Dual-band HF-UHF RFID tag antenna

P. Iliev, P. Le Thuc, C. Luxey and R. Staraj

A dual-band HF and UHF RFID tag antenna with two feeding points is presented, fabricated and measured. A convenient HF resonance is obtained with an HF ASIC chip as well as good impedance matching with UHF ASIC chip in the European RFID UHF band. Tuning techniques of the design parameters are proposed, and tag performance in both frequency bands is evaluated.

Introduction: Radio frequency identification (RFID) is gaining popularity in many applications since it is an automatic identification method for efficient tracking and managing of individual consumer goods. This technology has advanced to the current level [1] owing to recent progress in the microelectronics industry. An RFID transponder called 'a tag' consists of an antenna combined with an ASIC (application specific integrated circuit) chip. In the UHF band (860–960 MHz), in order to activate and detect a tag, a base station, called a reader, transmits a modulated signal with periods of unmodulated carrier. The RF voltage developed at the antenna terminal during the unmodulated period is converted into a DC voltage, which powers up the chip. The information is then backscattered to the reader by varying the chip front-end complex RF input impedance. The main challenge for this technology is generally to increase the detection distance of a tag [1]. Another challenge is the interoperability of these systems with HF loop antennas and circuits operating through magnetic coupling at 13.56 MHz. In fact, HF tags provide higher security and a larger information storage capability thanks to their near-field operation and ASIC complexity, whereas UHF tags have a better reading range and speed. Although the use of two chips would increase the tag's cost, combining both RFID standards on the same tag would increase its capabilities and could lead to new applications. By using the same tag, any customer might decide whether to focus on the security or on the speed of the identification and, therefore, the users could subscribe to multiple services.

Dual-band RFID tags combining the 13.56 MHz and 2.45 GHz bands [2] or 900 MHz–2.45 GHz [3] have been proposed. Structures combining HF and UHF bands remain few, and positioning the UHF dipole in the centre of the HF loop is difficult as mutual influence has to be controlled using coplanar strip techniques [4]. In this Letter, we present an antenna structure combining a UHF dipole, called here the S-dipole, and an HF coil. The influence between the two elements is evaluated and controlled to ensure good performance in both RFID bands. The antenna structure was fabricated and measurement results are presented here.

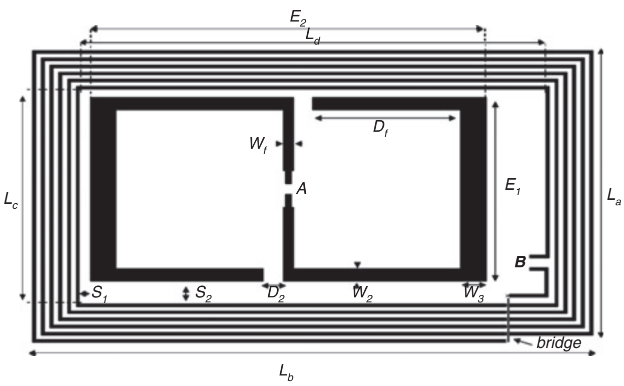

Fig. 1 *Antenna structure*

$E_1 = 30.5$ mm, $E_2 = 62.5$ mm, $D_1 = 14$ mm, $D_2 = 16.5$ mm, $S_1 = 1.5$ mm, $S_2 = 3.5$ mm, $W_1 = 1.5$ mm, $W_2 = 2$ mm and $W_3 = 4$ mm.

Antenna structure and tuning techniques: The antenna structure is shown in Fig. 1. It is printed on a substrate with thickness of 0.7 mm and relative permittivity of 2.2. 'A' indicates the UHF differential feeding point location and 'B' the HF one. The magnetic loop inductance is made up of six coil turns of 0.6 mm width, spaced by 0.4 mm. L_a, L_b, L_c and L_d are the loop external dimensions. The number of turns and their dimensions have been defined to obtain the HF resonance when a Philips Mifare UL ASIC chip having an input capacitance of 17 pF is placed at the differential feeding point 'B', corresponding to ISO 14443 type A operations. For the UHF operation, as the presence of the HF loop considerably decreases the UHF bandwidth, the resonance at the differential feeding point 'A' has to be tuned by slightly changing the external dimensions of the loop. However, the HF resonance frequency is still maintained. In this Letter, antenna dimensions have been optimised in order to obtain operation in the European RFID UHF band (865–868 MHz). Nevertheless, the tag can be tuned to operate in other UHF bands corresponding to the standards used in other countries (US: 902–928 MHz; Japan: 950–956 MHz).

The following dimensions, conforming to HF tags standard (ISO/IEC 14443-1), were obtained: $L_a = 49$ mm, $L_b = 83$ mm, $L_c = 37$ mm and $L_d = 70$ mm. E_1, E_2, D_1, D_2, W_1, W_2 and W_3 are the S-dipole dimensions. S_1 and S_2 are the spacing between the S-dipole and the HF loop. A bridged line is used to close the HF loop termination. This bridge is positioned over a thin non-conductive material, which is used to isolate it from the other arms of the coil. The parametrical studies realised on E_1, E_2, D_1, S_1 and S_2 have shown their considerable influence on the input impedance obtained at the 'A' differential feed point. Then, these dimensions were tuned in order to achieve a good UHF impedance matching. The design has been made to operate with an Impinj Monza ID V2 ASIC chip. Its measured input impedance is $Z_c = (20 - j110)\Omega$ at 866.5 MHz, which is the middle frequency of the European RFID UHF band. To transmit the maximum power between the antenna and the microchip, conjugate matching must be ensured. We achieved a good impedance matching with the dimensions given in the caption of Fig. 1.

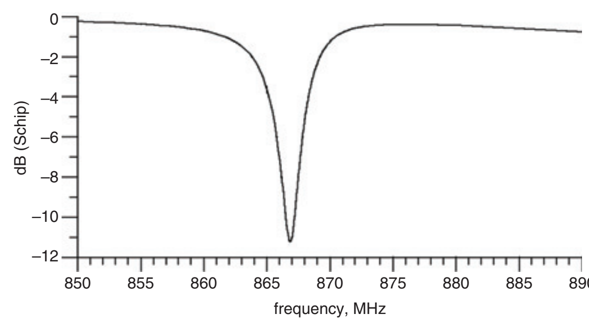

Fig. 2 *Simulated chip/antenna return loss*

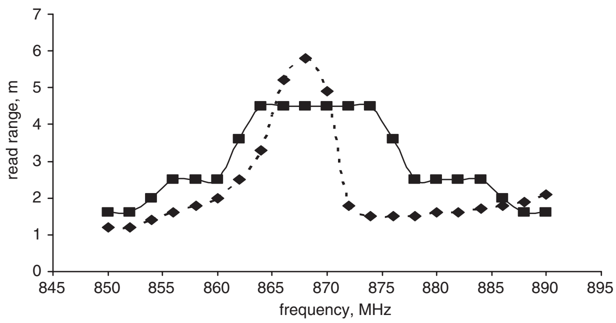

Fig. 3 *Read range in UHF band*

– – – – simulated
——— measured

UHF performance: The antenna structure has been designed and simulated with ADS-Momentum (2008 version). For all the UHF simulations, the presence of the HF capacitive circuit at the differential feed point 'B' has been taken into account. The simulated return loss between the chip and the antenna is shown in Fig. 2. A gain of 2.3 dBi is obtained in the best radiation direction and the simulated radiation efficiency is 96%. The read range of the obtained UHF tag operating with the chip connected at the differential feed point 'A' was then measured. The measurement equipment [5] was built on a National Instruments PXI (PCI eXtensions for Instruments) modular hardware platform. It is composed of a PXI-5670 RF signal generator, a PXI-5660 RF signal analyser, a LabVIEW controller and a circulator. The tag was located inside a compact anechoic chamber at a distance of 1 m away from the linearly polarised transmitting antenna, which has a 6 dBi gain. The minimum signal generator output power necessary to activate the tag at each measured frequency point was then obtained. From this value, the tag's maximum read range is calculated by using the Friis free-space formula [1, 5]. This is the maximum distance at which a tag can be detected when the maximum allowed equivalent radiated power (2W between 865.6 and 867.6 MHz) is transmitted (ETSI 302-208). The measured read range is shown in Fig. 3 and is compared to the calculated one from the simulated return loss. Some differences can be observed between the two curves, which can be owed to the fact that the association chip/antenna presents a larger bandwidth but a lower level of matching than the one presented in Fig. 2. Moreover, the sensivity and the tolerance of the measurement system also increases these differences. However, a read range of 4.5 m has been obtained and confirmed in front of a Samsys European RFID UHF reader.

HF performance: Normally, HF RFID tags should have a resonance frequency of about 13.56 MHz. Despite this, MIFARE HF RFID tags (ISO/IEC 14443 type A standard) have specific application recommendations: to operate properly with the HF reader performing a magnetic coupling at 13.56 MHz, the resonance frequency of these tags should be between 14.5 and 18.5 MHz. The HF tag measurement setup is shown in Fig. 4. Two testing loops are connected to the input and output ports of an HP E4411B ESA-L series spectrum analyser. The loops are placed one above the other and the existing coupling transmission is recorded. The tag under test (TUT) is then placed between the testing loops and the transmission is recorded. The linear gain shown in Fig. 5 is the difference between the coupling of the testing loops with and without the TUT. The maximum value of this gain depends on the tag's placement but the resonance frequency and the quality factor remain constant. Resonance is obtained at 16.1 MHz with a quality factor of 10.1, which is pretty suitable for MIFARE ISO 14443 type A operation. The tag functionality is then confirmed in front of an ASK RDR 400 HF contactless reader.

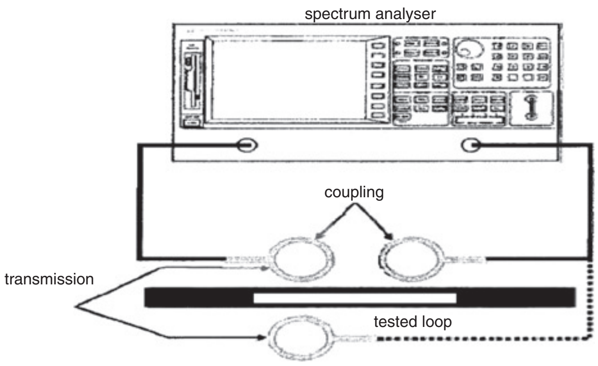

Fig. 4 *Magnetic loop testing*

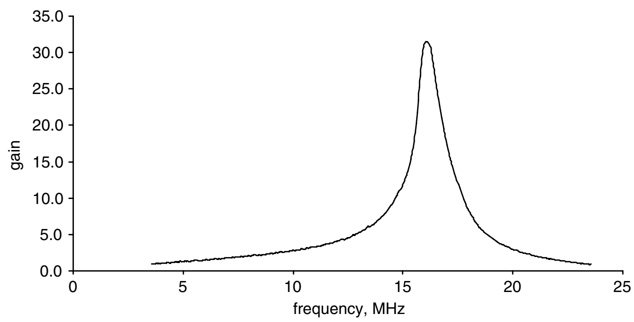

Fig. 5 *HF loop resonance frequency*

Conclusions: A simple dual-band HF-UHF RFID tag antenna showing very good performance in both bands has been proposed. It is composed of an S-dipole integrated in the HF coils. This technique allows the use of the HF coils, excited by an S-dipole element, as a part of the UHF antenna. The structure keeps small dimensions and is low cost concurrently with good performance in gain and reading distance. Fine tuning of the radiating elements has been realised taking into account the effects of the particular input impedances of the real HF and UHF circuits used. This tag design was dedicated for the UHF European standard, but other regional standards can be achieved with small modifications of the structure dimensions.

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