Class E Power Amplifier

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This entry aims to solve a problem that exists with impedance matching networks in terms of extra cost and power loss of electronic components in a four-coil wireless power transfer (WPT) system using class E power amplifier as power supply, which is not conducive to the improvement of system efficiency and output power. A design method of sharing the resonant inductor in class E power amplifier and the excitation coil in the four-coil WPT system is proposed. This method comprehensively considers the output power and transfer efficiency of the system, the number of coil turns, coil size and many other factors. Compared with the traditional four-coil system using a class E power amplifier as a power supply, the proposed method simplified the system structure by leaving out a resonant inductor and load matching circuit, which can reduce the power loss of system and improve efficiency. Moreover, the precisely tuning of resonant inductor was not necessary, which improved the stability of the system. The correctness and feasibility of the parameter design method were verified by experiments. The experimental results showed that the output power of the system was increased by 18.7%, the efficiency was increased by 11%, and the transmission distance was up to 0.7 m, which is suitable for wireless power supply of electronics and sensors.

Keywords: class E power amplifier ; wireless power transfer (WPT) ; resonant inductor ; electronics ; sensors

1. Introduction

Since 2007, wireless power transfer (WPT) technologies have been widely concerned and studied because of their flexibility and security in power supply [1][2][3][4]. It is troublesome to use a wired charging mode to charge electronics and sensors spread across a geographical area. However, existing wireless charging equipment has a short transmission distance. Four-coil WPT systems with class E power amplifiers as high frequency power supply are widely researched because of the advantages of long transfer distance, simple structure and high efficiency. In reference [5], a novel four-resonator coil structure is presented to improve system efficiency. The source and load coils are designed to acquire high-loaded Q (quality factor) and maximum cross coupling coefficients, which increase system efficiency effectively. In reference [6], a high-efficiency WPT system with an asymmetric four-coil resonator is proposed. Two intermediate coils boost the apparent coupling coefficient at around the operating frequency. Reference [7] proposes methods to improve the transmission range by optimizing the magnetic mechanism and the distribution of auxiliary coils. Reference [8] demonstrates, explains and analyzes frequency-splitting phenomenon by using the circuit theory. A solution is proposed that helps improve the efficiency when frequency-splitting occurs. The theoretical calculations and experimental results provide a sound basis. In reference [9], a four-coil WPT system is designed by laying a lumped coil on the ground to realize the wireless power supply over a distance of 0.4 m. The transfer distance is not enough for modern wireless systems especially for electronics and sensors, since they may be widely distributed in high-voltage facilities, for example, the Ubiquitous Electric Internet of Things (UEIOT). The power transfer distance needs to be increased to ensure the safety of charging process. In reference [10], the equivalent circuit model of four coil wireless energy transmission system is established and the efficiency analysis is carried out. The expression of coupling coefficient between coils is derived when the maximum system efficiency is achieved. It can be applied to optimize the parameters of four-coil system. Reference [11] analyzes the relationship between transmission efficiency, transmission distance and mutual inductance when using four-coil system to charge laptop, and the transmission efficiency is up to 52%. Further improvement on the transfer efficiency is necessary in practical applications.

For the traditional four-coil WPT system, the impedance matching network to make the equivalent resistance of coil system consistent with the ideal load of class E power supply is essential to keep high performance of output power. However, the impedance matching network will inevitably increase the system complexity and results in extra power loss. The existing studies mainly concentrate on improving efficiency and transmission distance of four-coil WPT system by optimizing the coupling coils, however, the solutions of integrated design of power supply topology and four coil coupling mechanism are not intensively researched.

2. Conclusion

In this entry, we propose a high-performance medium and long-distance wireless charging system with four-coil WPT system and class E power amplifier sharing a single resonant inductor. The proposed system does not use additional impedance matching network which reduces the complexity of the traditional four-coil system and has the characteristics of high efficiency, flexibility and long transmission distance. First, the theoretical model of four-coil system using resonant inductor in class E power amplifier is established and the principle of the model is analyzed in detail. The coil system is modeled based on mutual inductance theory and analyzed as the equivalent input resistance of class E power amplifier. The equivalent input resistance can be adjusted by the design of coil radius, turns and distances between coils. Second, the output voltage of class E power amplifier can be described as a function of input resistance when other parameters are constant. The design of power supply and four-coil system are combined forconsideration. Under the given design requirements, the output power and efficiency of the system can be expressed as a function of turns and diameter of coils only. Finally, an experimental prototype is designed based on this method and verified by simulation and experimental results. The performance of the traditional four-coil WPT system and the proposed WPT system using resonant inductor in class E power amplifier are compared. The experimental results show that the output power of the system is increased by 18.7%, the efficiency is increased by 11% and the transmission distance is up to 0.7 m, which is suitable for wireless power supply of electronics and sensors.

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