Broadband Printed Antenna for Radiofrequency Energy Harvesting

L. Vincetti[1] M. Maini[1] E. Pinotti[1] L. Larcher[2] S. Scorcioni[2] A. Bertacchini[2] D. Grossi[3] A. Tacchini[3]

Abstract **– In this work a broadband UHF antenna with high inductive input impedance for radiofrequency energy harvesting is presented. It consists of a small feeding loop and a biconical radiating dipole. A prototype has been fabricated on a FR4 substrate and tested. Experimental results show a -3dB power transmission bandwidth of about 135MHz (840MHz–975MHz).**

1 INTRODUCTION

In recent years, energy harvesting (EH) technique based on radio frequency (RF) electromagnetic waves has captured many research interest in many fields such as RF identification (RFID), wireless sensor networks [1], [2], and bionic implants [3].

Rectification circuits of the RF-EH systems must be optimized to reduce the minimum power-threshold needed for the system to operate. Usually to get that target, chips containing rectifier circuits exhibit a complex input impedance with a small resistance, and a high capacitive reactance. Since matching networks can not be used in order to minimize power loss, an impedance matching between chip and antenna is required. Broadband antennas play a key role in the RF energy harvesting if the frequency of the electromagnetic waves impinging on the system is not known *a priori*. Moreover broadband allows to compensate for the frequency shift due to the presence of unknown dielectric materials nearby the antenna.

In this paper, a printed antenna with high inductive input impedance over a broad band is presented. The antenna is composed of a small feeding loop and a dipole-like radiating body. The input resistance depends mainly on loop-radiating body distance, while the inductive reactance on the loop size allowing a easy design. The radiating body consists in a biconical shaped printed dipole. The two terminals of the loop are directly connected to the chip of the RF energy harvesting without any matching network. Experimental results show an antenna bandwidth of about 135 MHz from 840MHz to 975 MHz.

2 ANTENNA DESIGN

Because of power efficiency and fabrication requirements, antenna must be directly matched to the chip, that is the two impedances must be complex-conjugated. As demonstrated in [4], the rectification circuit exhibits an input impedance that can be represented as the parallel of a capacitance C_{IN} and a resistance R_{IN}. C_{IN} accounts for the rectifier transistors parasitic capacitance, while the active power flowing into the rectification circuit depends on R_{IN}. The antenna we present in this paper requires a differential conversion circuit, unlike the circuit proposed in [4] that exploits a single ended topology. However, the input impedance model is still valid, short off a factor of 2 on the input impedance due to the differential stimulus. In the chip input impedance model shown in Fig.1 also the bond wire parasitic resistance R_{BOND} and inductance L_{BOND} are included.

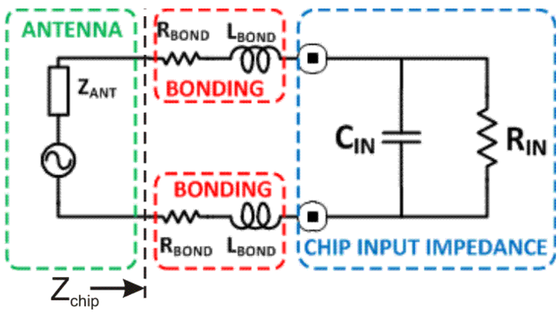

Figure 1: The equivalent circuit of the chip and antenna.

This allows to take into account the frequency dependence of the chip input impedance which is very important in broadband antenna design.

The structure of the developed antenna is shown in Fig. 2. It consists of a bow-tie radiating dipole

[1] Dipartimento di Ingegneria dell'Informazione, Università di Modena e Reggio Emilia, Via Vignolese 905b, 41124 Modena, Italy,
e-mail: luca.vincetti@unimore.it, tel.: +39 059 2056189, fax: +39 059 2056129.
[2] Dipartimento di Scienze e Metodi dell'Ingegneria, Università di Modena e Reggio Emilia, Via Amendola 2, 42122 Reggio Emilia, Italy,
e-mail: luca.larcher@unimore.it, tel.: +39 0522 522625, fax: +39 0522 522609.
[3] Reggio Emilia Innovazione scarl, Via Sicilia 31, 42122 Reggio Emilia, Italy,
e-mail: tacchini@reinnova.it, tel.: +39 0522 922238, fax: +39 0522 513772.

inductively coupled with the chip by means of a rectangular loop. By varying loop size and its distance from radiating dipole the required, the required value of the antenna input impedance can be easily obtained [5].

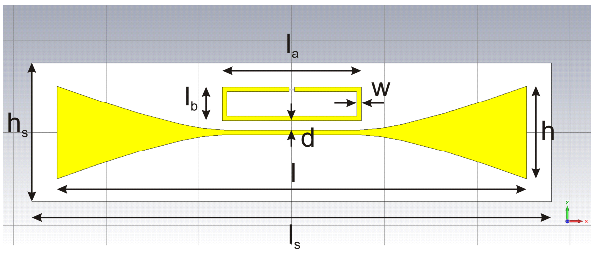

Figure 2: Antenna Layout.

Parameter	Value
l_a	30 mm
l_b	20 mm
d	2 mm
w	1 mm
l	101 mm
h	20 mm
l_s	110 mm
h_s	30 mm

Table 1: Antenna parameters and their values.

The antenna was designed for a chip with R_{IN}=10kΩ, C_{IN}=500fF, R_{BOND}=2Ω, and L_{BOND}=1nH and a FR4 substrate with ε_R=4.3 and thickness = 0.8mm. The input chip impedance correspond to Z_{chip}=(15-j320)Ω at f=868MHz. The antenna was designed by using CST Microwave Studios software. The parameters of the optimized antenna are reported in Table 1. The numerical values if the antenna input impedance $Z_{ant} = R_{ant} + jX_{ant}$ are reported in Fig. 3 and are compared with Z^*_{chip}.

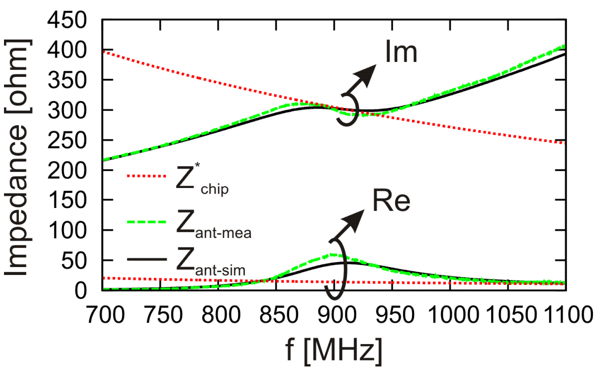

Figure 3: Antenna and chip conjugated input impedances.

The changing of the slope of X_{ant} around the resonance frequency of the radiating body *f=900MHz* allows to follow the conjugate chip reactance over a broad frequency range. The antenna resistance crosses the chip resistance at *f=840MHz* and is higher than R_{chip} at *f=900MHz*. This does not allow to obtain a perfect matching condition at a give frequency but broadens the antenna bandwidth. Figure 4 shows the power transfer coefficient τ [6]:

$$\tau = \frac{4R_{chip}R_{ant}}{|Z_{chip} + Z_{ant}|^2}.$$

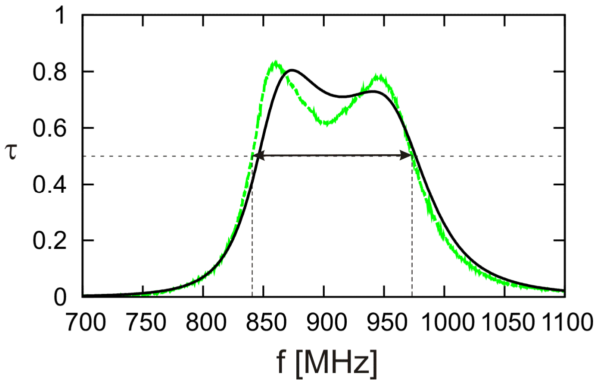

Figure 4: Simulated and measured power transfer coefficient τ.

By assuming a minimum acceptable value of 0.5, corresponding to a reduction of 3dB of the transferred power with respect to its maximum value, the bandwidth of the antenna is about 135 MHz. Simulated radiation patterns in E- and H-plane computed at *f=900MHz* are shown in Fig. 5.

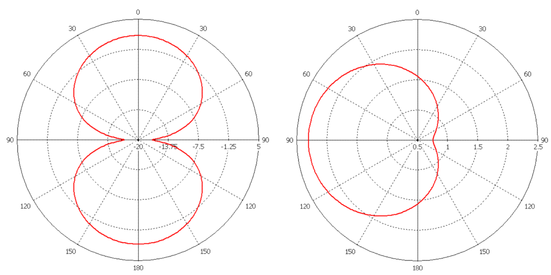

Figure 5: Simulated radiation pattern at 900MHz: (left) E-plane, (right) H-plane.

3 ANTENNA MEASUREMENT

A photograph of the prototype is shown in Fig. 5. Due to its symmetrical input port and significantly high mismatch with standard 50Ω components, the input impedance measurement is a quite critical step. One effective solution is to use just one half of the antenna placed above a conducting grounded plane. The coaxial cable of the vector analyzer is placed in the half space opposite to the antenna's one. The measurement set-up is shown in Fig. 6.

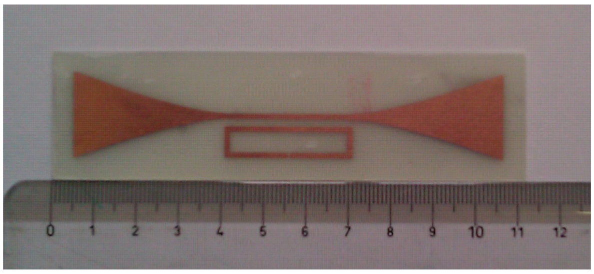

Figure 5: Fabricated antenna.

The conducting plane consists on 1 m sided square copper plate. The measured input impedance is shown in Fig. 5 and it is compared with the numerical one and with the conjugate chip impedance. The agreement between numerical and experimental results is good. The reduction of the experimental values of τ with respect to the numerical ones around *f=900MHz* is due to the higher input resistance of the prototype with respect to numerical expectation.

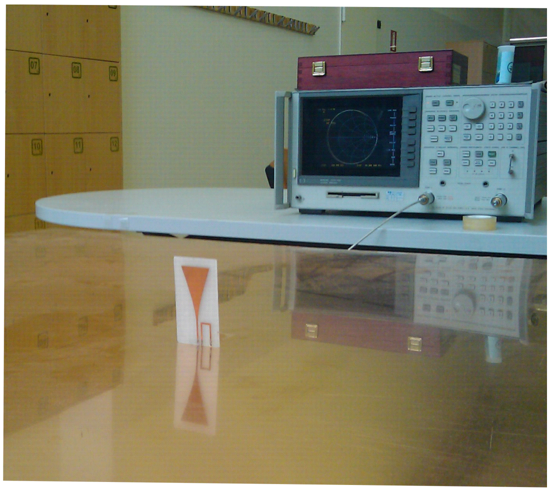

Figure 6: Antenna input impedance measurement setup. The ground plane size is 1m x 1m.

Despite that, the prototype exhibits a power transfer coefficient higher than *0.5* from *f=840MHz* to *f=975MHz* corresponding to a *-3dB* band of *135MHz*. This range covers *866-869MHz* (Europe), *902-928MHz* (America), and *950-956MHz* (Asia) UHF RFID bands, as well as the up (*890-915MHz*) and down (*935-960MHz*) links of Europe GSM-900 and the down link of the USA GSM-850 (*869- 894MHz*).

4 CONCLUSIONS

A simple broadband antenna for radiofrequency energy harvesting has been presented. By using an inductively coupling feeding structure the proposed antenna allows a easy way to match antenna and chip impedances. The biconical radiating dipole has been used to broaden antenna bandwidth. Experimental results show that the propose antenna exhibits a bandwidth of *135MHz* covering the three bands of the European, American, and Asian UHF RFID standards as well as the up and down links of the Europe GSM-900 and the down link of the USA GSM-850.

Acknowledgments

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