Frequency
f_o	-	Center Frequency
f_c	-	Frequency without Sample
f_s	-	Frequency with Sample
Δf	-	Frequency Shifting
f_1	-	Lowest Frequency
f_2	-	Upper Frequency
Q	-	Quality Factor

Q_{MUT}	-	Quality Factor of Material Under Test
Q_U	-	Unloaded Quality Factor
BW	-	Bandwidth
dB	-	Decibels
S_{11}	-	Return Loss
S_{21}	-	Insertion Loss

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LIST OF PUBLICATIONS

List of Conference

M. S. Yusri, M. H. Misran, N. Yusop, M. A. M. Said, M. A. Othman and S. Suhaimi, "Transfer Efficiency Enhancement on Wireless Power Transfer Using Metamaterial," *2023 International Conference on Information Technology (ICIT)*, Amman, Jordan, 2023, pp. 724-729, DOI: 10.1109/ICIT58056.2023.10226136

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Muhammad Sukriyllah Yusri [1], Mohamad Harris Misran [1], Tan Kim Geok [2], Sharul Kamal Abdul Rahim [3], Norbayah Yusop [1], Maizatul Alice Meor Said [1] and Azahari Salleh [1]. ‘A Review: Advanced Perspectives on Metamaterial Integration in Wireless Power Transfer’, *Applied Computational Electromagnetics Society Journal*, vol. 40, no. 03, pp. 237–252, Mar. 2025, DOI: https://doi.org/10.13052/2025.ACES.J.400308

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1

INTRODUCTION

1.1 Research Background

In the modern era, it is usual for individuals to own a wireless mobile device that serves multiple functions in both their professional and personal lives. Mobile gadgets, such as smartphones and tablets, have quickly become essential components in fulfilling the requirements of everyday living. The wire infrastructure is susceptible to potential breakdowns because of broken cables caused by natural disasters. This imperfection possesses the capacity to result in electrical leakage, presenting a substantial hazard to human well-being and security. Considerable efforts have been devoted to improve the Wireless Power Transfer (WPT) through careful experimentation and extensive research.

WPT is based on two primary types of principles: far-field (C. M. Song, 2021) (D. Sharma, S. Kumar, N. Singh, B. K. Kanaujia, 2023)(X. Gu, P. Burasa, 2021) and near-field energy transfers (J. H. Park, N. M. Tran, S. I. Hwang, 2021)(Degen, 2021), often known as radiative and non-radiative WPT, respectively. WPT systems can be classified into three categories: capacitive, inductive, and magnetic couplings, based on their unique features (M. Behnamfar, 2022) (X. Hou, Z. Wang, Y. Su, 2022). Every variant of WPT system possesses distinct characteristics and is well-suited for applications. Nevertheless, a shared characteristic across these devices is the wireless conveyance of energy from a specific origin to a recipient, with the two entities being physically separated by an empty space and lacking any tangible connections.

A fundamental configuration of a wireless energy system comprises two coils: a transmitter coil and a receiving coil, which are positioned apart from each other with air as the medium. The flow of alternating current (AC) via the transmitter coil results in the generation of a magnetic field. The magnetic field generated by the transmitter coil causes an electric current to be produced in the receiver coil, facilitating the wireless transmission of electric power from the transmitter to the receiver (Agbinya, 2022).

Antennas are used in the field of far-field radiative coupling to transmit electrical power by transmitting Radio Frequency (RF) waves (L. Xie, X. Cao, 2021)(Hassan et al., 2021). The receiver antenna intercepts these waves and transforms them into direct current (DC). Nikola Tesla coined the term "wireless power transfer" referred to the transmission of energy using radiation. Nevertheless, ongoing research has redirected its focus towards utilizing ambient radio frequency (RF) waves for the purpose of energizing low-power devices. This method, known for its capacity to transmit energy across long distances and its exceptional mobility, has garnered significant interest in the energy harvesting area. It involves generating a small amount of electricity to power several electronic devices across a large area, demonstrating a new facet of renewable energy research. Radiated WPT is appropriate for transmitting power over long distances, while non-radiated WPT is employed for communication within shorter distances, particularly in the intermediate range, utilizing electromagnetic fields (Mohammadnia A, Ziapour BM, Ghaebi H, 2021).

Non-radiated WPT is widely employed in various sectors to meet the power requirements, ranging from low to high, without the usage of radiation. Non-radiated WPT systems are commonly categorized into two types: capacitive and inductive energy transfer link. Capacitive transfer, on the other hand, encounters safety limits as a result of the impacts of the electric field (Moon J., 2021). On the other hand, inductive energy transmission is frequently preferred because to its capacity to reduce direct electrical field interactions between persons and gadgets (Bao J, Hu S, Xie Z, Hu G, Lu Y, 2022).

Significant advancements have been made in the fields of biomedicine, low-power charging devices, and wireless communication (Harshitha, H. M., 2021)(Pokharel, Ramesh K., 2021) (Ashraf, Nausheen, 2021). Nevertheless, the inductive WPT technology is recognised to