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Multi-standard UHF and UWB antennas for RFID applications

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Abstract— In this article, tag and reader multi-standards RFID antennas are presented. These antennas are matched on one the UHF RFID regulate frequency band (860-960 MHz) and on the ECC UWB frequency band (6-8.5 GHz). Tag is composed of two antennas, one match for the RFID applications with classical RFID input impedance, one for UWB matched at 50Ω . Tag sizes are limited to credit card sizes (85x54 mm). Reader antenna is an association of a bowtie and a dipole antenna and it is matched on 50Ω on twice bands. There is no sizes' specification for reader antennas. The substrate is FR4 0.8 mm thick for tag antennas and 1.6 mm for reader antennas. Epoxy's relative permittivity is 4.4 and its dielectric loss tangent is 0.02. Design rules, simulations, measures and perspectives are exposed.

I. INTRODUCTION

Radio Frequency Identification (RFID) is widely developed this last past years. One of the regulate frequency band for RFID applications is in the UHF band (860-960MHz). The main application is to identify automatically and in real time several devices thank to electromagnetic waves.

Some applications need to identify and localize precisely a device into a dense environment[1]. It's possible to localize a device with UHF RFID technology thanks to RSS signals [2] but the positioning resolution suffers from multipath. To enhance it there are actually some research which applied Ultra Wide Band (UWB) technologies for positioning applications[2]. UWB short duration pulses permit to distinguish direct responses to multipath responses and could pass through several objects like walls, clothes, etc...

Moreover UWB systems are low power consumption systems and can be used close to other UHF RFID systems without suffering from interference due to the different radio spectrum required [2, 3]. There are two main standards for UWB applications: FCC with a frequency band between 3.1 and 10.6 GHz for North America and ETSI 6-8.5 GHz for Europa. In this paper, two antennas' prototypes are presented, one for readers and the second one for tags. Reader and tag's antennas are designed to work in UHF RFID band (860-960MHz) and European UWB band (6-8.5 GHz). Reader antenna's sizes must be minimized because the overall system will be including into an embedded. In this, antenna's simulated and measured impedances and reflection coefficient are presented. Measure interpretations, design rules and radiation patterns are also available. Simulator used is Ansoft HFSS V 11.

II. TAG ANTENNA

A. Design

Tag is composed of two antennas, one for the UHF RFID frequency band and the other one for UWB communications (Figure 1). Constraints on RFID tag antenna an UWB antenna are obviously different. Due to the RFID chip input impedance, the antenna need to be very inductive with a few resistances [8, 9]. In order to be perfectly matched to the chip, the UHF RFID antenna's impedance should be $12+j200 \Omega$ at 868 MHz. Folded dipole respond to those specifications [10, 11]. The impedance in UHF frequency band can be easily modified by varying L1, L2, L3 and L4 length.

UWB systems are generally matched at 50Ω on the entire frequency band [12]. The small sizes of UWB antennas in comparison to UHF antennas permit to integrate them on a classical substrate UHF RFID substrate sizes. The shape and the way to match the UWB antenna are explained in [13].

The highest challenge is to minimize coupling effect between UHF and UWB antennas.

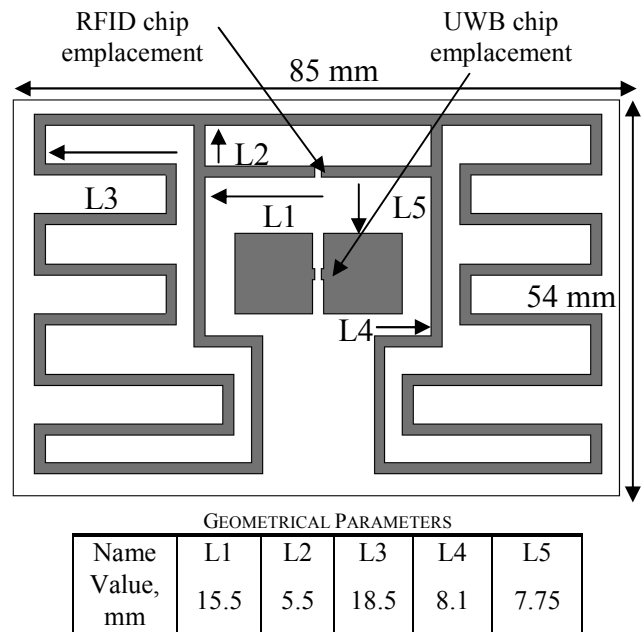


Figure 1: Tag antennas

B. Simulations and measures.

Tag Substrate is FR4 0.8 mm thick with a relative permittivity of 4.4 and $\tan\delta = 0.02$. Substrate sizes is equivalent to credit card sizes (85x54mm).

Measurement environments are described in [14]. In the measurement condition, the antenna must be symmetric. It allows to solder half of the antenna on a metal plate considered as ground plane. In those conditions, the antenna is feed by a SMA connector which permit to deduce input impedance after deembedding.

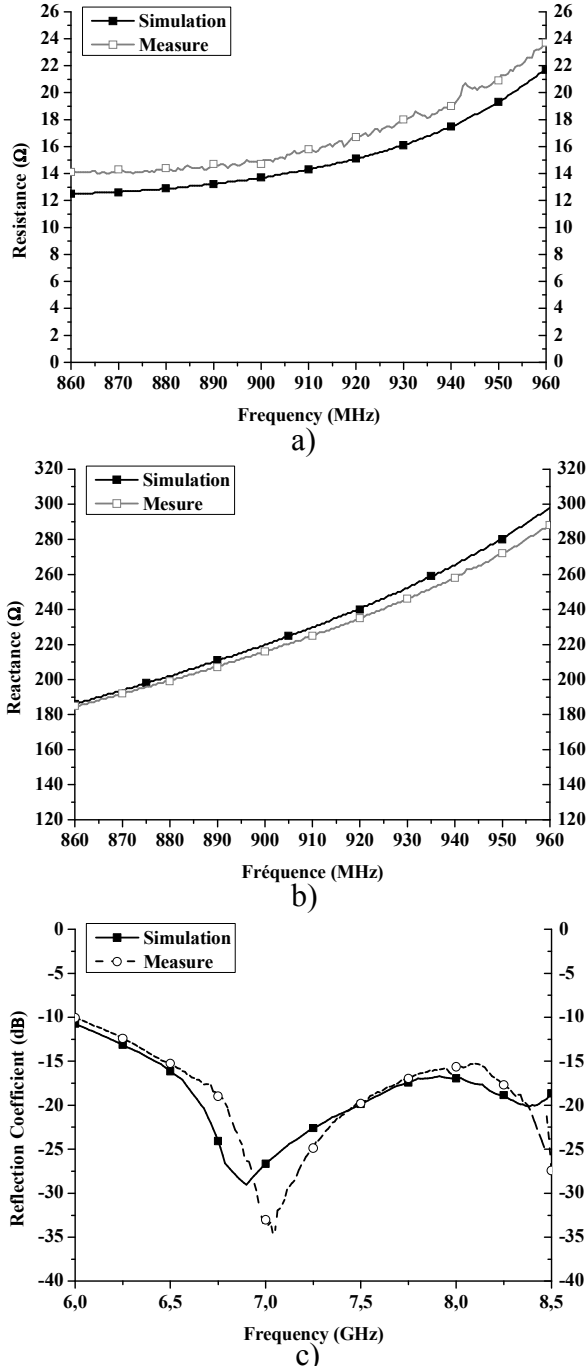


Figure 2: Tag antenna a) UHF resistance b) UHF reactance c) UWB reflection coefficient

In UHF RFID band (860-960 MHz) measurements are close to simulations (Figure 2.a,b)), the main difference is a resistance greater in measurement. The impedance at 915 MHz in simulation is $Z=14+j235 (\Omega)$ with 1.5 dBi gain (Figure 2 and figure 3.a)).

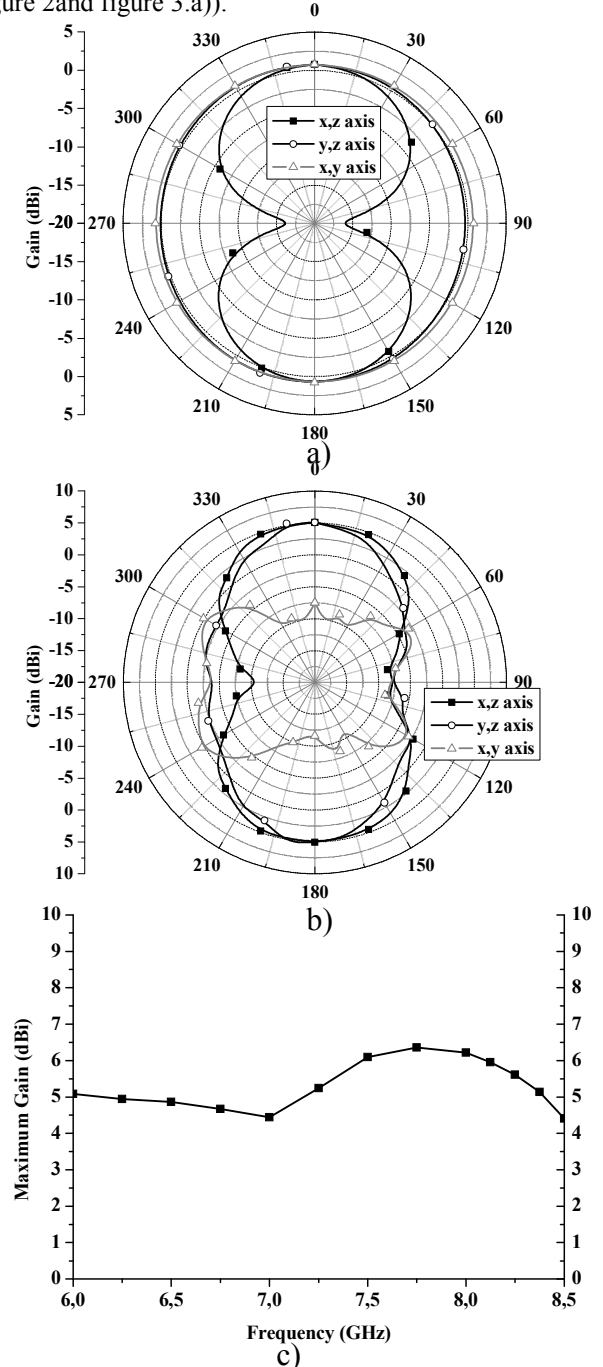


Figure 3: Gain and radiation patterns of tag antenna a) at 915 MHz b) at 7.25 GHz c) maximum gain on UWB band

UWB chip has an impedance around 50Ω in European UWB's band (6-8.5 GHz) and the antenna have a reflection coefficient lower than 10dB (Figure 2.c)) with average gain around 5.5 dBi (Figure 3.c)). Coupling between antennas are principally observed in the highest frequencies as shown in figure 3.c.

Tag antennas respect the specifications in term of sizes and matching. The RFID and UWB antennas are easily reconfigurable by varying the parameters previously describe. On UHF band, coupling effect between antennas are negligible, radiation pattern at 915 MHz have the classical shape for dipole without perturbations. Coupling effects between the antennas are more important in UWB frequency band as it shows on the radiation pattern at 7.25 GHz. The antennas have common directivity along Y axis.

III. READER ANTENNA

A. Design

The reader is a single antenna matched on twice band (860-960 MHz and 6-8.5 GHz) with an impedance of 50Ω . The substrate is epoxy 1.6mm thick with $\epsilon_r = 4.4$ and $\tan\delta = 0.02$. The antenna sizes are 131×18.8 mm and substrate sizes are 180×60 mm (Figure 4). Its structure is composed of planar dipoles. The reasons are: it is not necessarily to have a ground (because dipoles are differential antennas) and it is possible to make wideband matching [12, 13].

The main planar dipole is a straight dipole it's a narrow band antenna easily configurable on UHF RFID band. The other dipoles are bow-tie antennas mostly used for UWB applications [13]. Connections between these different dipoles are assumed by lines. These lines are as thin as possible (100 μ m) in order to have impedance close to open circuit on UHF band. Thanks to that, at 915 MHz most of the current is propagate through the straight dipole. In the highest frequencies current distribution is most homogeneous on all of the dipoles. Geometrical parameters are summarized on figure 4.

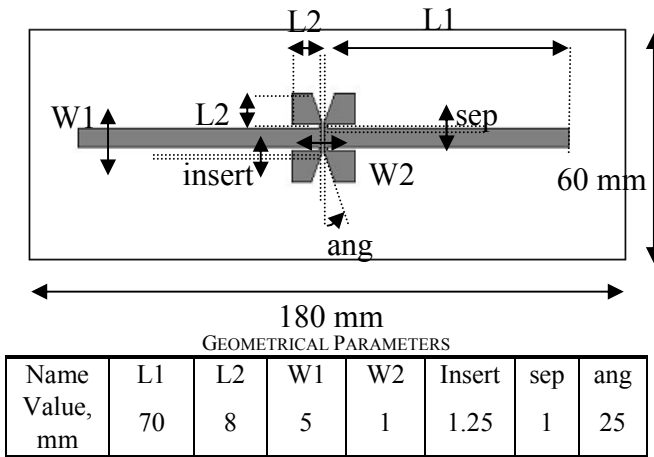


Figure 4: Reader antenna

B. Simulation and Measurements

In UHF band the reflection coefficient is lower than -10 dB. In this frequency band measures are not perfectly closed to simulation (Figure 5 b)) due to a difference of reactance (Figure 5 a)). Between 6 and 8.5 GHz reflection coefficient are lower to 14 dB in simulation and 12.5 dB on measures

(Figure 5 c)). The radiation pattern at 915 MHz is equivalent to a classical dipole radiation pattern because most of the current is propagated through the main dipole. At 915 MHz maximum gain is 1.8 dBi (Figure 6.a)). In higher frequencies, the current distribution is homogeneous so around 7.25 GHz the antenna radiates in many directions (Figure 6.b)). The main dipole is the most fluent parameter in UHF RFID band. To enlarge or shift the UWB match band without perturb too much matching in UHF band it is advised to only vary the sizes and the angle of the bow-tie antenna [6].

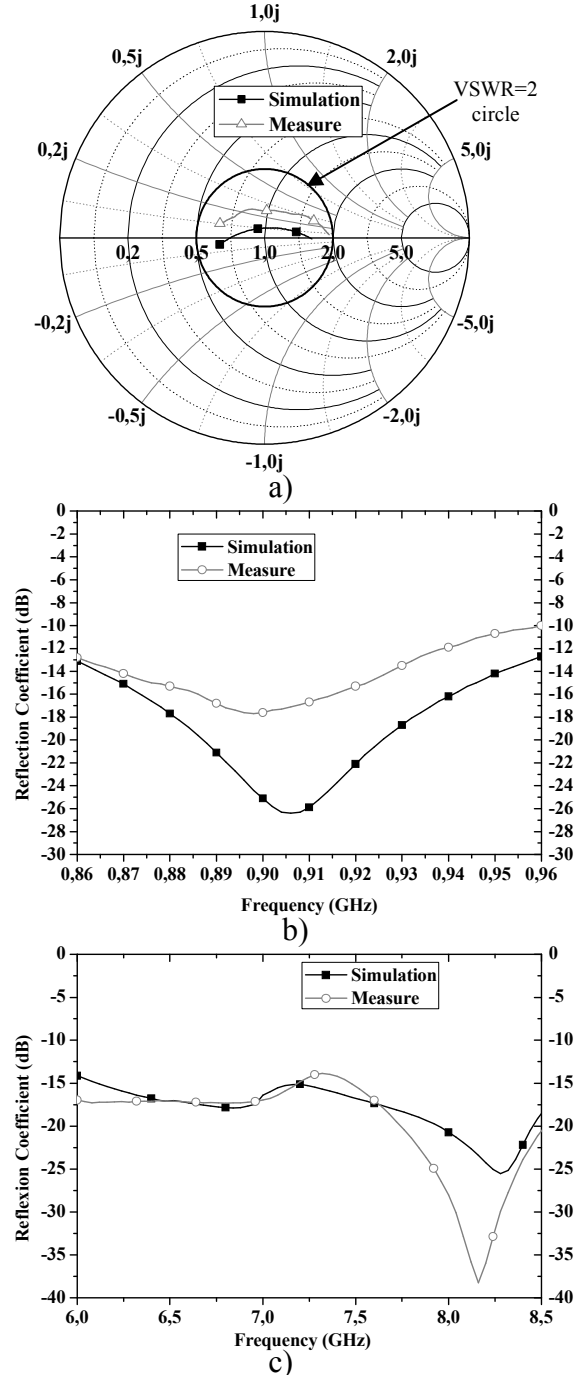


Figure 5: Reader antennas: a) impedance b) UHF RFID band and c) UWB band reflection coefficient

Reader antenna is the summation of two dipoles antennas. Each dipole is a classical antenna for the associate application. They are matched on twice band and have a common radiation area on UHF and UWB frequency band. Thanks to that it is possible to communicate and feed a tag on a direction. Substrate and fabrication process permit to minimize cost production.

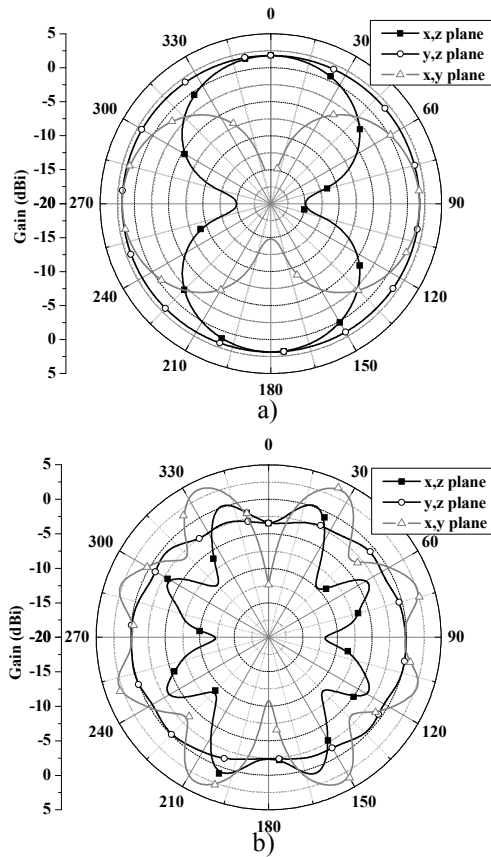


Figure 6: Gain patterns of reader antenna
a) at 915 MHz b) at 7.25 GHz

IV. CONCLUSION

This article presented different antenna's topologies for UHF and UWB RFID applications. Concerning tag antennas, a multi-chip solution was chosen and the main difficulties consist to minimize coupling effects between UHF and UWB antenna. UHF antenna has typical impedance and it is possible to reconfigure it easily to every kind of UHF RFID chip impedance. UWB antenna has a classical shape and the reflection coefficient is lower than 10 dB. Reader antenna cover twice band with an impedance of 50Ω . It's matched in simulation and measure to all UHF RFID and European UWB bands with a reflection coefficient lower than 10 dB. Perspectives are to design a reader and tag antenna matched on all UHF RFID and FCC UWB frequency band.[13]

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