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Design and Modeling of a Novel Dual-Band Circular-Polarization Antenna for Multi-Standard/Multi-Band "Universal" RFID Readers

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Abstract- As the range of applications for RFID's increases, the design and realization of multistandard/universal RFID systems becomes a critical issue for their large-scale implementation. Despite the fact that most of the research efforts have been dedicated to active, semiactive or passive RFID's, the readers play a very important role in both range and coverage. To alleviate interference in harsh environments and provide omnidirectional coverage, the RFID readers require compact antennas with high efficiency, broadband performance and circular-polarization with low cross-polarization levels. In addition, the two UHF RFID bands (active: 432-435 MHz, passive: 866-954 MHz) that have been recently approved, impose the need for dual-band antennas, something which is extremely challenging due to the large physical size of the UHF wavelengths. This paper proposes for the FIRST TIME, a novel circular-polarization antenna that utilizes the combination of a dual-square loop and a cross-dipole, and allows for the efficient coverage of BOTH bandwidths for universal operation (US, Asia, Europe). This innovative approach could be extended to 4G, WiMax and wireless broadband multimedia in millimeter-wave range and could also set the foundation for ubiquitous sensing / cognitive radio nodes.

I.Introduction

Recent advances in cost-effective low-power electronics and packaging have enabled the RFID tag to be a preferred substitute for barcodes [1] in industries such as access control, parcel and document tracking, distribution logistics, automotive systems, and livestock or pet tracking. In applications such as these, data is contact-free and transferred to a local querying system (reader or interrogator) from a remote transponder (tag) which includes an antenna and a microchip transmitter. A suitable antenna for these tags must be low cost, low profile and most importantly small in size. RFID tags also present challenges in behavioral modeling and simulation of the antenna and module/package integration due to 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. Specs of RFID Readers Antennas

To satisfy the frequency requirements for a universal supply chain tracking across Europe, USA and Asia, a global UHF RFID reader must have an antenna that can operate with a least a 9.6% bandwidth from 866 MHz to 954 MHz, assuming mostly passive RFID tags [2]. In addition, this reader has to be "flexible" enabling its functionality in different environments that potentially de-polarize linearly polarized waves (water, food, wood, plants, liquids) [3,4]. Finally, numerous RFID readers have to be portable or quasi-portable, limiting their size to only 30cm x 30cm.

Currently, there is only a limited number of commercial RFID readers with circular-polarization antennas covering the whole universal (866-954MHz) band. Still, they could

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provide the benchmarking design specifications for reader antennas [5][6]. A gain greater than 5 dBi is required for a read range of at least 10m (30-40 ft) for a beamwidth larger than 55^o x 55^o, while maintaining an axial ratio of less than 4 dB is required to guarantee low cross-polarization. In addition, a VSWR less than 2:1 throughout the entire frequency range is also necessary to provide adequate matching with the reader system, and to satisfy power efficiency requirements. The transverse (face) dimensions should be smaller than 40cm x 40 cm. It has to be noted that the maximum regulated output power is currently 4 Watts globally. In addition to the above features, future-generation RFID reader antennas are anticipated to demonstrate the following improvements:

- Mechanical stability to provide portability and resistance against harsh environments [4].
- A VSWR decreased down to 1.5:1 (return loss < -14 dB) for even higher power efficiency and range.
- Multiband capabilities including lower UHF bands approved for active RFID's (e.g. 432-435 MHz).

Especially the large requirement is very challenging <u>since no dual-band broadband circular-polarization (CP) antennas have been published in the past, and the antenna shown in this paper will be the first ever reported.</u>

III. Novel RFID Reader Antenna

Previous research efforts have demonstrated that a dual-rhombic loop can serve as a broadband CP antenna by adding appropriately positioned gaps [7]. This paper realizes the first dual-band CP configuration, using a dual-rhombic CP loop designed around 433 MHz, whereas the second resonance at 910 MHz was added without interfering with the radiation pattern by adding a cross dipole in the center of the loop with the arms oriented 45 degrees from the loop edges. Upon addition of the cross dipole, the loop gap position can be easily adjusted along with the height from the GND plane in order to achieve the optimum axial ratio of <4dB at both 433 MHz and 866 to 954 MHz. The combined geometry of the dual rhombic loop and cross dipole, shown in Fig.1, is backed by a square copper plate (i.e., a ground plane) at a height *h=135mm* for unidirectional radiation and fed through an SMA connector. Both antennas are realized on the top surface of the thickest available RT Duroid (ε_r=2.2) substrate of 12.7mm. The radiation pattern, AR performance and compactness are further enhanced by adding a 10mm layer of Duroid on top of the ground plane. The rest of the substrate space (112.3mm) is covered by foam.

The CP rhombic loop and cross dipole are driven at their center by a broadband balun, which was also fabricated on the same type of RT/duroid 5880 substrate in order to allow for the efficient impedance matching in both bands. The broadband balun can excite the balanced mode by making use of the coupling between the microstrip line printed on one side of the substrate to the slot which is etched on the other side (it also serves as the ground plane for the microstrip line) of the substrate. A good impedance matching can be achieved by adjusting the length of the slot, the height and the length of the microstrip line.

The optimized structure (Fig.1) was simulated using the full-wave electromagnetic simulators HFSS and TLM-based Microstripes and the S11 and Axial Ratio (AR) bandwidths, shown in Figs.2 and 3, verify that it can provide CP radiation with excellent matching for both 430-435 MHz and 866-954 MHz for the first reported time. The radiation patterns at the yz-plane for the two bands are shown in Figs.4 (433MHz) and 5

(910 MHz). The gains and beamwidths are 5.1dBi / 55^{o} x 55^{o} and 5.0dBi / 70^{o} x 70^{o} , respectively, satisfying the specs for the next generation of RFID Readers' antennas. The cross-polarization levels are -15 dB's below the main polarization level for both bands. It has to be noted that the proposed antenna realizes LHP for the lower frequency band and RHP for the upper frequency band, which further enhances the performance of this antenna geometry. Results from the fabricated prototype will be presented at the conference.

IV. Conclusion

In this paper, we proposed a novel circular-polarization antenna that utilizes the combination of a dual-square loop and a cross-dipole, and allows for the efficient coverage of both UHF RFID bandwidths for universal operation (US, Asia, Europe), namely 430-435 MHz and 866-954 MHz, for the first time. This topology satisfies the specifications for the future generation of dual-band RFID readers and enables a high read range with high data rate transfer. The proposed antenna may fit any type of environment (even harsh indoor ones) due to its good quality of circular polarization and could set the foundation for ubiquitous sensing / cognitive radio nodes, while it can be easily applied to 4G and mm-wave broadband wireless modules.

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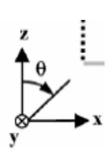

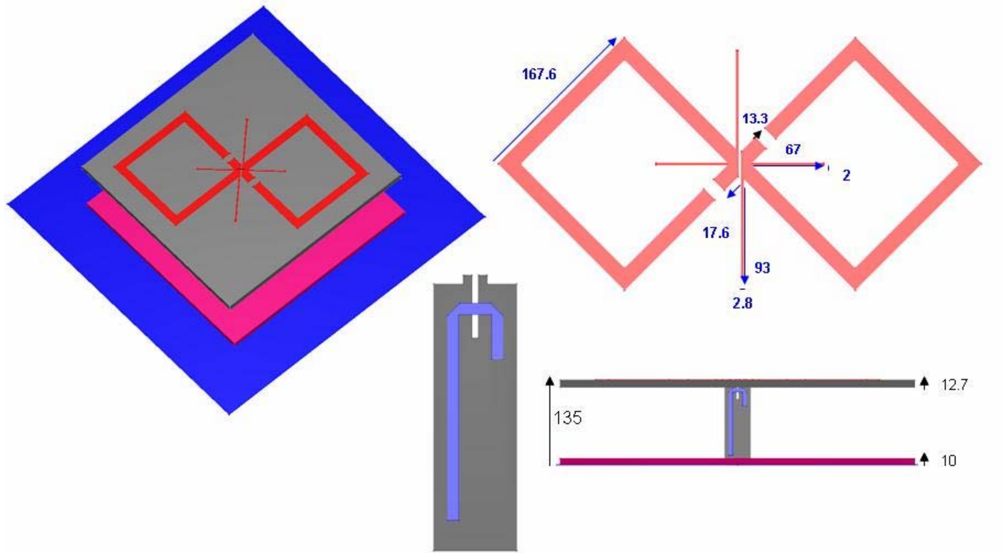

Fig.1. *(Top Left)* 3D antenna configuration, *(Top Right)* antenna dimensions (in mm), *(Bottom Left)* broadband feeding balun, *(Bottom Right)* Substrate: Duroid-Foam-Duroid configuration along with the feeding balun (in mm)

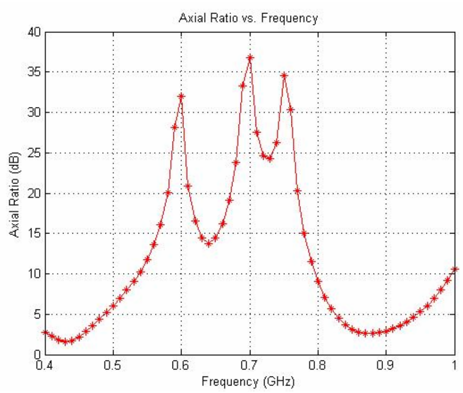

Figure 2. Axial Ratio Bandwidth

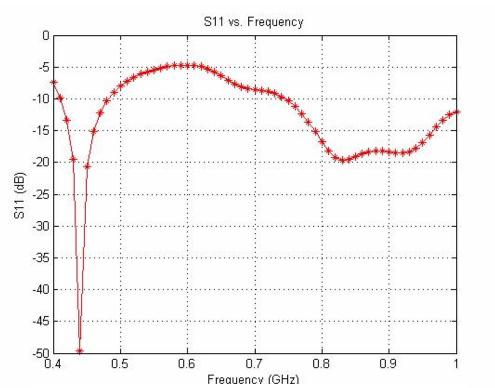

Figure 3. S11 Bandwidth

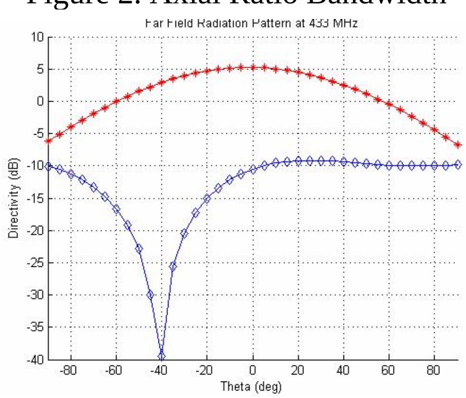

Figure 4. Radiation pattern @433 MHz [Red:LHC, Blue-RHC]

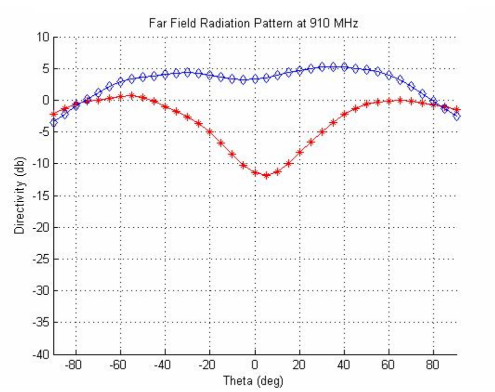

Figure 5. Radiation pattern @ 910 MHz [Red:LHC, Blue-RHC]