Smart Coat with a Textile Antenna for Electromagnetic Energy Harvesting

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1. INTRODUCTION

Nowadays, the socio-economic development and lifestyle trends indicate an increasing consumption of **technological products** and processes, powered by emergent concepts, **such as Internet of Things (IoT)** and **smart environments**, where everything is connected in a **single network**.

In this context, **wearable technology** has been addressed to **make the person**, mainly **through his clothes**, able to **communicate** with and be part of this **technological network**.

Wireless communication systems are made up of **several** electronic **components**, which over the years have been **miniaturized** and made **more flexible**, such as **batteries, sensors, actuators, data processing units, interconnectors and antennas**.

In these systems, the **antennas** have been **challenging**, because they are conventionally built on rigid substrates, hindering their **efficient** and **comfortable integration** into the garment.

Considering the **flexibility and dielectric** intrinsic **properties** of **textile materials**, **embedding antennas** into fabrics allow expanding the interaction of the **cloth** with some **electronic devices.**

Textile antennas that combine the **traditional textile materials** with **new technologies**, emerge as a **potential interface** of the **human-technology-environment** relationship, becoming an active part in the **wireless communication systems**[1], aiming applications such as tracking and navigation[2], mobile computing and other[3].

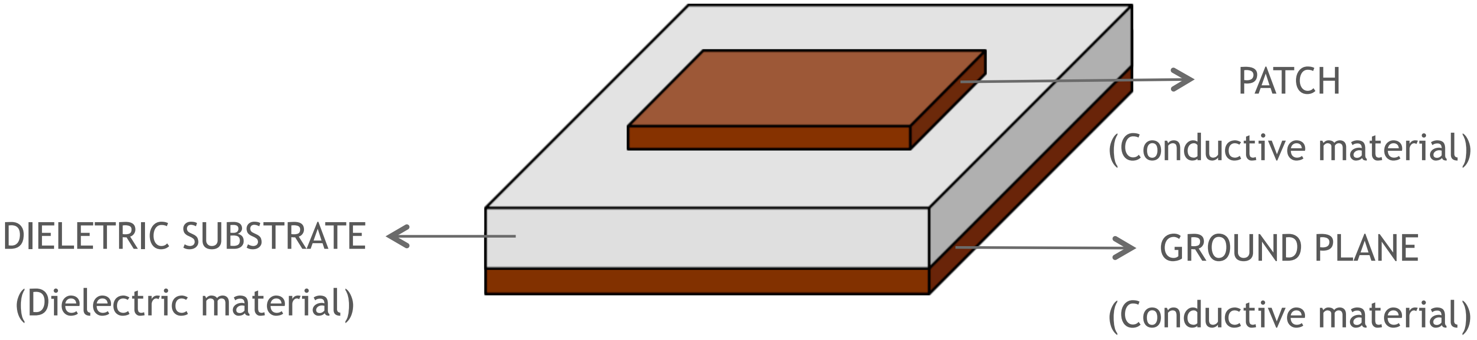
[1] R. Salvado, C. Loss, R. Gonçalves, and P. Pinho, "Textile materials for the design of wearable antennas: A survey," *Sensors J.*, vol. 12, no. 11, pp. 15841–15857, Jan. 2012.; [2] A. Dierck, F. Declercq, and H. Rogier, "A Wearable Active Antenna for Global Positioning System and Satellite Phone," *IEEE Trans. Antennas Propag.*, vol. 61, no. 2, pp. 532–538, 2013.; [3] C. Hertleer, H. Rogier, S. Member, L. Vallozzi, and L. Van Langenhove, "A Textile Antenna for Off-Body Communication Integrated Into Protective Clothing for Firefighters," *IEEE Trans. Antennas Propag.*, vol. 57, no. 4, pp. 919–925, 2009.

1.1 TEXTILE ANTENNAS

To obtain **good results**, wearable antennas have to be **thin, lightweight**, of **easy maintenance**, **robust,** and moreover, must be **low cost** for manufacturing and commercializing.
In this way, planar antennas, the **microstrip patch type**, have been proposed for **garment applications**.

These antennas are usually **formed by overlapping** conductive (patch and ground plane) and dielectric (substrate) layers.

Figure 1. Schematic of overlap layers of microstrip patch antenna



For this reason, the **knowledge of the properties** of **textile materials** is crucial as well as the **manufacturing techniques** for c**onnecting the layers** such as **glue**, **seam** and **adhesive sheets.**

The **microstrip patch antenna** radiates **perpendicularly** to a ground plane, which serves as a **shield** to the antenna radiation, assuring that the **human body absorbs** only a **very small** fraction of the **radiation.**

1.2 ENERGY HARVESTING

The **integration of electronic devices** on clothing still puts another question about **how to feed them**. The **batterie**s are an obvious choice, but they are **bulk**, require frequent r**eplacement** or recharging and their **finite lifetime** has become a major ecological concern over the past years.

Energy harvesting holds a **promising future** in the next generation of **Wireless Sensor Networks** (WSN). Since there are a variety of **energy sources** available for energy harvesting in the **environment,** the opportunities are vast[7].

[7] F. Yildiz, D. Fazzaro, and K. Coogler, "The green approach: Self-power house design concept for undergraduate research," *J. Ind. Technol.*, vol. 26, pp. 1–10, 2010.

Nowadays, **radio frequency (RF) energy** is currently broadcasted from **billions of radio transmitters** that can be collected from the ambient or from dedicated sources[8].

RF energy is universally present over an increasing range of frequencies and power levels, especially in **highly populated urban areas**. The **growing** number of **wireless transmitters** is naturally increasing **RF power density** and **availability**[9].

[8] H. Jabbar, Y. S. Song, and T. T. Jeong, “RF energy harvesting system and circuits for charging of mobile devices,” in *IEEE Transactions on Consumer Electronics*, 2010, pp. 247–253.
[9] J. Tavares et al. “Spectrum Opportunities for Electromagnetic Energy Harvesting from 350 MHz to 3 GHz,” in *7th International Symposium on Medical Information an Communication Technology*, 2013, pp. 126–130.

2. EXPERIMENTAL SECTION

2.1 DUAL BAND TEXTILE ANTENNA FOR ELECTROMAGNETIC ENERGY HARVESTING

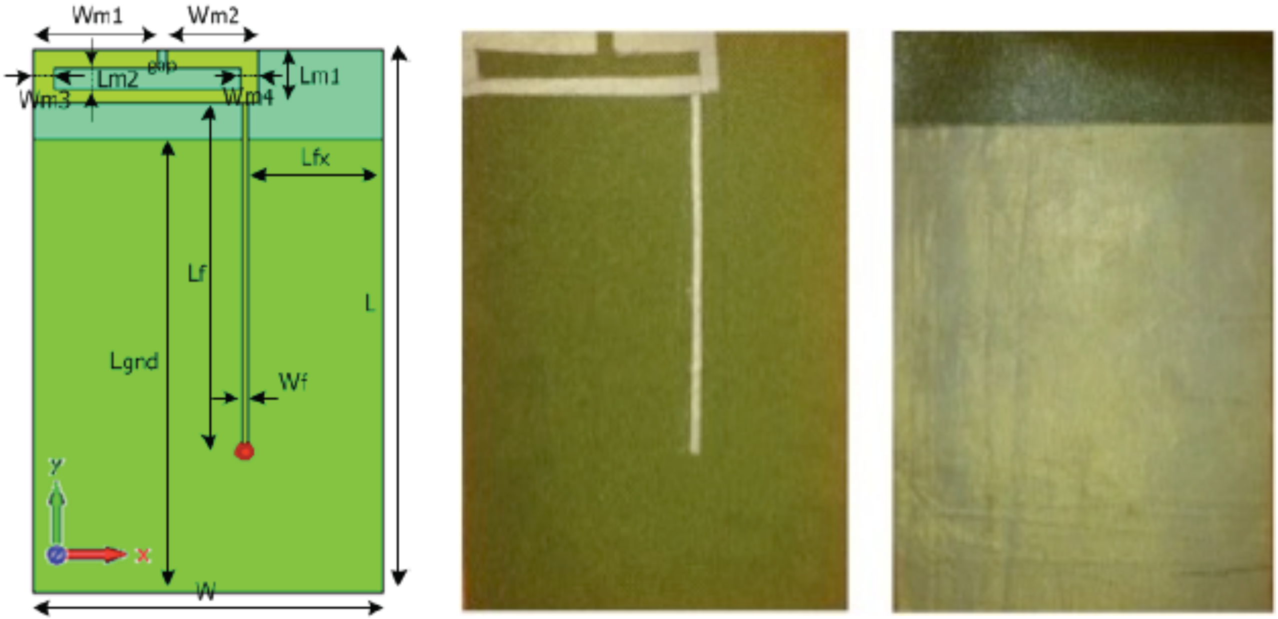
A study to **identify** the **spectrum opportunities** for the **RF energy harvesting**, through power density measurements from **350 MHz to 3 GHz**, was previously made and reported in[10].

Based on this identification, of the most **promising opportunities**, a **dual-band wearable antenna** operating at **GSM900 and DCS1800** bands was proposed[11].

[10] N. Barroca et al. "Antennas and circuits for ambient RF energy harvesting in wireless body area networks," in *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, 2013, pp. 527–532.; [11] R. Gonçalves, N. B. Carvalho, P. Pinho, C. Loss, and R. Salvado, "Textile antenna for electromagnetic energy harvesting for GSM900 and DCS1800 bands," in *Antennas and Propagation Society International Symposium (APSURSI) 2013*, 2013, vol. 1, pp. 1206–1207.

PROPOSED DUAL-BAND TEXTILE BAND FOR ENERGY HARVESTING

Figure 2. (**a**) Design of a dual-band textile antenna for energy harvesting (**b**) Front (**c**) Back



(**a**) (**b**) (**c**)

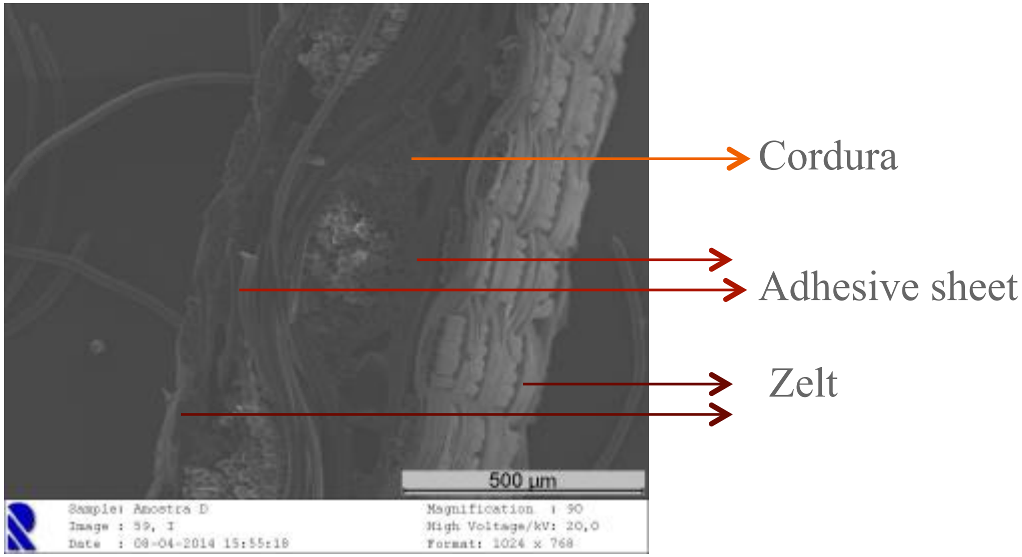
Table 1. Dimensions of the textile antenna

Parameter	Dimension (mm)
L, Lgnd, Lf, Lfx	120, 100, 78, 30
Lm1, Lm2, gap, W	12, 5, 31, 80
Wf, Wm1, WM2, Wm3, Wm4	1.5, 31, 21, 8, 4

A100% polyamide 6.6 fabric, named **Cordura®**, was considered for the **dielectric substrate**. This fabric presents a $\varepsilon_r \cong 1.9$, $\tan\delta$ = 0.0098 and 0.5 mm of thickness. For the **conductive parts**, a commercial available electrotextile, named **Zelt®**, with electric conductivity of 1.75105 S/m was considered.

The textile antenna was **manufactured** using an **adhesive sheet**, glued by a simple **ironing operation**.

Figure 3. SEM image – Antenna layers



2.2 E-CAPTION: SMART & SUSTAINABLE COAT

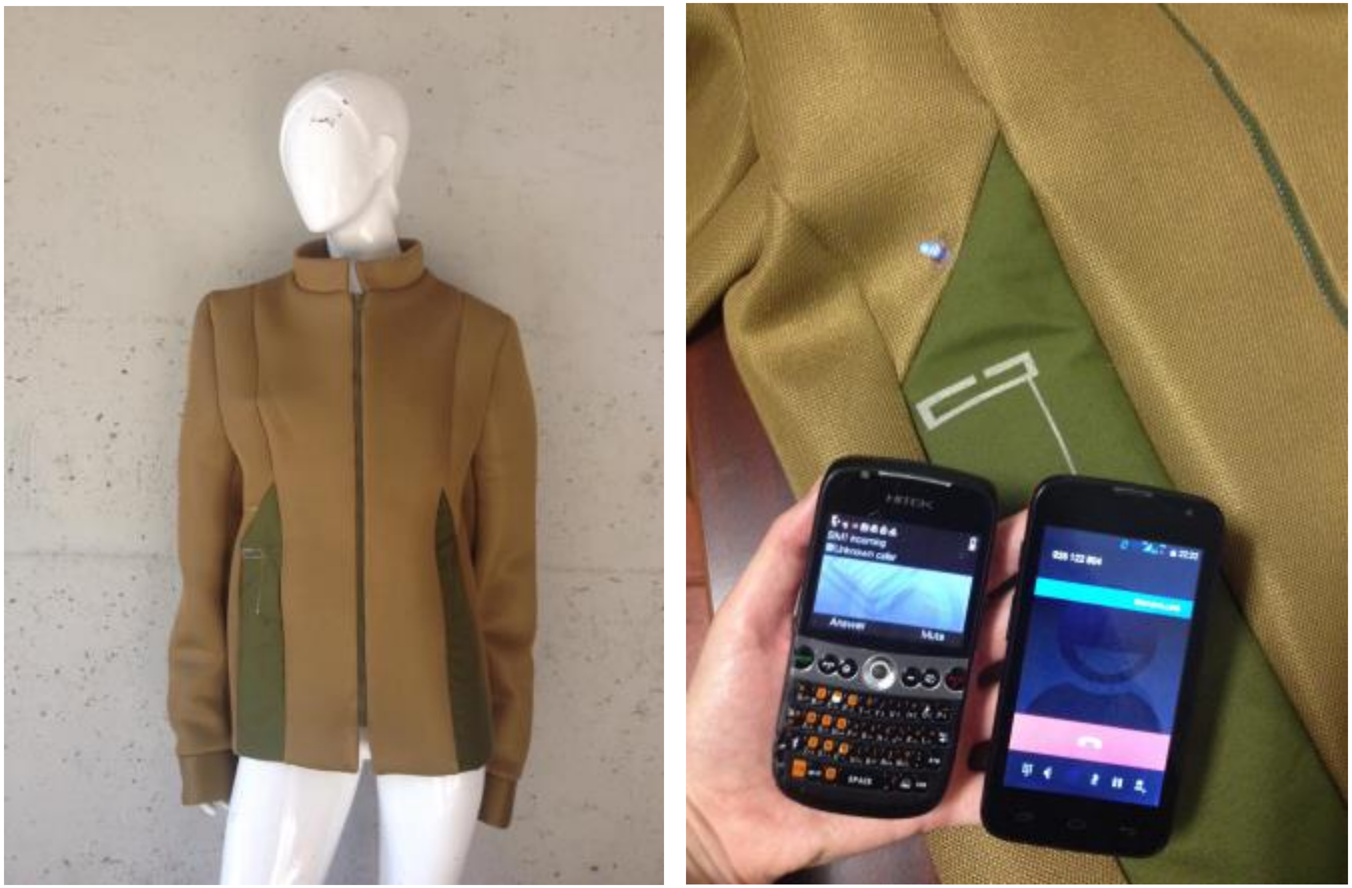
The integration of textile antennas for **energy harvesting** into **smart clothing emerges** as a particularly **interesting solution** when the **replacement of batteries** is not easy to practice.

Until now, in the **research field**, the **patch textile antennas** have been **built isolated** and then **posteriorly integrated** in the lining of garment or pockets.

In this work we present the "E-Caption: Smart & Sustainable Coat". It is a **smart coat** where the **substrate of the antenna is continuous** and was **cut following the patterning of the coat**, being thus part of it.

E-CAPTION: SMART & SUSTAINABLE COAT

Figure 4. (**a**) E-Caption: Smart & Sustainable Coat (**b**) Textile antenna for electromagnetic energy harvesting, in detail.



(**a**) (**b**)

3. RESULTS AND DISCUSSION

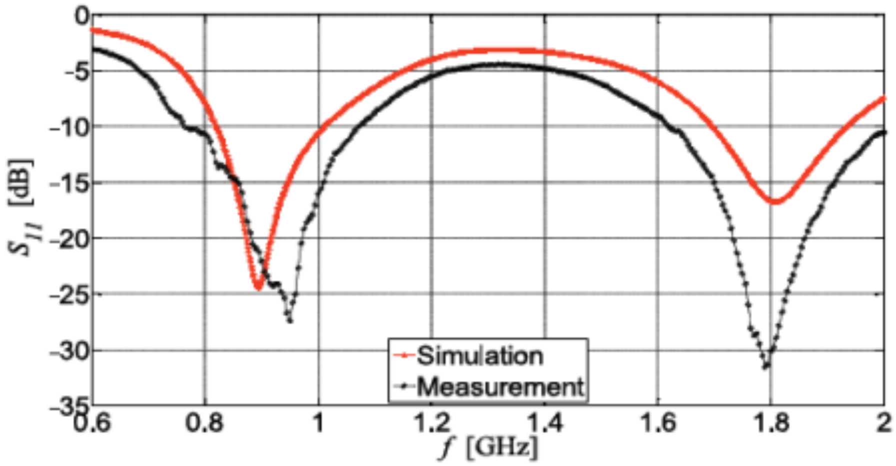
The **performance** of the antenna of the **E-Caption: Smart & Sustainable Coat** was tested in the **anechoic chamber**.

Figure 5. Measurement of antenna's behavior at anechoic chamber

The **textile antenna** presents an operating **frequency range** capable of completely covering the **GSM900** (880-960 MHz) and the **DCS 1800** (1710-1880 MHz). The **gain** obtained in the **simulation** is about **1.8 dBi** and **2.06 dBi**, with **radiation efficiency** of **82%** and **77,6%** for the lowest and highest operating frequency bands, respectively.

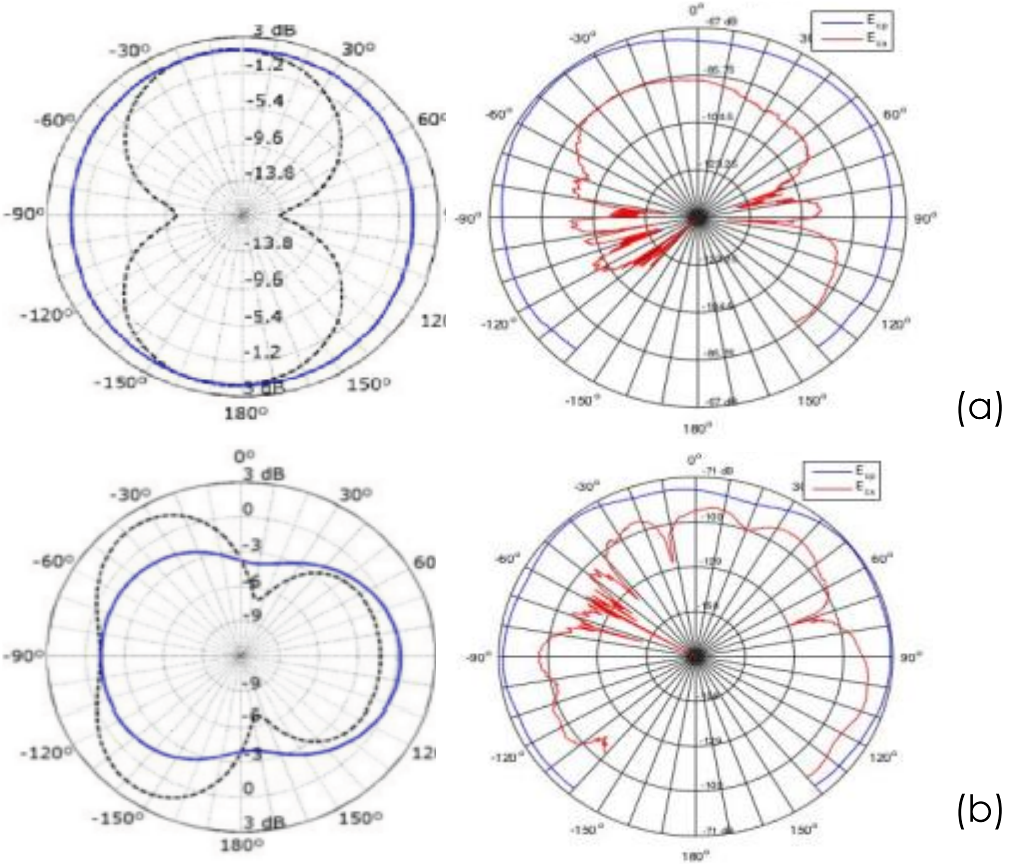
In the figure 3 is possible to see the **agreement** between the **simulated and measured results**.

Figure 6. Simulated and measured return loss



Even **after** the **integration** on clothing, the **radiation pattern** is clearly **omnidirectional**. Some **deformations** in the XZ plane (blue line) is due to the **non-uniform garment's structure**.

Figure 7. Comparison in the radiation pattern between the simulation and the measurement of the antenna fully integrated into the smart coat structure. YZ plane (dashed) and XZ plane (blue solid). Measured radiation pattern in the YZ plane (red line) and XZ plane (blue line) at (**a**) 900 MHz and (**b**) 1800 MHz



4. CONCLUSION

In the **future**, the garments will not only **communicate social** condition or **protect the human body** against the extremes of nature, but also will **provide information** about the state of user's **health and environment**.

With the **evolution of materials**, clothes are becoming able to **communicate via wireless**.

This is possible because **textile technologies** can produce new types of **sensors and antennas** that are so small, **flexible and inexpensive** that they can be applied in different types of **clothing, shoes and accessories**.

The **integration of textile antennas** for **energy harvesting** into **smart clothing** can be a solution for **recharge wearable devices**, such as **low-power electronics and Wireless Body Sensor Networks**.

Embedding antennas in clothing contributes for the **advance** of the **integration of electronic devices** in less obtrusive way making the smart clothes more **confortable**. Also, this work shows that a **continuous substrate** of the antenna does **not** influence its **performance**.

Finally, this might open **new horizons and concepts** in the clothing development and in the **sustainable communication**.

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Thank You!

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