

A Novel Textile Antenna for Passive UHF RFID Tag

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1. Introduction

The Radio Frequency Identification (RFID) has become, in recent year, very popular in different services and sectors. RFID system helps purchasing and distribution logistics. It provides information about people, goods and products in transit. RFID systems are considered regarding these criteria: read range, non line of sight, read/write data storage, memory capacity [1].

Nowadays, the new specific identification field of wearable textile labels, is quickly growing up. It is especially used for textiles traceability, positioning, broadcasting and also security [2-4]. Besides the lowest price textile tag antenna has to resist the laundry cycles, which means humidity, temperature and pressure. Furthermore, substrate electric parameters, such as permittivity (ϵ_r) and dielectric loss tangent ($\tan\delta$), vary a lot from one material to another [5]. It results in changes of substrate relative permittivity. Those variations affect the antenna parameters by modifying gain, radiation pattern, operating frequency and impedance matching. To overcome constraints and guarantee best performances, tag antennas have to be wideband.

This paper proposes a novel small and discreet textile antenna for UHF RFID frequency band. A meander line antenna was made using stainless electro-thread as radiating element and textile materials as substrate. The chip was packaged in order to be protected from laundry cycles. The antenna design is first discussed. Simulations results, carried out using ANSYS HFSS v14 are then considered. And finally, data from measurements are presented and compared to simulations.

2. Antenna Design

The meander line antenna is made of two elements coupled together. The first one, on which the chip is mounted, is a circular small loop antenna named "first antenna" [6]. Its perimeter is inferior to $\lambda/10$ in order to conserve a constant current inside. The "first antenna" is matched at 900 MHz, in the middle of RFID UHF frequency band [7]. To protect the chip from laundry cycles, the "first antenna" is packaged in a material whose electrical properties are close to the FR4. The second one is the radiating element called "second antenna". For the "second antenna", the ThN30 electro-thread [8] was used as a conductor and sewn on a 82 mm x 25 mm x 0.24 mm piece of polyethylene (PET). ThN30 is a multifilament conductive fiber of radius 300 μm , composed by hundred inox fibers coiled by a nonconductive duct. Its conductivity is $5 \cdot 10^5$ S/m. The PET's permittivity is 2.25 and the dielectric loss tangent is 0.001. Under temperature, the PET is adhered on the textile on which it is put on.

The "second antenna" is a logarithmic meander line antenna, based on the principle of the 'log-periodic dipole array' [9]. Antenna dimensions were scaled by the factor τ : $\tau = R_{n+1}/R_n$. As shown in Fig.1, R_n and R_{n+1} represent the spacing between each vertical wire. The scale factor τ was set to 0,75 and R_1 to 7 mm. These quantities were chosen for a perfect matching between antenna

and chip. Antenna tag impedance should be $27 + j*219 \Omega$ at 866 MHz [10]. Fig. 1 shows the topology of antenna mounted on the PET and adhered on piece of textile material.

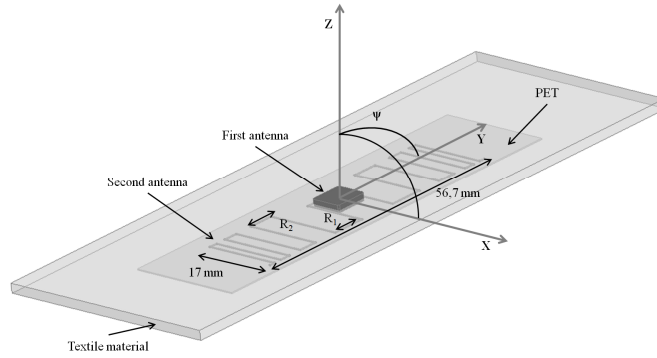


Figure 1: Topology and dimensions of the proposed antenna

3. Simulation

Simulations were carried out by the 3-D full-wave electromagnetic software : ANSYS HFSS v14. Analysis frequency band goes from 800 MHz to 1 GHz. Reflection coefficient, gain and read range are the characteristics of interest. Simulations are performed considering the textile material such as the tag environment.

3.1 Reflection coefficient

Reflection coefficient can be computed from the antenna impedance (Z_{ant}) and the chip impedance (Z_{chip}), by using equation (1):

$$\Gamma^* = \frac{(Z_{ant} - Z_{chip}^*)}{(Z_{ant} + Z_{chip}^*)}. \quad (1)$$

Fig. 2 shows variations of the reflection coefficient from 800 MHz to 1 GHz (Cf. Fig. 1).

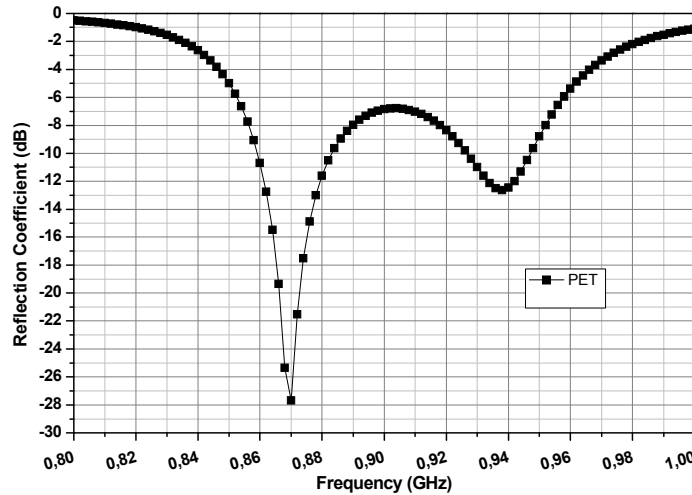


Figure 2: Reflection coefficient

Results show the wideband aspect of the proposed antenna. Indeed, in free space, at the ETSI band, 865.6 MHz to 867.6 MHz, reflection coefficient is less than -19 dB. At the FCC band, 902 MHz to 928 MHz, and Australian band 918 MHz to 926 MHz; reflection coefficient is less than -7 dB. And finally at the Japanese band, 952MHz to 954 MHz, reflection coefficient is less than -7 dB.

3.2 Gain

Antenna's gain and its radiation pattern are unchanged for different substrates. Fig. 3 exposes antenna radiation pattern at 866 MHz for E-plan and H-plan. The half power beamwidth is

around 88°. Radiation pattern is omnidirectional, defined as having an essentially nondirectional pattern in the H-plan.

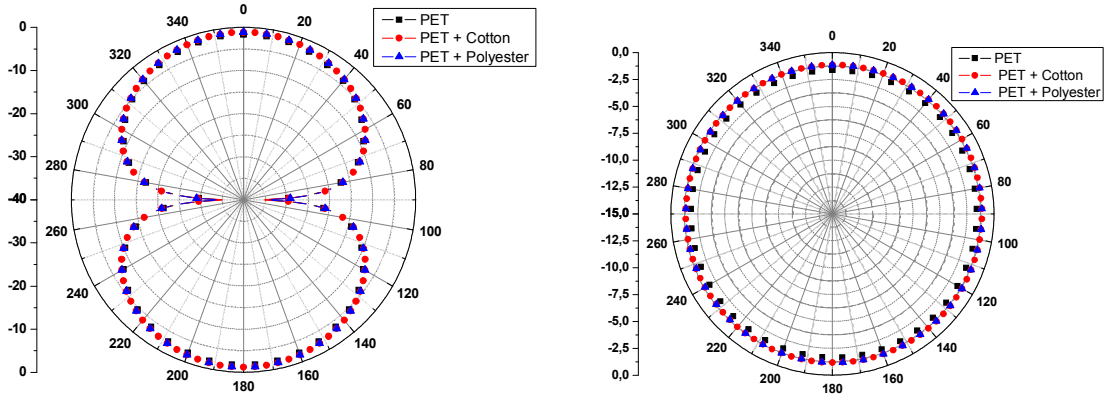


Figure 3: Radiation pattern

3.3 Read Range

Analysis of read range requires Friis equation which relates the power received to the power transmitted between two antennas separated by a distance R [7]. At 4W EIRP (effective isotropic radiated power), the read range was calculated for different textile materials.

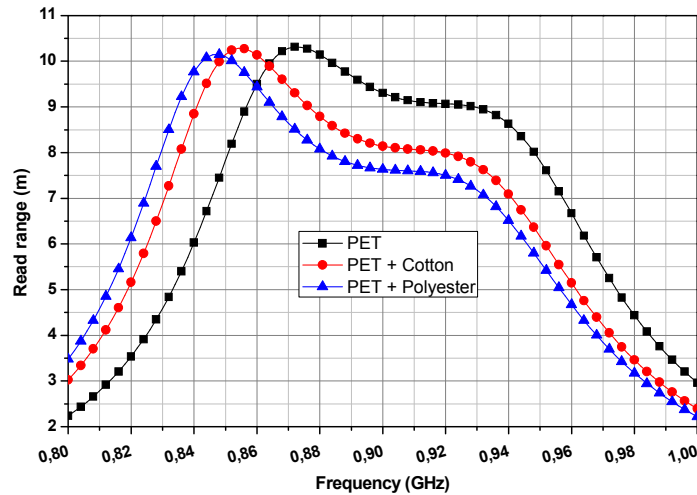


Figure 4: Simulation read range for different materials

Read range is over 6m, for the entire UHF RFID frequency band.

4. Measurements

Measurements were performed in an anechoic chamber. The maximal read range was obtained from Friis equation, at 866 MHz assuming a perfect polarization between tag and reader antenna. Antenna emitted power was fixed at 4W EIRP.

Tag antenna was fixed at $D_{Mes} = 1\text{m}$ from reader antenna. In accordance with the 4W EIRP, transmission power (P_{Trans}) delivered by reader antenna was increase to receive a minimum tag's response. Max read range is then deduced from equation (2)

$$Range_{Max} = D_{Mes} \sqrt{(P_{EIRP} \cdot L_C) / (P_{TransM} \cdot G_{Tx})} \quad (2)$$

Where P_{TransM} is the minimal power transmission, L_C cable losses and G_{Tx} the transmission antenna's gain (2.15 dB).

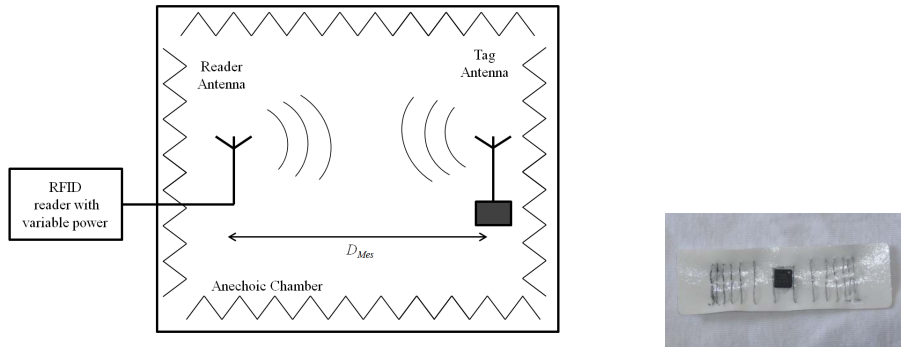


Figure 5: Proposed method for measurement and antenna prototype

Table 1: Read range comparison between simulation and measurement at 866 MHz

| Material | Read range (m) | |
|--------------|----------------|-------------|
| | Simulation | Measurement |
| PET | 10.5 | 6.5 |
| PET + Cotton | 9.5 | 6.3 |

Difference between simulation and measurement comes from uncertainty at substrate's thickness (0.2 mm), at the reader antenna's gain G_{Tx} (0.2 dB), at the reader antenna's VSWR, at distance between reader antenna and tag (5 cm), at cables losses L_c (0.5 dB) and at reader power step fixed at 1 dB. Furthermore, antenna was handsewn, which causes an inaccuracy in the size and the length of the wire. The whole introduces over 30% of uncertainty.

5. Conclusion

The paper puts forward a novel textile antenna designed and optimized to be used at the UHF RFID frequency band with best performances for different substrates material. Read range is over 6 m for UHF RFID frequency band, for different material. Measurements are close to simulation. The antenna's advantage is being resistant to laundry cycles compared to bibliography. To improve the results and minimize the uncertainty, an automated process would be used for fabrication of the antenna.

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