Analysis of a Polycarbonate RFID Tag for Blood Chain Tracking

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Abstract— In this paper we describe an antenna especially designed for a RFID passive tag working at UHF (867 MHz), for healthcare applications. In particular for the transfusional medicine and the blood supply chain. The tag has to be able to work placed on the top of a blood bag, while the bag is full of blood, and the antenna has been designed with this goal in mind. Therefore we require an antenna able to work close to a (relatively large amount of) lossy medium with high permittivity. Moreover, the bag shape is curved but its shape cannot be predicted exactly, so that the antenna must retain its behavior for a large set of different environments. In order to comply with all those requirements, a printed slot antenna built with a exible substrate has been selected, so that the whole tag can be exible too. The first step was the optimization of the working parameters of the antenna while placed on a perfect planar surface (i.e., assuming the blood bag to be a parallelepiped). Since the actual bag shape is not known, this choice allows to take into account the lossy material, but using a simple geometry. The antenna has been optimized to get the maximum reading distance. Then we consider the effects of a real blood bag (i.e., a curved one), filled with blood, on the antenna behavior. We consider a bag with a transverse section bounded by two arc of circles (with a radius quite larger than the bag size). Since we found a reasonable agreement with the planar antenna we can assume that the antenna behavior is quite insensitive to the bag shape. A robustness analysis, respect to the bag curvature radius, has been performed, too, to assess the antenna use in real environments.

1. INTRODUCTION

RFID is the acronym for Radio Frequency Identification and refers, as the name suggests, to the technology [1] that take advantage of radio frequency for identification purposes. Such a technology has been adopted in many fields. One of these is the healthcare [2].

The present leading technology for healthcare applications is the optical barcode, but recently the RFID technology has been introduced and is proving remarkably successful. Localization of critical items is one of the most promising one, in particular the localization and identification of blood bags [3].

The bag is usually filled, stored and used in different locations and, since the bag often carries with itself delicate and important informations, the RFID technology offers many improvements in this direction. Using RFID tag instead of optical one allows to store informations about the blood bag into the tag itself and improves significantly the reading distance.

To fully exploit the RFID technology in the supply chain an adaptation, or better, a re-engineering of the technology is needed. One of the part which can benefit from a re-engineering is the tag antenna, so that it can be adapted to the environment where it has to work. At the moment, the most popular solution is represented by the use of general purpose tag antennas which are not optimized to work in presence of lossy materials. Actually, the antenna environment is the blood bag, filled with a lossy dielectric with a large dielectric constant (the blood which, at UHF, has a typical relative dielectric constant of 61-j33).

The blood thus affects negatively the performances of an antenna designed to work in free space. Another important aspect is represented by the shape of the medical grade PVC bag. Since the tag is tipically built using flexible substrates and the bag can easily change its shape, the tag can modify its shape and, as a consequence, the performances of the antenna can be adversely affected.

Keeping in mind all the considerations explained above, a printed slot antenna realized on a grounded slab and able to work at UHF RFID band (867 MHz) has been designed. The design of the antenna has been assessed by verifying that the antenna behavior is quite insensitive to the bag shape.

2. STRUCTURE

Printed slot antennas are not very popular as RFID tag antennas, though same proposal have appeared in the literature [4–6]. Actually, the peculiar feeding arrangement (a RFID chip) is not compatible with a standard printed slot. On the other hand, it allows to use a dipole radiating in the slot as primary feed. This leads to the basic antenna concept shown in Figure 1, where the vertical microstrip lines act as a short dipole (with a constant current). This dipole is the source of the slot aperture field which, because of the equivalence current [7], radiates the antenna field.

Of course, this simple shape must be engineered and carefully optimized to get an high-performances RFID system. This must be done on the chosen RFID chip and material. We have selected the NXP Semiconductors UCODE G2iM+.

The G2iM+ has Z_{chip} load impedance of 27-j234 Ω at 867 MHz, good sensitivity in reading (−17.5 dBm) and high user memory (640 bit). Since the input impedance of this chip is not so different from many others, a good matching performances can be retained also with different chips.

The application we have in mind requires a flexible substrate, and we select polycarbonate. The antenna has been first designed, and optimized when located on a blood bag with a rectangular shape [8], and thus with a planar shape.

This optimized antenna has then be located on a curved blood bag, as shown in Figure 2. Since the exact bag shape is not known, we have selected an average shape, made by two cylindrical surfaces with a radius of 13.5 cm. The curved and the rectangular bag have the same volume (450 ml). The blood parameters was defined at 1 GHz and at a temperature of 4°C (while the PVC data are essentially constant up to many GHz, so that available data at 1 MHz have been used) as summarized in Table 1. To evaluate the performances we designed and simulate the antenna with the software CST Microwave Studio [9].

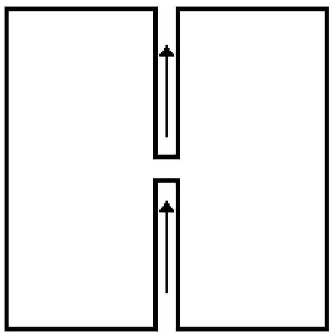

Figure 1. Feed of the patch.

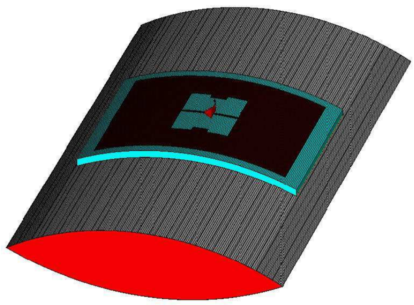

Figure 2.

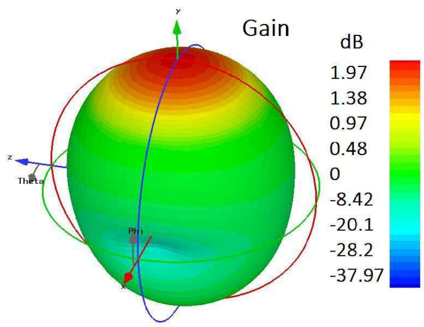

Figure 3. Radiation pattern of the antenna upon the blood bag.

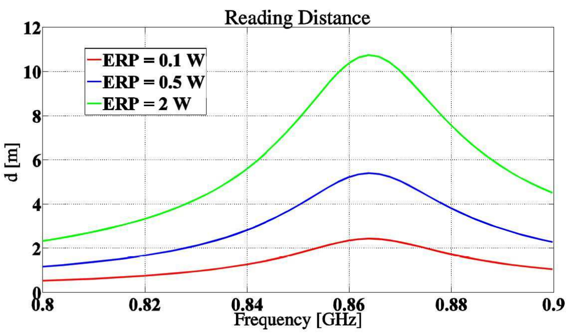

Figure 4. Reading distance.

Table 1. Blood and PVC parameters.

Layer	Dielettric constant ε_r	Loss Tangent	Conductivity σ [S/m]	Density [Kg/m^3]	Thickness [mm]
PVC Layer	3.1 (@ 1 MHz)	0.015 (@ 1 MHz)	-	-	0.15
Blood	61.06 (@ 1 GHz)	-	1.5830 (@ 1GHz)	1050	25.2

3. RESULTS

The 3D radiation pattern of our optimized antenna is shown in Figure 3. The pattern is omni in the upside direction, with a gain around 2 dB.

From these data, we can predict the reading distance, which is shown (for different transmssion ERP, up to 3 dBW) in Figure 4. Actually, even for an ERP as low as −10 dBW (a value which comply with every national regulation) the reaching distance is larger than 1.5 m in almost all the useful bandwidth.

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