Highly Integrated Uniplanar Rectenna Operation Without Reflecting Plate for 2.45 GHz Wireless Power Transmission

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1. Introduction

In recent years, wireless power transfer has gained a great attention in many of wireless sensor applications [1-4]. As a key component in a wireless power transmission system, a rectenna undertakes the task to convert the received RF power into dc power which can then be consumed by other subsystem [5-9]. From the literatures [5-10], a rectenna design is a system design, which commonly includes antenna, filter, matching network, and part of rectifying circuit. For accuracy, most of the design work need system Circuit/EM Co-simulation to guarantee the required performance [3-10], and these processes lead to increase the design cycle time a lot. On the other side, compact size, low cost, and high integration have been required in modern wireless communication system. Several compact and low cost and uniplanar rectenna systems have been reported with high conversion efficiency [5, 7]. However, the operations of the reported rectennas need a tuneable reflecting plate which may disobey the tendency of easily and highly integration in modern wireless communication system. In this paper, a novel and highly integrated uniplanar rectenna system is proposed. The proposed rectenna works in the direction along the substrate, and then, no conventional reflecting plate is needed. A 2.45 GHz rectenna system is designed and measured to guarantee their microwave performances.

2. Rectenna Design

Recently, a wideband planar folded dipole antenna with self-balanced impedance has been studied [11]. About 50% bandwidth is reported at 1.7 GHz. In the operating band, the gains of the antenna are almost constant (2 dBi) and the radiation patterns are very similar to those of a normal dipole antenna. In this paper, the method to reach the self-balanced impedance is used to build the proposed highly integrated rectenna system. The proposed rectenna is shown in Fig. 1. When the RF energy transfers to the rectenna, benefiting from the RF short chip capacitor, the RF signal is received by the diode-loaded wideband folded dipole without the upper coplanar strip line and load resistor. The diode rectifies the RF energy received from antenna directly which saves the matching network. From DC point of view, the RF-short chip-capacitor forbids the DC signal to pass through it, and thus the received RF energy would be delivered to the load resistor. Impedance matching is an important factor for the system efficiency. Thanks to the impedance-tuning potential of such wideband folded dipole, the conjugate matching design between the antenna and diode by tuning the structure of the folded dipole is possible. The harmonic-rejecting requirement is also considered by introducing a pair of super-strip line in the centre of the bottom side of the folded dipole as shown in Fig. 1. The ¼ λ coplanar strip line is used for connecting to the load resistor to realize a RF open effect at the position of load. To save the tuneable reflecting plate the folded dipole antenna is designed for operating in the direction along the substrate. The f value in Fig. 1 is important for the antenna gain. There are several advantages we can expect from this simple rectenna system. No diode matching network needed in this system, and thus the components can be saved, and theoretically the improved efficiency can be obtained. The rectifying circuit is almost embedded in the antenna, thus the system size is much decreased. In addition, since the antenna part is in front of the other parts of the proposed rectenna system, most of the RF energy will be first received through the part of antenna and there will be less effect on the other part of the system compared with the one with the reflecting plate [5, 7]. To guarantee this simple rectenna system, a 2.45 GHz rectenna is designed and fabricated on the 0.54 mm thick Teflon substrate (dielectric constant = 2.54) with 0.018 mm copper cladding. The general design flow is similar with our recent article [12]. A Murata 2.5 pF chip capacitor is used for this 2.45 GHz operation for good insertion loss. A Schottky Mixer Diode (HSMS-8101) is used as the rectifying device. Agilent Advanced Design System (ADS) 2008 is used to find the diode matching impedance. The total rectenna system including chip capacitor and load resistor are finally optimized by Full-wave EM simulator IE3D based on method of moments with the finite substrate. The detailed size of the designed rectenna is tagged in Fig. 1.

3. Rectenna Measurement

The measurement setup and conversion efficiency calculation is followed by the study [6], while the horn antenna is replaced by a 2×2 patch array with the gain of 9.8 dBi as the transmitting antenna. The external resistive load used in measurement is 270 Ω. The detailed setup is shown in Fig. 2. To calculate the system efficiency, the proposed folded dipole antenna gain is needed. However, the proposed folded dipole antenna is not designed based on 50 Ω, and it is hard to measure accurately the proposed antenna gain in that situation. To calculate the conversion efficiency, the simulated gain is used. The wideband characteristics of the designed rectenna make the calculation more safety, since the simulated results show almost constant gain from 2.3 GHz to 2.6 GHz. Finally, the gain of 2.05 dBi is used in the efficiency calculation. It should be pointed out, in conventional calculation of conversion efficiency of the rectenna, the antenna with filter network is used for the design and measurement without considering the effect of load and diode. Since the proposed rectenna gain is simulated including all the system components, it is a more systematic design method, and very suitable for the first-pass system success. Fig. 3 shows the experimental results of output voltage and calculated conversion efficiency against power density. In the measurement, when we rotate the rectenna from the proposed working direction to the direction with the reflecting plate as in Fig. 2, the measured output voltage is much reduced, which means the incident RF power has a noticeable effect on other than the part of antenna for system performance. So, the uniplanar type of rectenna mostly use a tuneable reflecting plate to not only improve energy received of the antenna part but also tune the effect caused by exposing the other part of the system in radiation environment for finding the best operating performance for the final rectenna system.

4. Conclusion

A simple and highly integrated uniplanar rectenna system has been developed. It has been shown that the proposed rectenna system can be worked without the reflecting plate which meets the requirement of integration in modern wireless communication system. The proposed rectenna has a compact size, uni-planar, and low cost. It is very easy to fabricate and connect to the other subsystem to offer the power. Considering the above advantages, this novel rectenna system is very suitable for the small wireless sensor application system such as bio-sensor or totally passive low cost RFID system to provide the power.

5. Figures and Tables

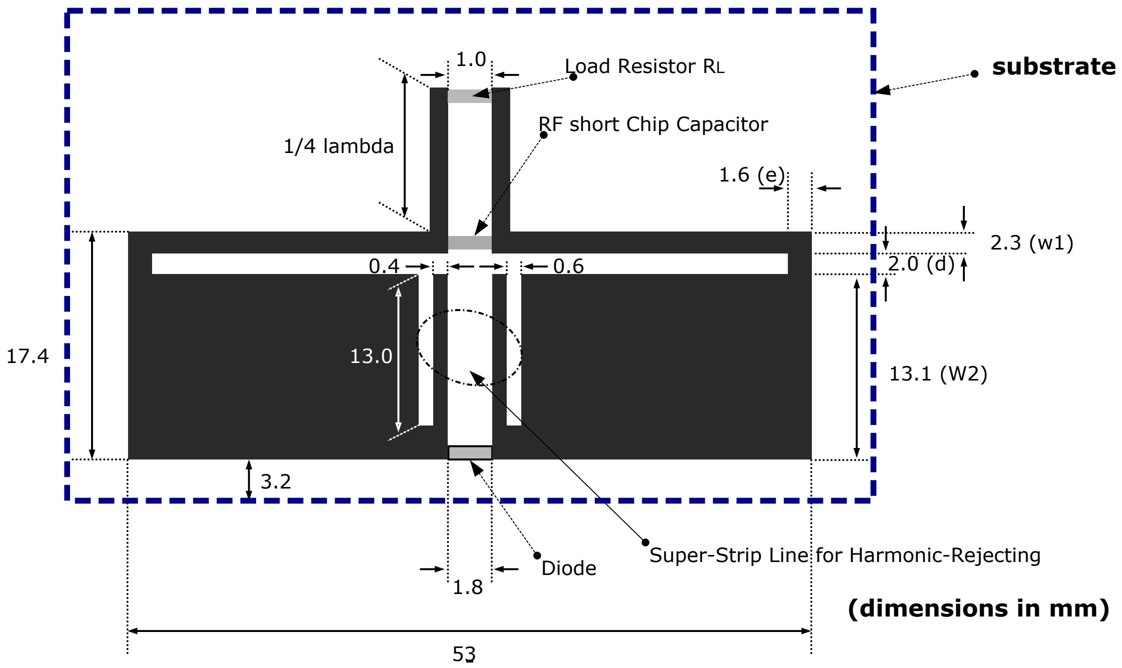

Fig. 1 Geometry of the proposed rectenna with detailed size

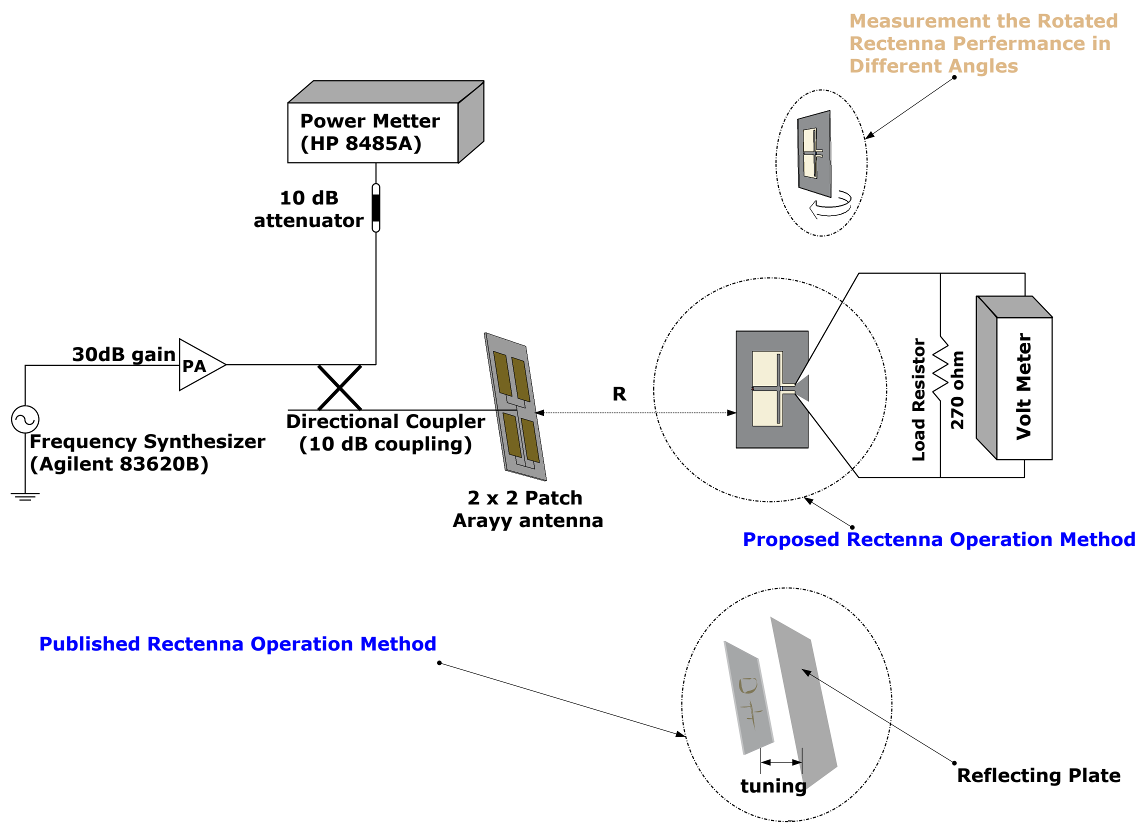

Fig. 2 Rectenna measurement setup including both conversional and proposed operation method

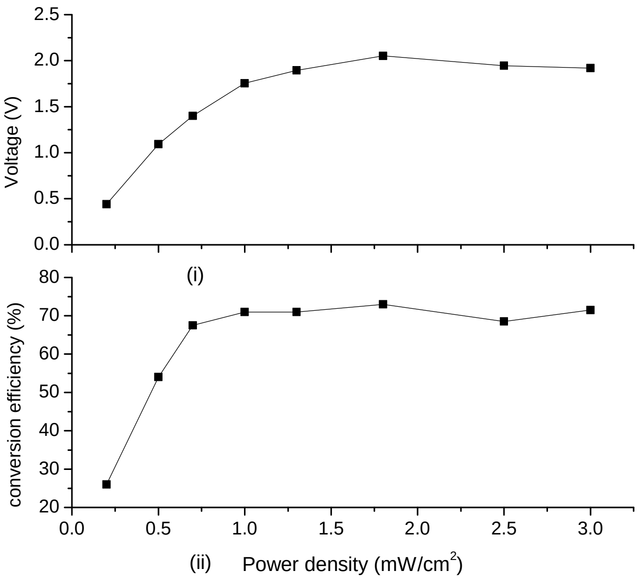

Fig. 3 (i) Measured DC output voltages (ii) Calculated conversion efficiencies

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