# Low cost microwave rectifier
# for low and high powers

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## Abstract

Studies on various microwave power rectifier configurations show that a bridge configuration is better than a single diode one. But the dimensions and the cost of that kind of solution do not meet our objective. This study consists in designing and simulating a single diode power rectifier "in hybrid technology" with improved sensitivity at low power levels. We achieved good matching between simulation results and measurements thanks to the optimisation of the packaging of the Schottky diode. The simulation results obtained in OMMIC Technology demonstrate the good efficiency of the circuit for high powers.

## I. Introduction

Microwave energy transmitted from space to earth apparently has the potential to provide environmentally clean electric power on a very large scale. The key to improve transmission efficiency is the rectifying circuit[1],[2],[3]. The aim of this study is to make a low cost power rectifier for low and high power levels at a frequency of 2.45 GHz with good efficiency of rectifying operation. The objective also is to increase the detection sensitivity at low levels of power.
Different configurations can be used to convert the electromagnetic wave into DC signal, the study done in [4] showed that the use of a bridge is better than a single diode, but the purpose of this study is to achieve a low cost microwave rectifier with single Schootky diode for low and high power levels that has a good performances.
This study is divided on two kind of techhnologies the first is the hybrid technology and the second is the monolitic one.

## II. Hybrid integrated microwave technology

The goal of this investigation is the development of an hybrid microwave rectifier with single Schottky diode. The first study of this circuit is based on the optimisation of the rectifier in order to have a good matching of the input impedance at the desired frequency 2.45GHz. Besides, the aim of the second study is the increasing of the detection sensitivity at low levels of power.
The purpose is to achieve a microwave rectifier at 2.45 GHz with good optimisation of the microstrip lines that has good performances. This circuit is achieved using two kinds of PCB (Printed Circuit Board) materials: FR4 and RO3003. The principle proprieties of these materials are given in table 1.

| Materials proprieties | FR4 | RO3003 |
|---|---|---|
| Copper thickness: T | 0.035 mm | 0.035 mm |
| $e_r$ | 4.7 | 3 |
| Dielectric thickness: h | 1.6 mm | 1.52 mm |
| Tangential losses: tan$d$ | 0.0013 | 0.0013 |

*Table 1. Materials proprieties*

### *A- RF to DC conversion circuit*

Rectifier circuit(fig.1) is simulated using AgilentADS (Advanced Design System), with the HB "Harmonic Balance" and LSSP simulators, for the RF-DC conversion we have used an HSMS2820 zero bias Schottky diode from Agilent Technologies[5]. We have optimised the circuit by introducing the parasitic elements [6] of the Schottky diode which were optimised [4] to reach a good impedance matching and an important conversion efficiency for the both PCB at the desired frequency 2.45 GHz .

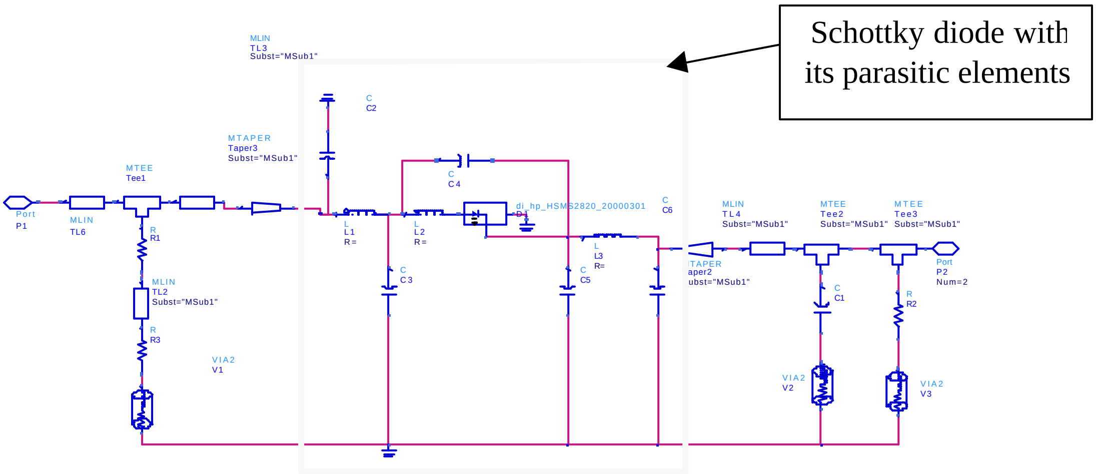


*Fig.1. Microwave rectifier at 2.45 GHz*

Simulation results (fig.2) show that the microwave rectifier begins to detect at –5 dBm for the both substrates FR4 and RO 3003. The conversion efficiency reach 90% for 24 dBm with a good impedance matching, for example at 10 dBm we have S11 = –28dB for RO3003.The simulation demonstrates also that the choice of the load resistance is so critical for the optimisation of the impedance matching. As a conclusion the detection sensitivity is so small for low power levels, then the aim of the second study is to improve it.

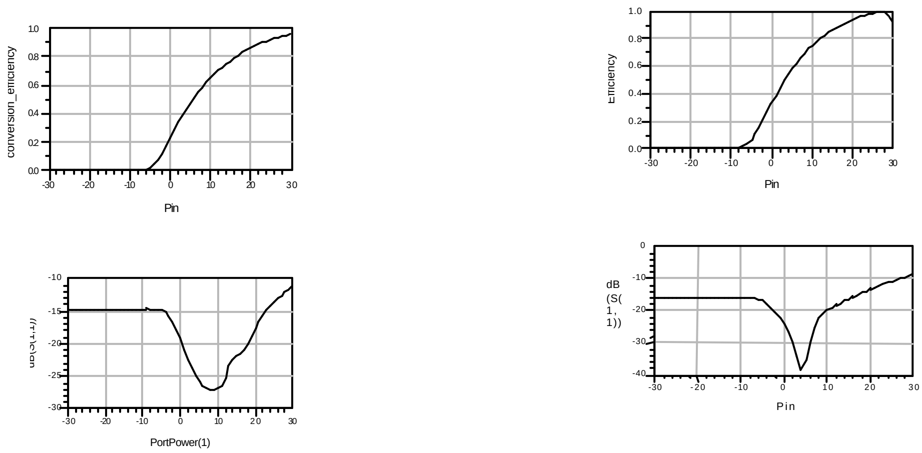


*Fig.2 . conversion efficiency, reflexion coefficient for RO 3003(left) and FR4(right)*

## *Measurements results*

The realization of the microwave rectifier is done using the both PCB FR4 and RO3003, for the load resistance we have taken 230Ω for RO 3003 and 270Ω for FR4, for the DC low pass capacitor is equal to 100pF.
As shown on (fig.3) the measurements results agree with the simulation which improve the performance of the rectifier circuit at 2.45GHz for the matching of the impedance and also the conversion efficiency.

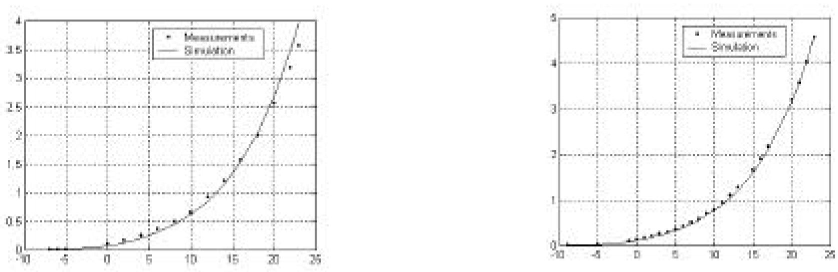

*Fig.3. DC output voltage (V) versus input power for RO 3003(left) and* FR4(right)

*B- Sensitivity improvement*

As showed before the detection sensitivity is small at low power levels then this study is to improve the conversion circuit sensitivity at 2.45 GHz for RO3003 substrate. The technique that we have used to increase this sensitivity is to add the same HSMS2820 in series with the load resistance.

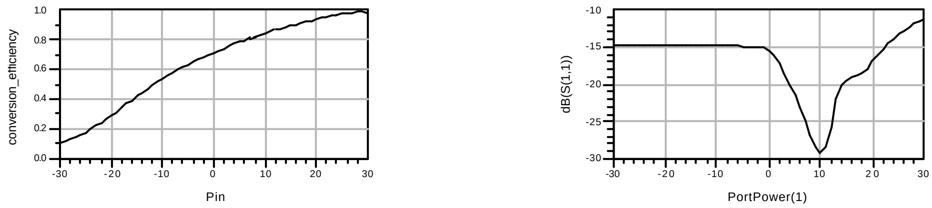


*Fig.4 . Simulated conversion efficiency and reflexion coefficient versus input power for Ro 3003*

The simulation results (Fig.4) show that with this technique the detection sensitivity is increased . It starts at –30 dBm with good conversion efficiency for example we have 97% for 25 dBm and a good impedance matching.

*Measurements results*

The realization is done for the both substrates FR4 and RO 3003, measurements results are shown in (fig.5). Measurements and simulation results agreed fairly well for the both PCB and The detection sensitivity is increasing. The rectifier starts to detect at –20dBm in comparison with –5dB obtained without using the increasing sensitivity technique .

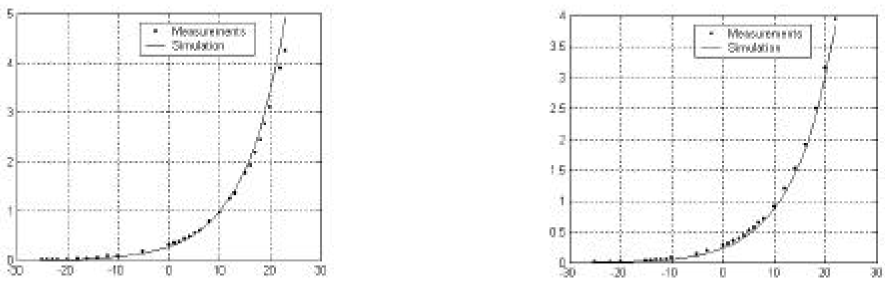


*Fig.5. DC output voltage versus input power for RO 3003(right) and FR4(left)*

## III. Monolithic technology

The rectifier simulation is done on monolithic technology using ED02AH (OMMIC KIT), the circuit (Fig.6) is simulated and optimised using the HB simulator at the desired frequency 2.45 GHz. The diode used for rectifying operation is digmED2 for large signal.

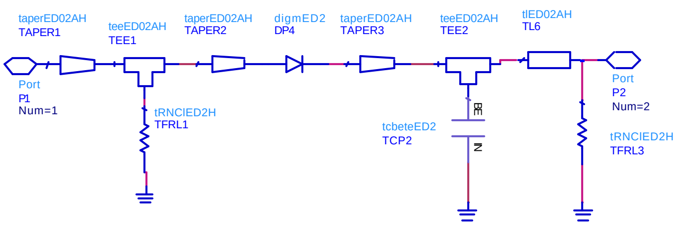


*Fig.6. Monolithic microwave rectifier*

The simulation results (Fig.7) allow to obtain a monolithic microwave rectifier with an interesting conversion efficiency for large variation of power levels and a good impedance matching optimisation.

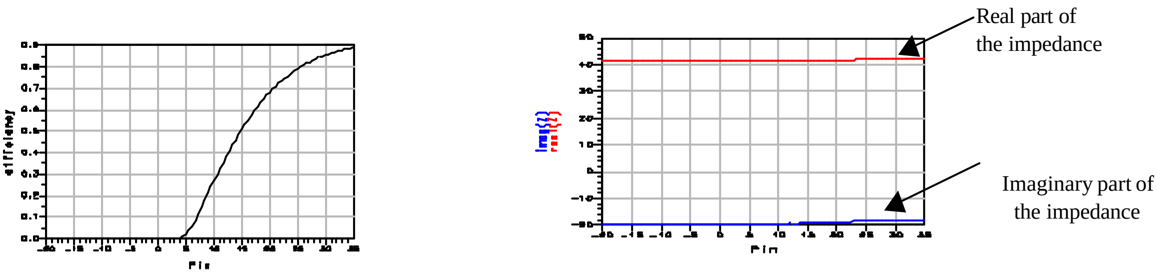


*Fig.7 . Simulated conversion efficiency and real and imaginary input impedance versus input power*

To increase the sensitivity of the rectifier we have used the same technique chosen for hybrid technology and also using the same diode digmED2 in series with the load resistance. The simulation results are presented on (Fig.8).

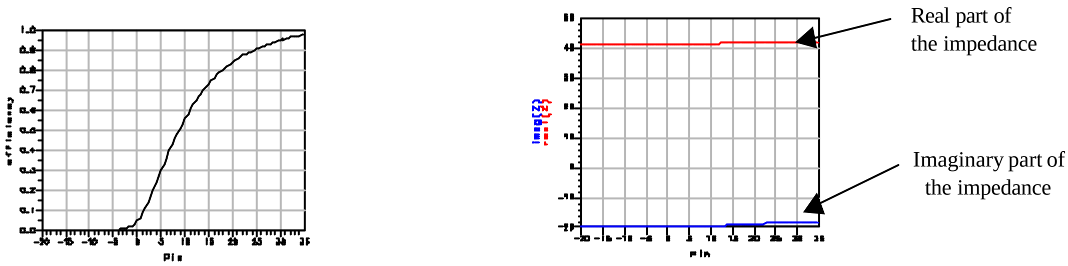


*Fig.8 . Simulated conversion efficiency and real and imaginary input impedance versus input power*

As a comparison the detection sensitivity with this technique is increasing. the circuit detect at -5 dBm and without it the circuit begin to detect at 5 dBm then the sensitivity of the rectifier circuit is improved.

## VI. Conclusion

The best agreement between simulation and measurements is achieved in hybrid technology permits to make a microwave rectifier with good performances, besides the sensitivity detection of the circuit is improved for low power levels. The exploitation of the methodology of the simulation of the rectifier circuit in monolithic technology demonstrated the feasibility to achieve a rectifier with low cost and better performances for small and large signal.

## References

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[6]Application Note, Alpha industries "Circuit Model for Plastic Packaged Microwave Diodes " .