

# A Compact Dual Band Antenna For Microwave Power Harvesting

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## Abstract

This paper presents a novel antenna operating at 5.8 GHz and 10 GHz for power receiving (power harvesting). The antenna consists of a crossed slot antenna with two loops. Using the proposed design, its maximum aperture dimensions are smaller than a length of a normal slot antenna. Calculated RF-to-dc conversion efficiencies at 5.8 GHz and 10 GHz are 61% and 63.1 % with 3V dc voltage.

**Keywords :** Rectenna, Hairpin lowpass filter, Crossed slot antenna, Rectifier circuit, Wireless power transmission

## 1. Introduction

A rectifying antenna (rectenna) is a device which collects and converts RF power into dc power. Since Tesla's experiments, many kinds of rectennas have been developed for wireless power transmission, and a history of the development is reported well in [1]. In the early time, rectennas were mainly designed for high power transmission. However, recently, low power rectennas have been also researched to provide dc power for wireless sensor networks (WSN) and radio frequency identifications (RFID) [2], [3], [4]. Usually, WSN and RFID require small volumes of power modules. Hence, the rectennas should have small volumes as well. This trend results in small volumes of antennas, and printed antennas can be a solution for this challenge. Several authors have already studied about printed antennas operating at a single resonant frequency or dual resonant frequencies for power harvesting [5], [6], [7]. However, aperture dimensions of these antennas are about a half wavelength or even more.

To overcome this problem, a new compact dual band antenna for rectifying RF power is presented in this paper. The proposed antenna is designed to operate at 5.8 GHz and 10 GHz simultaneously. Higher resonant frequencies can benefit longer distance power transmission and size reduction of the rectenna. Even though some compact antennas do not have high radiation efficiencies, the antenna has high radiation efficiencies over 85 % at 5.8 GHz and 10 GHz, individually. And, aperture dimensions of the antenna are about 30% smaller in comparison with a normal slot antenna (a half guided wavelength). A full-wave EM simulator, CST Microwave Studio, is used to design and optimize the antenna.

## 2. Design and Results

The structure of the antenna is presented in Figure 1. The antenna is printed on a front side of Rogers RO4003 substrate with  $\epsilon_r = 3.38$  and thickness of 0.508mm, and a microstrip transmission line is printed on a back side of the substrate. The geometrical parameters and values are obtained from full-wave simulations and provided in Table I. Detailed principles of a crossed slot antenna, fed by coplanar waveguide transmission lines, were studied in [8]. In [8], it was used to radiate dual-polarized electric fields by two orthogonal feeding lines. In this paper, two loops are inserted into the crossed slot for dual band operation at 5.8 GHz and 10 GHz. This antenna is simply fed by the microstrip line which have the advantage of selecting the load resistance conveniently. Another advantage is protecting a rectifying circuit from undesired incident RF waves with a ground plane.

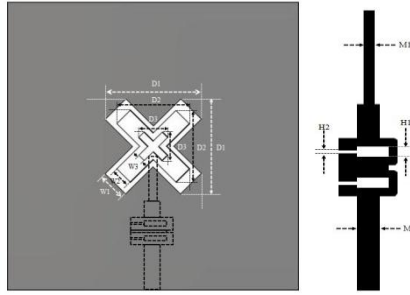


Figure 1 : The topology of the antenna and the the hairpin lowpass filter.

Table I : The geometrical parameters and values

| Parameters  | D1  | D2  | D3 | W1 | W2 | W3  | M1  | M2   | H1  | H2   |
|-------------|-----|-----|----|----|----|-----|-----|------|-----|------|
| Values (mm) | 9.9 | 7.5 | 3  | 3  | 2  | 0.8 | 0.6 | 1.13 | 0.5 | 0.17 |

A prototype of the dual band crossed slot antenna is simulated to calculate a frequency response. The frequency response is shown in Figure 2. This result verifies that the antenna operates at dual resonant frequencies. As shown in Figure 2 (a), the antenna produces undesired higher harmonics. In addition to these harmonics, a non linear diode also generates higher harmonics. To increase RF-to-dc efficiencies of the rectenna, all undesired higher harmonics should be refrained. Therefore, a lowpass filter should be added to the antenna. In this paper, a hairpin lowpass filter is selected. The hairpin lowpass filter was already used to design a compact size rectenna in [9]. Figure 2(b) shows the frequency response of the antenna with the hairpin lowpass filter. It is verified that the undesired harmonics were effectively suppressed. The measured frequency responses with the lowpass filter are presented shown in Figure 3. Mismatches of the simulated and measured responses are due to fabrication tolerance. The calculated radiation patterns are shown in Figure 4, and, the radiation efficiencies are 88% at 5.8 GHz and 96% at 10 GHz.

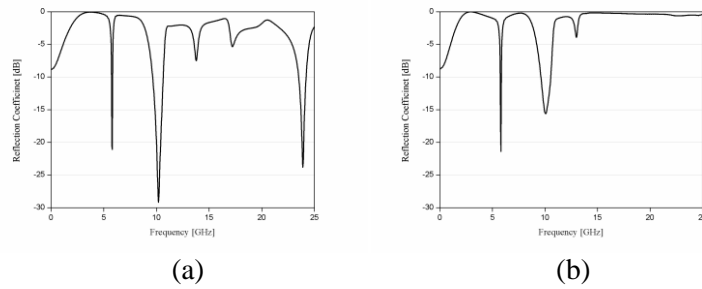


Figure 2 : The calculated frequency responses of the antenna (a) and with the lowpass filter (b)

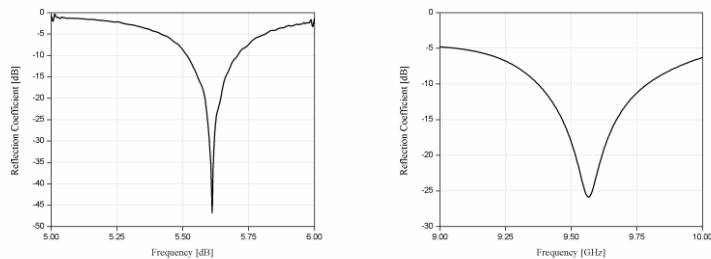


Figure 3 : The measured frequency responses of the antenna with the lowpass filter

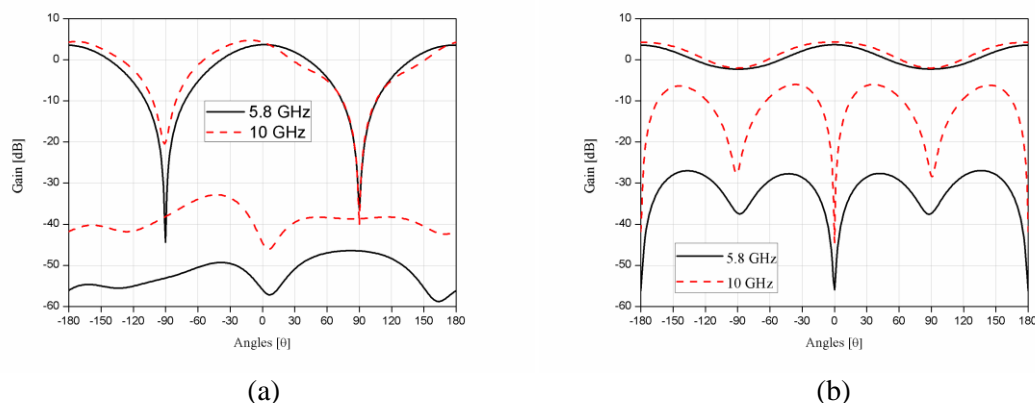


Figure 4 : The calculated radiation patterns in (a) E-plane and (b) H-plane

Generally, a rectifying circuit consists of a Schottky diode, a dc block capacitor and a load resistance. Detailed design of a rectifying circuit for a microstrip transmission lines was already studied in [9]. In this paper, a GaAs Schottky diode (MA4E1317) is also used to obtain dc output. A zero-bias junction capacitance of the diode is 0.02 pF, and a series resistance is 4  $\Omega$ . Its breakdown voltage is 7 V, and a forward-bias turn-on voltage is 0.7 V. The RF-to dc conversion efficiencies of the diode can be easily calculated using equations in [5]. Figure 5 shows the calculated efficiencies at 5.8 GHz and 10 GHz with 3V dc output. In this paper, a 58  $\Omega$  load resistance and a 470  $\mu$ F dc block capacitor are selected.

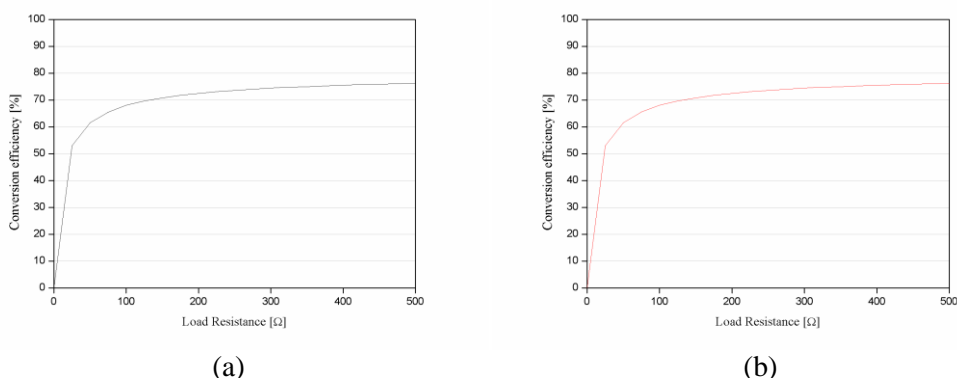


Figure 5 : Calculated RF-to-DC conversion efficiencies at (a) 5.8 GHz and (b) 10 GHz

## 4. Conclusion

A dual band antenna for harvesting RF power was developed. A crossed slot antenna with two loops was designed to operate at 5.8 GHz and 10 GHz. The proposed antenna has high radiation efficiencies, even though its size was reduced. Undesired higher harmonics were effectively suppressed by using a hairpin lowpass filter.

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