Reactive nonlinearity for power harvesting-inspired frequency downconverter

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1. Introduction

Every low power harvesting system has to cope with low efficiency issues. As the most common nonlinear element in rectification, Schottky diode has advantages of being broadband and loosely sensitive to load variation. However, it is a nonlinear resistive device which causes significant Joules loss in low power rectification, and thus results in low RF-to-DC conversion efficiency. For an input power in the μW range, the efficiency for a Schottky diode-based rectifying circuit is usually few percent [1].
This problem might be circumvented with a purely nonlinear reactive element because in that case the energy stays in the system until it is converted and harvested. Moreover, the inherent narrow band characteristic of a reactive system is not a limitation for such applications since a basic rectifier is generally designed to be narrowband. The best nonlinear reactance devices commercially available that are low loss and present satisfying nonlinearity are varactors [2]. Although the parasitic resistance also induces power or signal losses, a typical varactor has a series resistance less than 1Ω.
In this paper, a hyper-abrupt varactor-based frequency downconverter is designed and simulated in Advanced Design System (ADS). A conversion efficiency around 15% is achieved, when the input RF and LO power are both -30dBm.

2. Varactor-Based Frequency Downconverter

The basic concept of the proposed circuit is to realize RF/DC conversion by merging a varactor-based frequency downconverter followed by a lower frequency AC/DC synchronous rectifier. The AC/DC converter is used because the impedance of varactor at f = 0Hz will be infinite. However, it is not investigated in this paper.
For a frequency downconverter, two input signals, namely RF and LO signal, are required. Considering a practical power harvesting system, the RF and LO signals are assumed to have the same power level of -30dBm. For demonstration, the RF (ω_s) and LO (ω_p) frequencies are designed as 3GHz, and 2 GHz, respectively. Figure 1 shows the diagram of the varactor-based downconverter. A commercial hyper-abrupt varactor with a series resistance of 0.6 Ω is utilized.

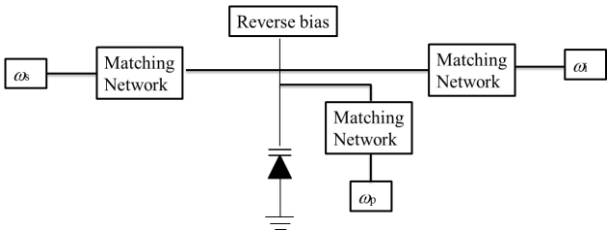

Figure 1. Diagram of the proposed varactor-based frequency downconverter.

The conversion efficiency is calculated as:

$$\eta_{RF\to IF} = \frac{P_i}{P_s + P_p} = \frac{P_i}{2P_s} \quad (1).$$

where P_i, P_s, and P_p is the IF, RF, and LO power, respectively. A power around 300 nW was obtained at the IF (1GHz) load, and the conversion efficiency is about 15% using *Eq*.(1).

3. References

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2. P. Penfield and R. P. Rafuse, *Varactor applications*:MIT Press Cambridge, 1962.