Investigation of Unequal Planar Wireless Electricity Device for Efficient Wireless Power Transfer

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Abstract. *This article focuses on the design and investigation of a pair of unequally sized wireless electricity (Witricity) devices that are equipped with integrated planar coil strips. The proposed pair of devices consists of two different square-shaped resonator sizes of 120 mm × 120 mm and 80 mm × 80 mm, acting as a transmitter and receiver, respectively. The devices are designed, simulated and optimized using the CST Microwave Studio software prior to being fabricated and verified using a vector network analyzer (VNA). The surface current results of the coupled devices indicate a good current density at 10 mm to 30 mm distance range. This good current density demonstrates that the coupled devices' surface has more electric current per unit area, which leads to a good performance up to 30 mm range. Hence, the results also reveal good coupling efficiency between the coupled devices, which is approximately 54.5 % at up to a 30 mm distance, with both devices axially aligned. In addition, a coupling efficiency of 50 % is achieved when a maximum lateral misalignment (LM) of 10 mm, and a varied angular misalignment (AM) from 0° to 40° are implemented to the proposed device.*

Keywords

Coupling efficiency, magnetic resonance coupling, misalignment, wireless power transfer, Witricity

1. Introduction

Wireless power transfer (WPT) has been a subject of interest among researchers since the feasibility of transmitting power wirelessly was reported by Nikolai Tesla in 1900 [1], [2]. This research interest is further stimulated by the evolution of wireless technologies from fourth generation (4G) to fifth generation (5G) technologies, expected to become mainstream in the year 2020. Compared to 4G, 5G technologies are more focused on the device-to-device communication (D2D) and wearable devices [3]. To facilitate wearable devices, various designs of WPT systems have been introduced through the use of such methods as strong magnetic resonance coupling, also known as Wireless Electricity (Witricity) [4], [5], conventional inductive and capacitive coupling [6], [7] and rectifying antennas (rectennas) [8]. The strong magnetic resonance technique uses two coupled magnetized objects within a non-radiative near-field region at megahertz (MHz) frequencies. As reported in [4], the most efficient way to realize this technique is to couple two identical designs on a similarly resonant frequency. The majority of commercial modern gadgets, including smart phones, tablets, notebooks, and pacemakers, possess the capacity to utilize Witricity. These devices are usually designed to be compact in size. While Witricity transmitter sizes are typically not critically constrained, it is crucial for the Witricity receiver to be as compact as possible in order to be placed in the intended device to be powered. However, there is a drawback when designing a compact Witricity device. The range of transferred power firstly depends on Witricity size, which corresponds to the wavelength. Thus, smaller Witricity device tends to transfer less efficient power compared to larger Witricity device. Therefore, the feasibility of coupling unequally sized transmitter and receiver Witricity devices is shown in this article. Nevertheless, the level of transferred power is not limited by the size of the device, but also influenced by the transfer distance and alignment of the transmitter and receiver as presented investigation.

In a bid to achieve compact designs, planar-type Witricity devices have been proposed in [9–12]. These designs use flat single or multilayer coils, with different conductor levies, to create a homogenous magnetic field between transmitter and receiver [9]. In [10], the authors have proposed a Witricity design with equal transmitter and receiver ($162 \times 162\ mm^2$) sizes by using a plastic lamella board, and investigate the performance of the Witricity devices when angular and lateral misalignments occur. Copper tape is used as the inductor coil and capacitor plates. For the single coil, copper wire has been attached to the capacitor plates. This single coil provides high inductance due to its loop's large diameter and thick cross-sectional area. Another Witricity design has been proposed in [11], which is a quarter of the size ($80 \times 80\ mm^2$) of the design reported