A Compact Shorted Patch Rectenna Design with Harmonic Rejection Properties

Jui-Hung Chou[1], Ding-Bing Lin[2], and Ling Tien[2]
[1]Electronic System Research Division, National Chung-Shan Institute of Science and Technology, Taiwan
[2]Department of Electronic Engineering, National Taipei University of Technology, Taiwan

***Abstract* – This paper presents a compact design of shorted patch rectenna with the harmonic rejection properties for the applications of wireless power transmission. In order to improve the power conversion efficiency (PCE), the harmonic rejection filter (HRF) is replaced by etching a U-shape slot resonator on the shorted patch antenna. As a result, this method may improve the PCE without sacrificing the capability of higher order harmonic noise rejection.**

***Index Terms* — Rectenna, harmonic rejection, wireless power transmission.**

1. Introduction

Microwave wireless power transmission (WPT) has recently received much attention from the field of space-based solar power transmission research because of its potential to deliver green energy from space. In particular, the rectifying antenna (rectenna) plays an important role in WPT system to collect the wireless energy transmitted by electromagnetic (EM) waves in free space and transform this energy into DC voltages [1]. In general the rectenna consists of six core components including a receiving antenna, harmonic rejection filters (HRFs), impedance matching networks, rectifying diodes, DC pass filters, and resistive load [2], where the energy is first collected by the receiving antenna, and the higher order harmonic noises generated by the rectifying diodes are then rejected by using HRFs.

This paper presents a compact design of shorted patch rectenna with harmonic rejection properties for wireless power transmission. In order to improve the PCE of the receiving rectenna, the HRFs in the conventional design are removed to prevent the additional insertion loss caused by the HRFs.

2. Rectenna Configuration

(1) The Configuration Antenna and its Characteristics

The geometry of the proposed shorted patch rectenna with harmonic rejection properties is illustrated in Fig. 1. In the design, the receiving antenna consists of a metal shorted radiating patch with a U-shape half-wavelength slot resonator on the top layer, a system ground plane as the second layer, and a microstrip-line matching network with the rectifying circuit on the bottom layer. Thus the length of the U-shape slot resonator is determined by the 3rd harmonic frequency of the proposed receiving rectenna to alter its resonance. To match the input impedance of the proposed antenna, rectifying circuits were replaced with microstrip lines with a characteristic impedance of 50 ohm.

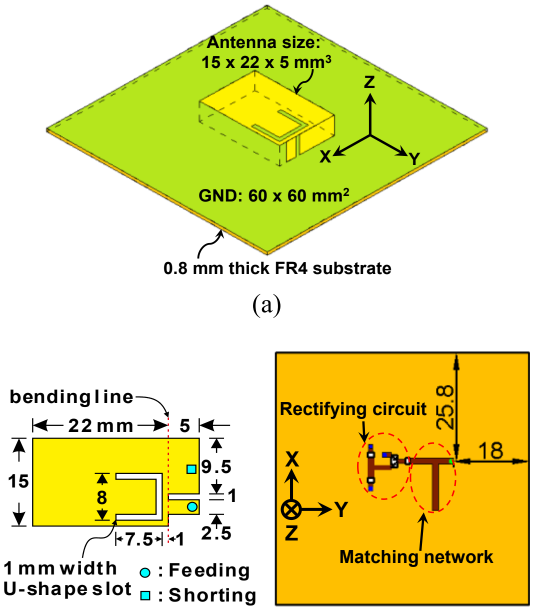

Fig. 1 The geometry of the proposed rectenna with the harmonic rejection functions. (a) 3D view, (b) the detailed dimensions of antenna, (c) bottom view.

The simulated and measured reflection coefficients in Fig. 2. The operational bandwidth at the 1st resonant frequency (2.45 GHz) is approximately 85 MHz defined by the threshold of -10 dB reflection coefficient. The radiation characteristics are shown in Fig. 3. The slight difference along the -Z direction can be attributed to the coaxial cable and SMA connector used in the measurement, which however does not significantly affect the performance of antenna since the EM waves are incident from the antenna boresight in the practical applications. In this design, the measured gain is approximately 4 dBi in the boresight direction.

(2) Mechanism of Harmonic Rejection

The U-shape slot resonator is designed to replace the HRFs in this rectenna system to avoid re-radiation at the higher

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order harmonic frequencies, where the signals are caused by the rectifying diode, which will help to simplify the system. The conventional design of HRFs intends to retain the fundamental signal while in the meantime rejecting the high-order harmonic noises generated by the diodes. As exhibited by the measured reflection coefficients in Fig. 3, the measured reflection coefficient at the 2^{nd} (4.9 GHz) and 3^{rd} (7.35 GHz) harmonic frequencies are -0.96 and -1.1 dB, respectively.

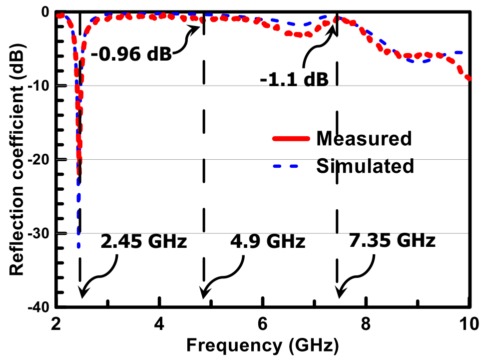

Fig. 2 Measured and simulated reflection coefficients of the proposed antenna.

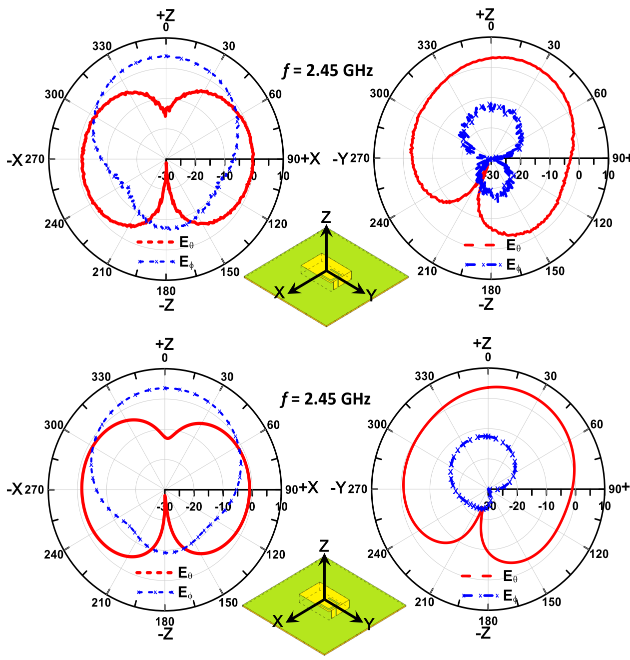

Fig. 3 Measured and simulated radiation patterns of the proposed antenna.

By observation of the current distribution and the simulation results to determine the U-shape slot position (detailed dimensions show in Fig. 1(b)). The comparison of antennas' reflection coefficients with and without the U-shape slot is shown in Fig. 4. It may be observed that the reflection coefficients have changed from -0.47 and -5.26dB to -0.37 and -0.67dB for the 2^{nd} and 3^{rd} harmonic frequencies, respectively.

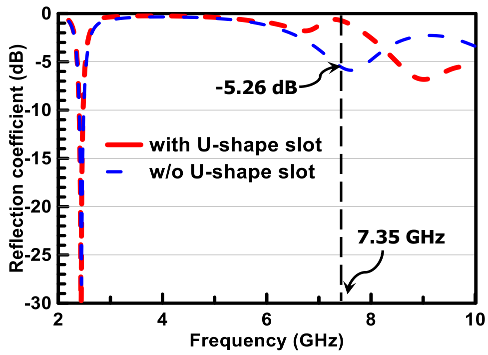

Fig. 4 Simulated reflection coefficients of the proposed antenna with and without the U-shape slot resonator.

(3) Rectifying Circuit

The rectifying circuits are used for transforming RF power into DC power. Due to the harmonic rejection properties of the conventional rectifying circuit integrated with the proposed receiving antenna, the HRFs in the proposed rectifying circuit can be removed. In order to collect the wireless energy from free space and convert it to DC voltage more efficiently, the input impedance (Z_d) of the rectifying circuit at P_{inc} = 20 dBm is selected to be 15.1 – j1 Ω at a load impedance R_L = 1 KΩ. Thus the input impedance looking into the receiving antenna (Z_a) is Z_a equals Z_d^* for a perfect conjugate matching in impedance to achieve maximum power transformation.

3. Measurement Results

Here the PCE (η_{CE}) is defined by:

$$\eta_{CE}\% = \frac{P_{DC}}{P_{inc}} \times 100\% = \frac{V_{DC}^2}{R_L \cdot P_{inc}} \times 100\% \qquad (1)$$

,where V_{DC} represents the output voltage measured on the load resistance R_L, and *Pinc* represents the incident power delivered to the rectifying circuit. The maximum P_{CE} can be up to 83.1% when the incident power increases to 21 dBm. The corresponding output voltage Vout at the maximum PCE is approximately 10.23V.

4. Conclusion

A compact shorted patch rectenna with harmonic rejection properties, including 2^{nd} and 3^{rd} harmonic noise rejection, has been proposed. The results show that the conversion eff-iciency of the proposed rectenna reaches its maximum 83.1% at a circuit incident power 21 dBm, and an output voltage of 10.23 V.

References

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