Design and Modeling of Novel Multiband/Wideband Antennas for RFID Tags and Readers Using Time-/Frequency-Domain Simulators

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ABSTRACT — **In this paper, an overview of novel design and integration approaches for improved performance UHF Radio Frequency Identification (RFID) tags and readers is presented. Ultra-low-cost organic substrates, such as paper, with inkjet-printing capability are investigated for the UHF frequency band. The proposed technology could potentially revolutionize sensor nodes and RFID topologies for various applications such as security, logistics, automotive and pharmaceutical.**

Index Terms — **RFID, Time/Frequency-domain simulators.**

I. INTRODUCTION

The recent advances in cost-effective low-power electronics and packaging have enabled the RFID tag as a likely substitute for barcodes [1] in industries such as access control, parcel and document tracking, distribution logistics, automotive systems, and livestock or pet tracking. In these applications data are contact-free transferred to a local querying system (reader or interrogator) from a remote transponder (tag) including an antenna and a microchip transmitter. A suitable antenna for these tags must have low cost, low profile and especially small size. The RFID tags also present challenges in behavioral modeling and simulation of the antenna and module/package integration in parameters such as the pad capacitance, the estimation of the parasitics due to the proximity of IC and antenna, and the identification of a low-cost low-loss light material. On the other side, antennas for RFID readers require circular polarization and wideband/multiband performance in order to enable operation in different environments and standards (US, Europe, Asia) [2]. This paper presents for the first time the design, modeling and optimization of a dual-band circular-polarized antenna for universal UHF RFID readers in the two most common bands for UHF RFID applications (432-435 MHz-active RFIDs/866-954 MHz-passive RFIDs).

II. UHF RFID TAG ANTENNA

The upper UHF RFID band ranges from 860 MHz to 955 MHz. A half wavelength antenna is typically used in RFID applications due to its omnidirectionality enabling the tags' communication with the RFID reader in any orientation and for a variety of environments.

Directivity- The design of a highly directive RFID antenna is an effective method to increase the read range of a tag for manufacturing applications, such as boxes, palettes or items placed on conveyor belts (known position of tag). However, the radiation pattern of most RFID antennas is constrained by their intrinsic dipole nature (omnidirectional) with limited directivity (~2 dBi). A new topology, named dual-body configuration is presented in Fig. 1. Two meander-line arms are placed on each side of the feeding loop. In this case, the current directions are opposite along the arms and the radiation patterns cancel out each other in most of the directions. Thus, in this inductively coupled RFID antenna, the radiated energy is focused directionally in a dumbbell shape as shown in Fig. 2, and a high directivity of 5.62dBi is observed. In general, a highly increased effective range is expected to achieve with RFID antennas in such a configuration.

Paper is considered one of the best candidates for organic substrates for RFID/sensing applications. In terms of mass production and increased demand, this makes paper the lowest cost material made. Paper also has low surface profile with appropriate coating. This is very crucial since fast printing processes, such as conductive paste inkjet-printing, can be used instead of metal etching techniques. In addition, paper is compatible with circuit printing by direct write methodologies. This is one of the biggest advantages since active tags require additional modules like sensors and batteries to be mounted on or embedded in. The half wavelength tapered width dipole benchmark antenna we decided to fabricate using inkjet-printing was designed to cover the UHF North America RFID freq. band (902MHz→928MHz) with a center frequency of 914MHz.

As shown in Fig. 3(a) the two stubs namely: inductive and resistive stubs are responsible for the conjugate matching of the antenna to the reactive and resistive part of the IC respectively. The target Z_{IC} used in this design was Philips EPC 1.19 Gen 2 RFID ASIC IC which exhibits a stable impedance behavior of 16-j350 over the frequency 902MHz→928MHz. Return Loss (RL) plot is shown in Fig. 3(b) with a bandwidth of 905MHz→925MHz defined by a value of RL<-10dB for optimum antenna efficiency and an excellent read range of the RFID tag. The RFID antenna was ink jet printed with overall dimensions of: 8.2cm x 4.5cm. The radiation pattern of the antenna is quite similar to that of a classic dipole as shown in Fig. 3(c) which is desirable in most RFID applications. The inkjet printing on-paper approach is very repeatable, allows for features down to 20um and can be easily utilized for other passive functions, such as filters, baluns in single or multilayer (multi-sheet) configurations. Results from on-paper active RF modules including embedded batteries and IC's in addition to the antenna and stubs will be

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presented at the conference for universal (868-924 MHz) operation.

III. RFID READER ANTENNA MODELING AND DESIGN

It has been recently found that the bandwidth of the dual-rhombic loop could be further improved by adding a pair of parasitic rhombic loops inside the original loop [3]. This design was extended for dual-band circularly polarized (CP) RFID reader antennas covering the 433MHz and 910MHz band for “universal” coverage. The proposed topology (Fig. 4) consists of a single-layer CP dual-square-loop/cross-dipole configuration. The “dual” square-loop covers the 433 MHz band and the cross-dipole, branching from the loop, covers the 910 MHz band. The antenna is fed in parallel using a broad-band balun positioned underneath and normal to the antenna. The balun consists of a 50 Ohm ‘wrenching’ microstrip-to-slot transition that is connected to the antenna on both sides of the feeding slot. Starting from the GND plane, is one layer of Teflon substrate, followed by foam (surrounding the balun), and a top layer of Teflon substrate of which the antenna is placed on.

The 433 MHz loops support a traveling wave current distribution, that is optimized by adjusting the position of two gaps, and the height above the GND plane in order to achieve an Axial Ratio < 2dB for LHCP. The 910 MHz cross dipole arms are positioned 45 degrees from the loops in order to minimize crosstalk, and have two different dipole arm lengths in order to achieve an Axial Ratio < 5dB for RHCP. The current size of the reader antenna with the feed and substrate is 40cm x 40cm x 13.5cm. This is suitable for a stationary RFID reader that can be easily mounted on a wall.

The modeling and simulation were performed using initially NEC1.1 and then with the full-wave TLM technique (Microstripes 6.5 CAD tool) and the results are shown below. The results (Fig.5) for each band verify the effective performance of this antenna.

IV. CONCLUSIONS

In this paper, we proposed the modeling and design of novel multiband/wideband antennas for RFID Tag and Reader applications, that will enable the low cost and large-scale implementation of RFID-enabled semi-autonomous sensors for “cognitive-intelligence” applications. The three suggested antenna structures may fit any type of application (worldwide frequency coverage, harsh environments, and enhanced directivity) in UHF/RF bands, which will enable a high read range with high data rate transfer.

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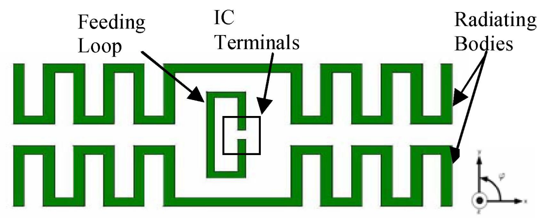

Fig. 1. Dual Radiating Body Configuration..

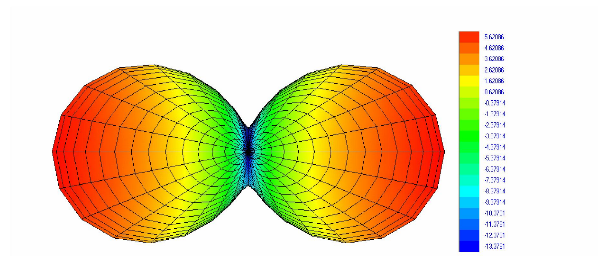

Fig. 2. Dual Radiating body radiation pattern (theta=0°, directivity=5.62 dBi).

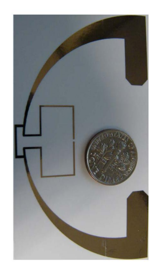

Fig. 3a. Inkjet-printed RFID Antenna on-Paper.

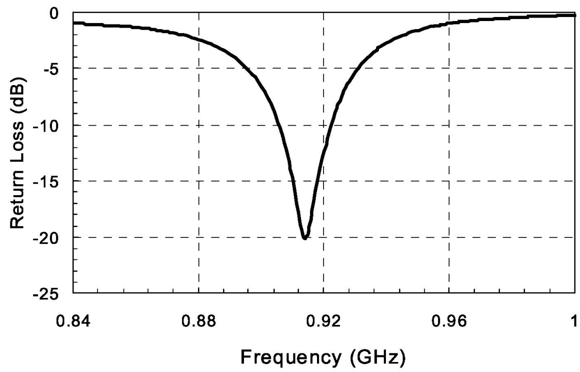

Fig. 3b. Return loss of inkjet-printed antenna.

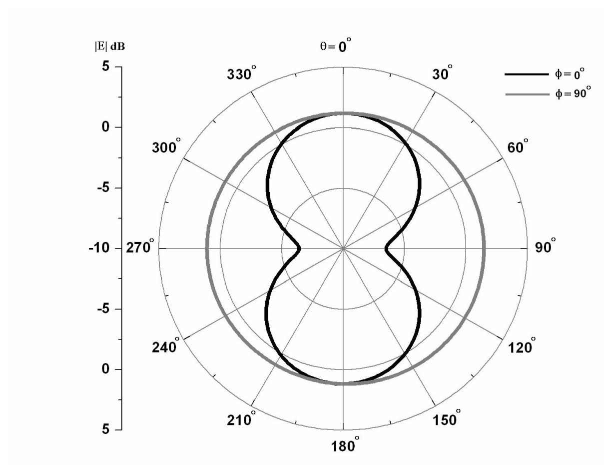

Fig. 3c. Radiation pattern of inkjet-printed antenna.

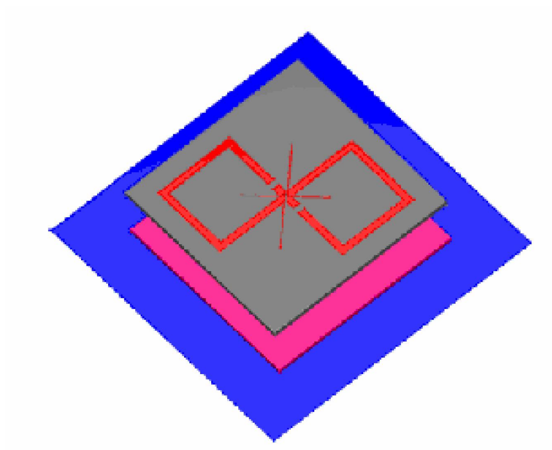

Fig. 4. DBand CP Reader antenna.

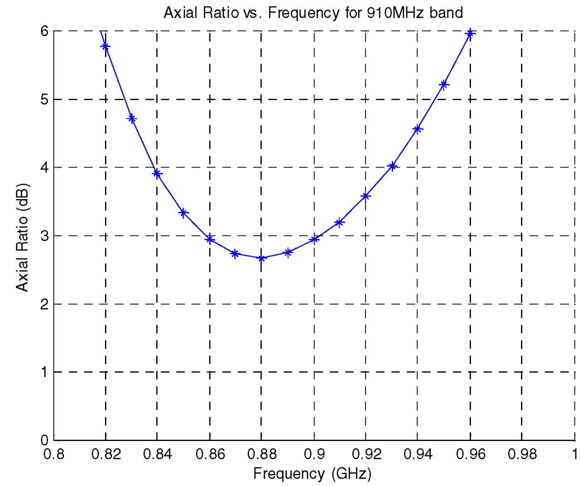

Fig. 5a. Axial Ratio for 910 MHz.

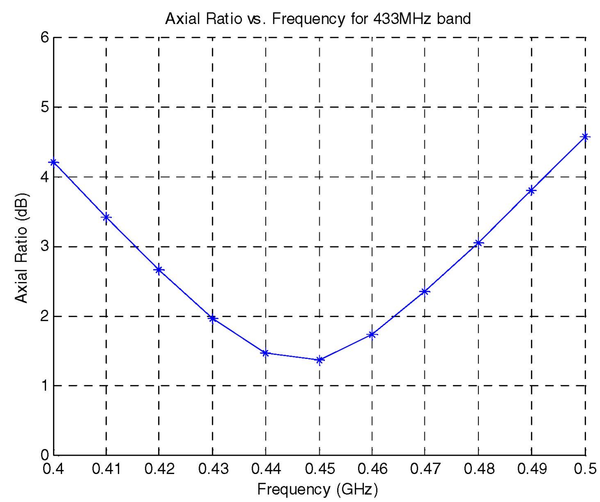

Fig. 5b. Axial Ratio for 433 MHz.