# Enhanced Narrow-Band Operation of Ultra-Fast Rectennas

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***Abstract*—An effective impedance matching technique for rectennas (an antenna coupled with rectifier) operating at specific frequencies is presented. The rectifier consists of an MIM junction with a molecular insulator. The method used two coplanar strip lines emerging from the antenna feed-point, to correct for the reactive component of the antenna impedance on one side, and to connect the rectifier and transform its impedance on the other side. Microwave and mm-wave characterization of the devices showed that the responsivity of the impedance matched rectenna is almost an order of magnitude higher than that of a control device without matching network at 20 GHz.**

## I. INTRODUCTION

A rectenna is a rectifier coupled to an antenna, which can convert electromagnetic radiation to an electrical dc signal. Fast rectifiers, such as metal-insulator-metal (MIM) junctions, Schottky diodes, and more recently the self-switching nanodiode, are often used in these applications [1-2] due to their ability to operate at frequencies well into the terahertz range. The major drawback of these devices, however, is the relatively low external conversion efficiency, caused mainly by the mismatch between the impedance of the antenna –tens to hundreds of Ω– and that of the rectifier, which is typically as high as several kΩ [2].

This work presents a simple and effective technique for matching the impedance of a typical bow-tie antenna to a rectifier with a zero-bias impedance of several kΩ. The device operates as a high-efficiency rectenna, which can be used in applications where efficient narrow-band operation ranging from microwaves to terahertz is of paramount importance, as well as to maximise the signal-to-noise ratio in detection and imaging systems.

## II. RESULTS

Preliminary work [3] presented this impedance matching idea via numerical simulations; here we report on the first experimental results, which confirm our original model. The equivalent antenna impedance seen by the diode was transformed by two coplanar strip lines connected to antenna feed-point, as shown in the fabricated structure of figure 1 (c). The function of the top line is that of an open-circuit stub of length $L_{STUB}$, whose susceptance $B_{STUB}$ is in parallel to the antenna admittance $Y_A$. The line on the bottom, of length $L_{FEED}$, connects the diode to the antenna, and transforms the antenna-stub admittance to match the complex conjugate admittance of the diode $Y_D$:

$$Y_D^* = Y_0\left(\frac{1-\Gamma e^{-2ikL_{FEED}}}{1+\Gamma e^{-2ikL_{FEED}}}\right) \quad (1)$$

where

$$\Gamma = \frac{Y_0 - Y_A - iB_{STUB}}{Y_0 + Y_A + iB_{STUB}}, \quad (2)$$

$$B_{STUB} = Y_0 \tan kL_{STUB}, \quad (3)$$

$Y_0$ and $k$ being the characteristic admittance and phase velocity of the coplanar strip lines, respectively.

Rectennas operating microwave and mm-wave frequencies were designed with a self-complementary bow-tie antenna on a low-loss glass substrate (εr ≈ 4.8), using our MIM junctions as the rectifier. The optimal line lengths were determined by solving Eqs. (1)-(3) using Matlab optimization toolbox. The design was then imported into ADS for the simulation of the impedance and radiation pattern, further optimizing the line lengths accounting for the parasitic capacitances introduced by the line ends, and to study other possible loss mechanisms.

The dimensions found with the above method where used for the final device fabrication. Preliminary microwave characterization at 20 GHz showed that impedance-matched rectenna (figure 1 (c)) resulted in improved responsivity almost one order of magnitude higher than that of the control non-matched (figure 1 (a)) devices.

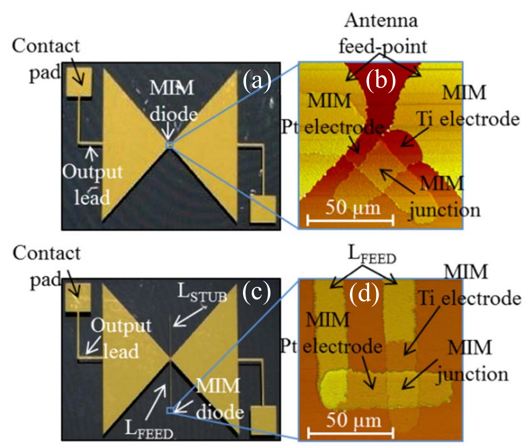


**Fig. 1.** Optical image of the fabricated rectenna structures. (a) Is the non-matched device. (b) Is an AFM image of the MIM junction connected at the antenna feed-point of the non-matched device. (c) Is the impedance-matched device, and (d), an AFM image of the MIM junction connected at the coplanar strip line end of the impedance-matched device.

## III. SUMMARY

A simple and elegant technique to match the low impedance of an antenna to the high impedance of a fast rectifier has been implemented and tested in zero-bias rectennas. The design is suitable for narrow-band applications, which, combined with MIM junctions can extend up to THz frequencies.

## REFERENCES

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