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Enhanced wireless power transfer system using integrated RF amplification

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A B S T R A C T

This paper focuses on the concept of wireless power transfer, a technology that allows power to be transmitted over a certain distance without wires. In this paper, we focused on the power support to the implanted biomedical devices, where supplying power using wires is challenging. It can also be implemented on various low powered electronic devices to deliver power efficiently. This study presents an optimized WPT system that enhances power transmission efficiency by integrating a novel three-coil design and an advanced RF amplification approach. Our proposed system operates within the radio frequency (RF) range, initially at 3 MHz, unlike conventional designs, this model integrates an oscillator with an RF amplifier directly into the coil, eliminating the need for separate power amplification and impedance matching network while improving signal strength and power delivery. The suggested method provides consistent power transfers up to 13 cm, exceeding typical two-coil systems. Experimental results show a maximum efficiency of 69 % at 7 cm for a two-coil system and 71 % at 13 cm for a three-coil arrangement. RF amplification boosts received output power by 42 %, while overall system efficiency improves by 36 %. Resonant tuning minimizes midrange power loss by 28 %, allowing for consistent performance across long distances. Circuit simulations were carried out using Multisim, MATLAB, and the CST Studio Suite. The proposed design operates safely under SAR limitations ($<1 \times 10^{-6}$ W/kg), making it ideal for biomedical implants, mobile device charging, and tiny electronics. This paper proposes a feasible and scalable engineering solution for efficient mid-range WPT applications.

1. Introduction

Wireless power transfer, or WPT, is gaining popularity in academia and industry due to the pressing need to wirelessly charge a wide range of electronic devices (such as smartphones, laptop computers, wearable technology, medical implant devices, and so on) and systems that require significantly more power (such as electric vehicles and robots). Nowadays, near-field WPT is widely employed. For example, it employs inductive resonance coupling in the industrial, scientific, and medical (ISM) bands at 6.78 and 13.56 MHz, which can operate at both kilohertz (kHz) and multiple megahertz (MHz) [1]. In WPT, there is often a basic trade-off between kHz and MHz operation: kHz operation provides higher efficiency and power transfer capabilities [2], whilst MHz operation allows for longer-distance power transfer and increased resistance to coil misalignment [3]. For a long time, the kHz and MHz WPT standards will coexist [4].

Many ways for wirelessly charging electrical devices have emerged over time. Based on resonant or inductive coupling techniques, near-field wireless power transfer (WPT) has improved technologically, resulting in profitable mobile device charging solutions [5]. Despite its excellent power transfer efficiency, near-field WPT's restricted charging range severely limits its applicability. Even if the connection is not made directly to the target device, the devices must be located close to the power supply, preferably at a defined location [6].

However, radio frequency (RF) WPT, which is based on electromagnetic (EM) waves, can transmit wireless power over hundreds of meters [7]. Furthermore, one significant advantage of RF WPT is its ability to be expanded to simultaneous wireless information and power transmission (SWIPT) [8]. However, it is difficult for the RF WPT system to meet this performance goal because an IoT device requires around 1 mW of electricity to work [9]. Because of the dispersive nature of free-space electromagnetic waves, only a small percentage of the radiated radio frequency power can be collected at the receiver after it has dissipated into the environment. This is the primary difficulty with RF WPT is its low power transfer efficiency.

According to IMARC Group, the global market advantage of

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