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# A Flexible printed dual-band antenna dedicated to RF Energy Harvesting Application

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**Abstract**—A flexible printed dual-band dipole antenna, operating at 900 MHz and 2.44 GHz, is developed and fabricated using low cost fabrication process. The antenna acts as a receiving antenna and is connected to a 4-stage RF-DC converter manufactured on FR4 substrate. The assembled RF Energy harvester is tested in a wireless power transfer scenario. In dual-band configuration, the harvester provides a 1V DC voltage for a power density of  $0.7 \text{ mW.m}^{-2}$  at 900 MHz and  $1.1 \text{ mW.m}^{-2}$  at 2.44 GHz.

**Keywords**—Flexible antenna, Dual-band antenna, Wireless Power Transfert – Screen printing technology

## I. INTRODUCTION

With the growing popularity and applications of large-scale sensor-based wireless networks, the need to adopt inexpensive, green communications strategies is of paramount importance. To address such purpose the top most challenge concerns the supply and management of the energy required to operate the system. One approach is to deploy a network comprising self-powered nodes extracting their power from a variety of natural (sunlight, thermal...) and/or man-made (propagating radio waves, mechanical vibration...) sources for sustained network operation [1]. Thus there is a strong motivation to enable off-the-shelf wireless sensor devices with energy harvesting capability that would allow sensor nodes to fill part or all of its energy costs. A wireless energy harvester is suitable for these applications. Three building blocks are required to develop a RF harvester (Fig.1). The antenna performs the transduction of an electromagnetic energy into an electrical signal. To transfer a maximum of the signal to the rectifier a matching network is introduced. The rectifier converts the AC signal into a DC voltage charging a storage capacitor.

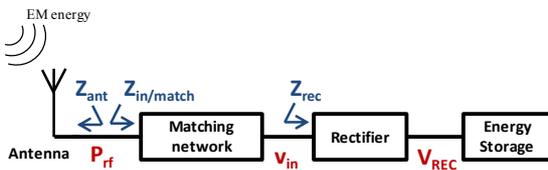


Fig. 1. Building block of the RF Harvester

In addition, the potentiality of flexible and printed electronics offers the advantages of portability, lightweight and low manufacturing cost. The present work combines these two topics of interest to explore innovative solutions for Energy Harvesting. The main objective is to develop a flexible dual-band dipole antenna operating in the 900 MHz and

2.4 GHz. The design, implementation and characterization of the antenna on a flexible substrate are first described. The measurement results focused on a scenario of wireless power transfer are then presented.

## II. DUAL-BAND DIPOLE ANTENNA

For energy harvesting purpose, micro-strip patch or dipole type antennas are commonly used [2]. In this work, we have chosen a dipole type antenna. Indeed, the performance of such kind of antenna, and specifically the radiation efficiency are weakly dependent of the substrate characteristics. The length of dipole antenna is determined by the operating frequency. The total length of the antenna is a half of a wavelength. The substrate is a polyimide film, Kapton® HN-500, 125  $\mu\text{m}$ . This substrate has a dielectric constant ( $\epsilon_r$ ) 3.1, and the loss tangent ( $\tan \delta$ ) is 0.0111. Those electrical properties are experimental results extracted with cavity perturbation method. The final geometry of the antenna is described in Fig.3. The longer arm (2.5 cm) is for 900 MHz and the 1.2 cm segment for 2.45 GHz. The simulated E-plane and H-plane radiation patterns of the antenna at 900 MHz and 2.45 GHz are represented in Fig.2. At 900 MHz, the E-field calculated by HFSS is very close to the E-field of a usual dipole. At 2.45 GHz the antenna is more directive and provides a higher gain.

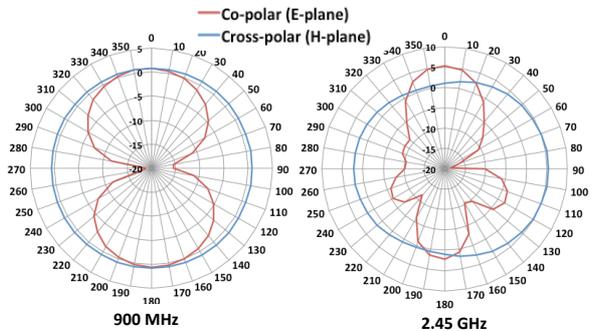


Fig. 2. Radiation patterns and simulated gain at 900 MHz and 2.44 GHz for Kapton® substrate

The upper and lower parts of the co-polar radiation patterns, and the left and right sides of the cross-polar radiation patterns are not symmetrical. This is due to the dissymmetry of the antenna along the x axis. Even if the antenna is symmetric along y axis, there is break of this symmetry on the left and right sides of the co-polar patterns. The cable and the coaxial connector are included in the antenna simulations and are responsible for this unbalance supply. The use of a balun improves the symmetry but we do not introduce this

element here. The coaxial cable will be later replaced by the rectifier which includes a microstrip or CPW feed line.

### III. FABRICATION AND CHARACTERIZATION RESULTS

The dual-band dipole antenna is first printed on the Kapton® by screen-printing technology with a polymer silver conductor (1901-S). Since the substrate property has a small impact, the same design is also printed on two others flexible substrates: Polyethylene terephthalate (PET) and Paper-film (Fig.3).

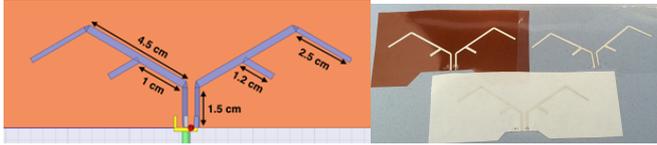


Fig. 3. Dimensions of the dual-band dipole antenna and picture of printed antennas on Kapton®, PET and Paper-film

The input return loss is measured with a HP8720 network analyzer, to compare the performance of the printed antenna with the simulation results (Fig.4). For the lower band, 900 MHz, the three antennas exhibit a return loss,  $S_{11} < -15$  dB in good agreement with simulation results. At 2.44 GHz, the antennas have a larger bandwidth and a  $S_{11}$  below -15 dB from 2.416 GHz to 2.606 GHz, except for the paper-based antenna. Indeed, the high loss tangent of paper at 2.44 GHz does not make it suitable for RF operations in this band.

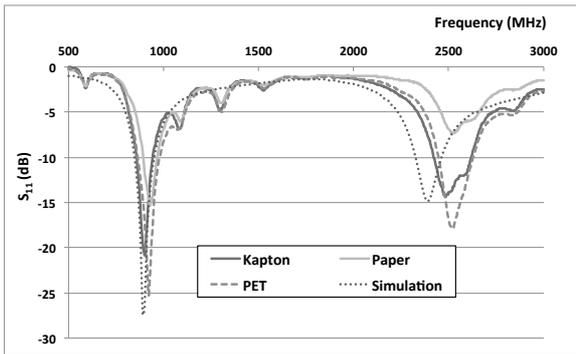


Fig. 4. Return loss coefficient simulated with Kapton and measured for the Kapton®, PET and Paper-based antenna

Table I sums up the calculated gain of the dual-band dipole antenna for the different substrates.

TABLE I. MEASURED GAIN OF FLEXIBLE ANTENNAS

Frequency	Gain (dBi)		
	Kapton	Paper	PET
900 MHz	1.9	1.6	2.7
2.44 GHz	4.6	1.3	3.7

### IV. ENERGY HARVESTING APPLICATION

This part exposes the measurement of the printed antennas (Kapton®, and PET) assembled with a rectifier. The architecture of the circuit includes a matching network and a 4-stage voltage multiplier based on Schottky diodes, HSMS<sub>285</sub>, [3]. The hybrid harvesters are characterized according the setup described in Fig.5. The power density is measured with a

radiation dosimeter (EMR-30). Table II summarizes the measurements with the Kapton® and the PET antennas. We look for the minimum density of energy required to rectify 1 V.

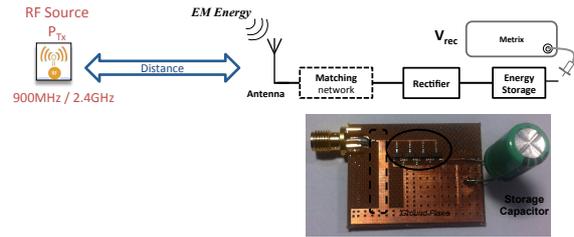


Fig. 5. Schematic of the setup experiment and picture of the RF/DC circuit

With the Kapton antenna, if only one band is exploited, we need  $1.9 \text{ mW.m}^{-2}$  at 900 MHz and  $3.5 \text{ mW.m}^{-2}$  at 2.4 GHz. Or in the dual-band mode, only  $1 \text{ mW.m}^{-2}$  is needed to rectify 1V. The PET antenna exhibits better performance with only respectively 0.7 at 900 MHz and  $1.1 \text{ mW.m}^{-2}$  at 2.44 GHz in dual-band mode. According Table II, we can notice a difference between the two types of substrate. The difference is due to the antenna gain. If we increase the gain of the antenna, the power available is also increased at the input of the rectifier.

TABLE II. EXPERIMENTAL RESULTS

Substrate	Power density ( $\text{mW.m}^{-2}$ ) for $V_{\text{rec}} = 1\text{V}$	
	900 MHz	2.44 GHz
Kapton®	1.9	X
	X	3.5
	1	1.1
PET	1.6	X
	X	4.1
	0.7	1.1

### V. CONCLUSION

This paper presents the design, the simulation and the measurement results of 3 dual-band dipole antennas printed on various flexible substrates. Assembled with FR4 dual-band rectifier, the hybrid RF harvesters are characterized in a scenario of wireless power transfer. For a single tone excitation of  $1.6 \text{ mW.m}^{-2}$  at 900 MHz, or  $4.1 \text{ mW.m}^{-2}$  at 2.44 GHz the harvester rectify 1V. In a dual-band mode, only 0.7 and  $1.1 \text{ mW.m}^{-2}$  at 900 MHz and 2.44 GHz are needed. The overall sensitivity of the assembled harvesters to the available RF energy in each band is significantly improved by dual-band mode operation. This capability makes them suited for an opportunistic harvesting of surrounding RF energy.

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