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Design and Implementation of passive UHF RFID system

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***Abstract*—In this paper, the implementation of passive UHF RFID, using Agilent Advanced Design System, is constructed. The implementation of this system is divided into two main parts, the reader part and the tag part. The architecture of each part is described in details and is implemented. During the design process, we propose models for building blocks of different encoding types used in RFID system. A dipole reader antenna, with a center frequency of 915 MHz is also proposed and designed. Finally, we present some implementation results.**

***Index Terms*—UHF passive RFID system, RFID reader, RFID tag, Agilent ADS.**

I. INTRODUCTION

Radio Frequency IDentification (RFID) is a generic term used to describe a system that transmits the identity of an object or person wirelessly using radio waves. Nowadays, RFID technologies are applied to various fields such as transportation, medical treatment, smart card, attendance system, item tracking, supply-chain management, etc. [1].

Generally, the RFID system consists of two basic components, a reader and a tag. The reader is composed of a radio-frequency module, a control unit and an antenna. The tag attached to an object, consists of an antenna and a silicon chip containing a small amount of information [2]. According to the operating frequency, RFID systems can be distinguished into four frequency bands: the low frequency (LF) band around 125 kHz, the high frequency (HF) band at 13.56 MHz, the ultra high frequency (UHF) band at 860-960 MHz, and the microwaves band at 2.4 GHz. For LF and HF RFID systems, the read range is less than 1m; for UHF RFID system, the read range generally reaches around 5m [3]. The RFID system can be also classified into passive tags which have no independent electrical power source and have no radio transmitter. Semi passive tags have a local battery only to power the tag circuitry, and active tags with a battery for both a local power source and a radio transmitter [4]. In this paper, we are interested in the design of the passive UHF RFID system. This operation is achieved through modeling and implementation using the rapid prototyping environment of Agilent ADS (Advanced Design System) [7]. The latter environment provides a block diagram interface, an integrated design environment to designers of RF electronic products, graphic and programming functionalities. Agilent ADS supports many steps of the design process: schematic capture, layout, frequency-domain and time-domain circuit simulation, and electromagnetic field simulation.

The paper is organized as follows: in section 2, we build and describe different blocks of RFID system implementation, section 3 deals with the results of the implementation. Finally, concluding remarks are drawn in section 4.

II. RFID SYSTEM IMPLEMENTATION

A RFID reader is a radio transceiver, meaning that it consists of a transmitter and receiver working together to communicate with the tag. In this section, we describe models of the reader and the tag parts.

A. Reader transmitter model

The reader transmitter, shown in Fig.1, is implemented using the co-simulation between the numeric front end and the radio front end. The transmitter is mainly made up of a source encoder, raised cosine filter that removes the Inter Symbol Interference to satisfy Nyquist criteria. In other hand, in the radio front end, we find a non-ideal mixer for up-conversion, a high-power amplifier and band pass filter with bandwidth lying (860-960) MHz, used to remove the out- of-band spectrum. The implementation of the radio front end is depicted in Fig.2.

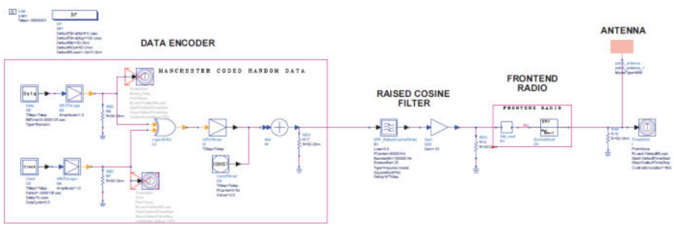

Fig. 1. RFID transmitter implementation

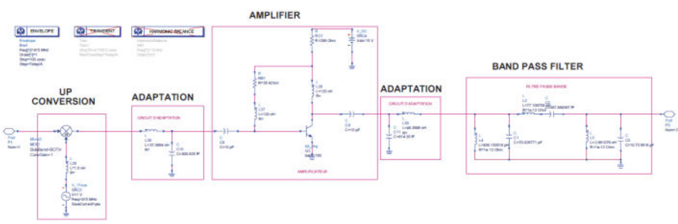

Fig. 2. Transmitter radio frontend

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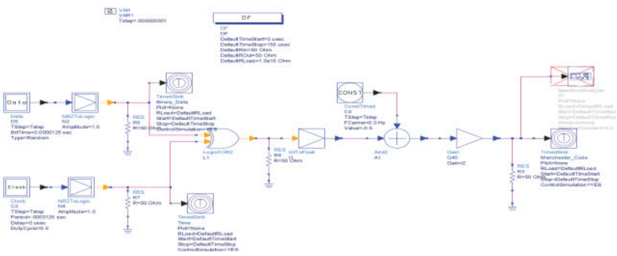
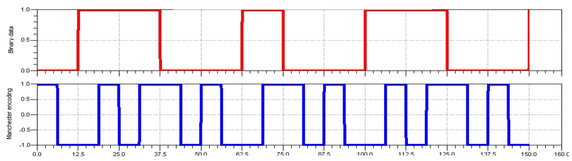
In Gen2 (second RFID generation), the reader transmitter uses DSB-AM (Double Side Band-Amplitude Modulation) or SSB-AM (Single Side Band-Amplitude Modulation) [3]. According to the architecture of the reader transmitter shown in Fig.1, only the DSB modulation is presented.

1) Transmitter data encoding: In Gen2 protocols, the generated binary data by the reader is coded using Manchester encoding [5]. In Fig.3(a) we propose schematic blocks to build the Manchester encoder. The obtained Manchester encoding result for the sequence “011001001100” is depicted in Fig.3(b).



(a) Manchester encoder



(b) Manchester encoding example

Fig. 3. Manchester encoder & encoding

B. The reader receiver

The basic receiver architecture for a RFID receiver is based on a direct-conversion I/Q demodulator. Fig. 4 sketches the radio frontend of the receiver. The received signal from the tag is directed first to a band filter, to remove signals laying outside the frequency band of interest. Then, the resulting signal is split and directed to two branches of demodulators. One branch has a mixer excited with the local oscillator signal and the other has a mixer excited with the local oscillator signal shifted by 90 degrees. The demodulated signal is then filtered to remove the carrier frequency and harmonics.

To explain how the receiver works, we present in Fig.5 the return link communication implementation (from the tag to the reader).

While the reader is listening for the tag response (return link), the reader transmitter must send the continuous wave (CW) to power the tag, and to backscatter the tag data encoded as FM0. It means that the tag will respond to reader, by sending over the CW, the data stored on it [6]. The communication channel is modeled as an additive white Gaussian noise channel to introduce noise sources from environment.

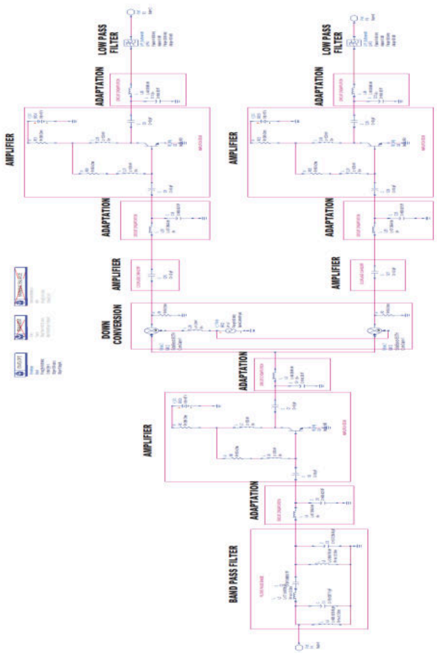


Fig. 4. Receiver radio frontend

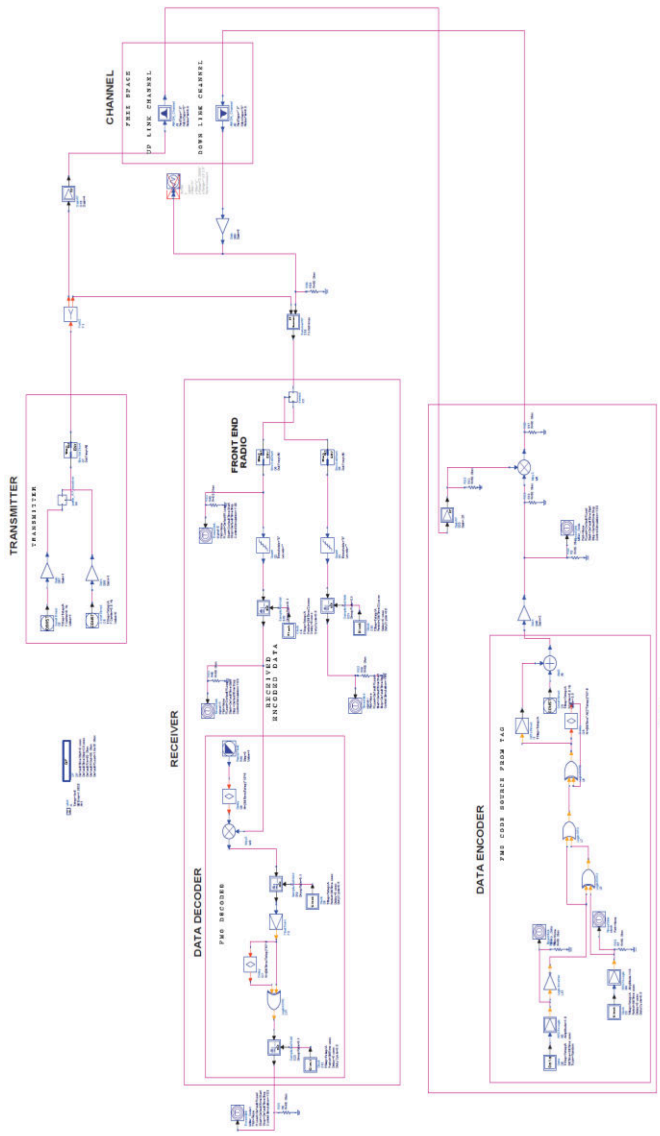


Fig. 5. Return link implementation

C. The tag model

1) Signal detection: Generally, The passive tag is composed of two envelope detectors; each one includes a diode used to rectify the voltage and a capacitor used for signal smoothing. The first envelope detector has a big capacitance value that creates a constant voltage used to power the tag. The second one uses a smaller capacitance value to recover the information from the reader [4].

In Fig.6, we propose an implementation of the envelope detectors, the top envelope detector has a capacitance value of 1 *nF*, is used to recover the modulated transmitted signal. The second one on the bottom, has about 4.6 μF as capacitance value, and is used to recover the power source.

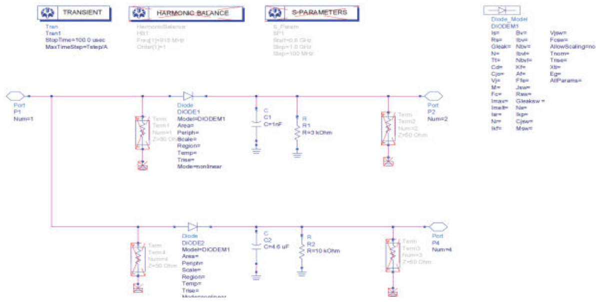
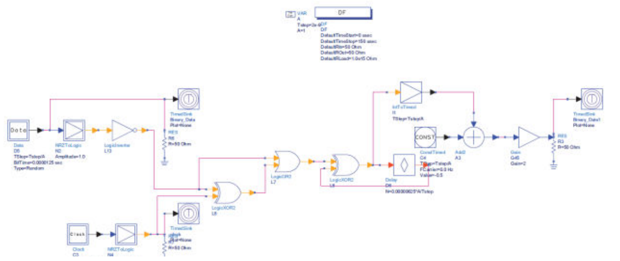


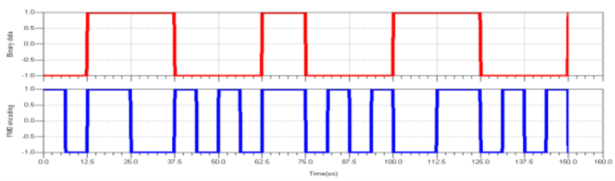
Fig. 6. Envelope detectors

2) Binary data encoding: For the return link, tags should encode the backscattered data as either FM0 baseband or Miller encoding [3]. Only FM0 encoding is presented in this paper.

In Fig.7(a), we propose a model of blocks for generating the FM0 encoding. The data-0 or data-1 should be encoded like the form in Fig.7(b). FM0 inverts the phase at every symbol boundary; a data-0 has an additional mid-symbol phase inversion [3].



(a) FM0 encoder



(b) FM0 encoding

Fig. 7. FM0 encoder and encoding data

Every communication process between readers and tags are based on identification or authentication protocols. This part is not included in this work, but we are interested on RFID tag signal in its general form.

D. Reader antenna

In this section, we propose the design of a compact printed dipole antenna for UHF RFID reader. Fig.8 gives the overall dimension of the antenna. Our dipole antenna mainly consists of two radiating arms separated by a 6 mm width slot. At the end of the slot, there is a 1 mm shorting strip, which connects two radiating arms. The antenna is a simple meandered dipole which occupies the volume of (78x30x1.6 mm^3). The width of the radiating arms is fixed to 4 mm as an optimized result.

The feeding of the antenna is done in A and B. The value of the distance between A and B is fixed to 6 mm to achieve a good impedance matching.

It is worth to mention that the length of the conventional dipole antenna is about half the resonant wave length that is 164 mm at 915MHz. Tthe size of the antenna is reduced by 54% compared to the size of a conventional dipole antenna.

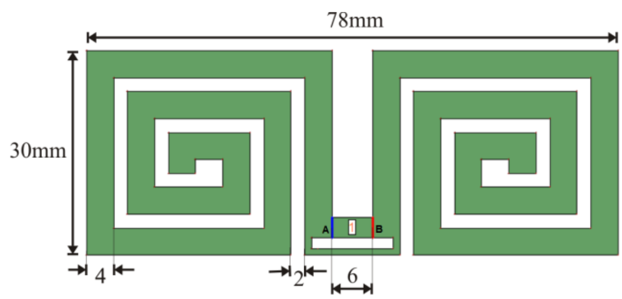


Fig. 8. Reader dipole antenna

For the demonstration purpose, the proposed antenna was designed on a FR4 epoxy substrate with a dielectric constant 4.32 and loss tangent of 0.017. In this case, the final antenna parameters are optimized using the commercial electromagnetic (EM) IE3D simulator. Fig. 9 shows the antenna response behavior at 915 MHz with return loss about -27 dB.

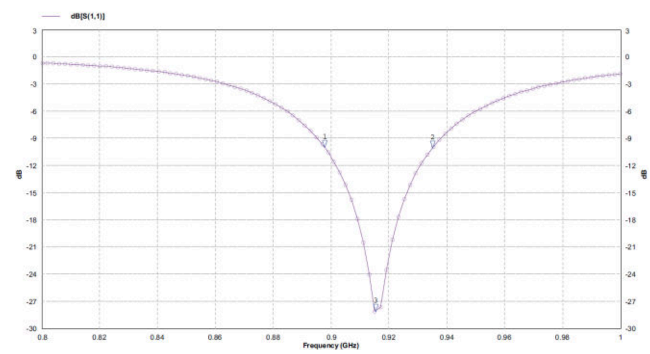


Fig. 9. Reader dipole antenna return loss

Finally, based on the antenna's results, it can be stated that the designed model of antenna is suitable for the RFID application.

III. RFID IMPLEMENTATION RESULTS

In this section, some implementation results are presented for each part of UHF RFID system.

A. Implementation results of the transmitter

Figure 10 shows the DSB transmission of Manchester encoding with 80 kbits/s data rate for 30% modulation depth.

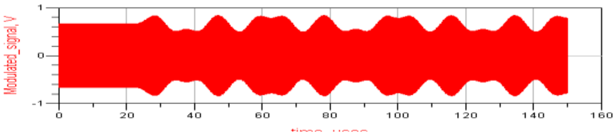


Fig. 10. DSB transmission of Manchester encoding (30% modulation depth)

The Gen 2 modulated signal shown in Fig.10 will be transmitted and will be recovered by the tag.

B. Implementation results of the reader receiver

Figure 11 shows the FM0 encoded data from the tag on the top, the demodulated signal just after the low-pass filter in the receiver, and in the bottom, the encoded received data.

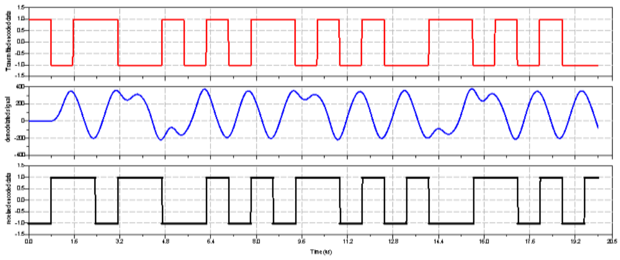


Fig. 11. FM0 demodulated signal and encoded received data

Bit Error Rate (BER) is used to evaluate the performance of the communication from the tag to the reader (return link communication). Figure 12 depicts the BER vs. SNR of the return link communication of FM0 encoded data, where the BER is inversely proportional to the SNR. From the Fig.12, the BER reaches 10^{-3} for an SNR of 9 dB.

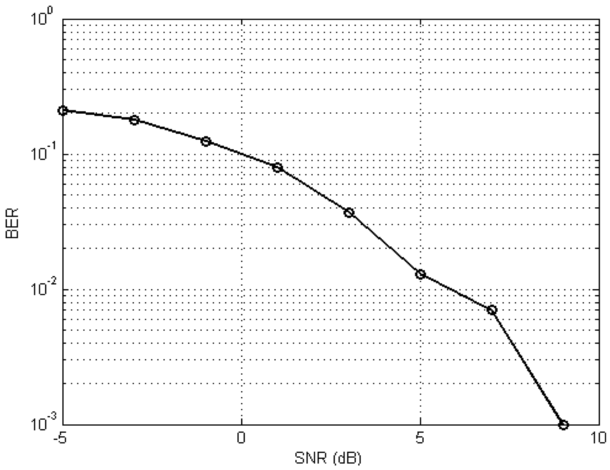


Fig. 12. BER performance of the return link communication

C. Implementation results of the tag

Figure 13 shows the envelope detection of the Manchester DSB modulated signal from the reader transmitter.

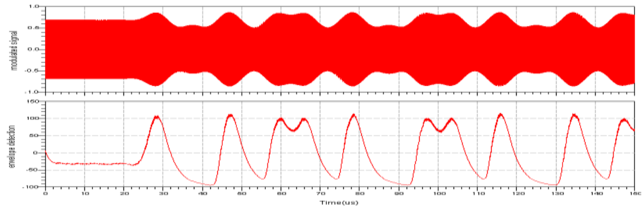


Fig. 13. Envelope detection

The detected envelope is then rectified by a limiter in order to get the received encoded data as shown in Fig.14. We present, on the top of Fig.14, the transmitted encoded data from the reader transmitter, and the bottom received encoded data by the tag. We can see that the tag can recover the same data as transmitted with a time delay.

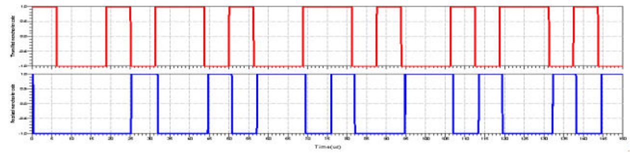


Fig. 14. Received encoded data

IV. CONCLUSION

In this paper, both RFID reader and tag is modeled and implemented using Agilent ADS environment. During the implementation, we proposed to use the co-simulation between the numeric front end and the RF front end for each part of the RFID system (reader and tag). Different blocks for encoding types are proposed. A low-cost reader antenna is also designed. From the obtained results, the received data by either the receiver or the tag are successfully and entirely demodulated. Finally, the implemented RFID system allows us to state that the passive UHF RFID system can be easily manufactured using low-cost components.

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