Design of Miniaturized Multi-Protocol UHF RFID Reader Module

Jian Li, Jun Chen, Zhong Huang, Boyang Zhang, Yongjun Huang, and Guangjun Wen
School of Information and Communication Engineering
University of Electronic Science and Technology of China, Chengdu 611731, P. R. China
lj001@uestc.edu.cn, yongjunh@uestc.edu.cn

***Abstract*—An UHF RFID reader module is designed in this paper, which supports the international standard ISO/IEC 18000-6C and the Chinese standard GB/T 29768-2013. High isolation is achieved by a directional coupler based double-tuning RF transmit-receive circuit with a compact structure, which alleviates the linearity requirements of the receiver front-end. The designed reader module working in 920~925 MHz band with a saturate output power of 29.6 dBm, and the inventory range is larger than 15 m for both the international and the Chinese standard tags. The miniaturization of the reader module is realized by using the compact transmit-receive isolation circuit and sandwich-stack packaging of the printed circuit boards, and the volume is only 70×60×15 mm^3.**

Keywords—UHF RFID; reader module; multi-protocol; high isolation; miniaturization

I. INTRODUCTION

Ultra high frequency (UHF) Radio Frequency identification (RFID) technology brings about a lot of attention and applications because of its characteristics of long distance recognition [1]. The UHF RFID system has been widely used in the production and logistics management duo to its passive tag with advantages of low cost, small size and no battery power supply.

At present, the main UHF RFID standard is the international one called ISO/IEC 18000-6C [2]. In 2013, China also released the national standard called GB/T 2978-2013 to accelerate the application of UHF RFID technique in various fields [3]. The commonly used UHF RFID reader chip, such as the R2000 of IMPINJ [4] and the PR9200 of PHYCHIPS [5], have integrated the dedicated digital baseband circuit for the ISO/IEC 18000-6C standard, and cannot make corresponding modifications to support the national protocol (GB/T 2978-2013). As a result, the multi-protocol UHF RFID reader with discrete components not using a dedicated reader chip will have great advantage and important value.

The UHF RFID reader needs to transmit the unmodulated carrier to supply the passive tag while receiving the returned signal from the tag, which leads to a serious self-jammer problem. By adopting independent receiving and transmitting antennas, the isolation of 40 dB can be achieved [6], but this will increase the size of the reader and increase the system cost [7]. The isolation of the transceiver circuit based on the circulator is only 25 dB [8], and its large size restricts the miniaturization of the reader.

In this paper, a UHF RFID reader module is designed, which can support the international standard ISO/IEC 18000-6C, the Chinese standard GB/T 29768-2013 and other self-defined protocol. This module integrates a small-size directional coupler instead of circulator, and just with an additional L-type matching network at the output of the coupler, the isolation of the transceiver circuit can be increased substantially. In addition, the whole reader module realizes miniaturization through the three-dimensional stacking of the circuit board.

II. SYSTEM DESIGN

The designed system architecture of UHF RFID reader module is shown in Fig. 1. The transmitter is an orthogonal direct frequency conversion structure, with advantages of simple structure and less use of devices. In the transmitter, the orthogonal modulation structure can also realize three modulation modes, such as DSB-ASK, SSB-ASK, and PR-ASK, which have great flexibility. Meanwhile, the receiver also adopts direct conversion structure. The 12-bit ADC and DAC realize the conversion between the analog signal and digital one. The FPGA baseband circuit cooperating with the MCU supports the ISO/IEC 18000-6C, GB/T 29768-2013 and other self-defined protocol.

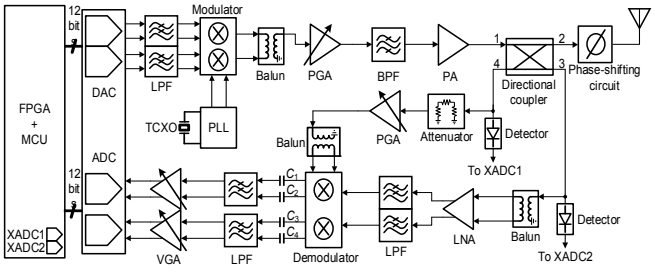

Fig. 1. The system architecture of UHF RFID reader module.

III. SELF-JAMMER SUPPRESSION

In order to realize the miniaturization of the reader module, a small directional coupler is used as the RF transceiver device, and the transceiver structure is shown in Fig. 2. An additional LC circuit is used to tune the amplitude and phase of the reflection coefficient at the output of the directional coupler (port 2) connected to the antenna. In addition, a π-type attenuator is applied to tune the matching between the port 4 of the coupler and the programmable gain amplifier (PGA). The transmitting

signal power leaked to the port 3 of the coupler can be expressed as in

$$P_3 = P_1(S_{31} + S_{21}\Gamma_2 S_{32} + S_{41}\Gamma_4 S_{34}) \quad (1)$$

where P_1 stands for the input power at the port 1 of the coupler, S_{ij} $(i,j = 1,2,3,4)$ stands for the scattering parameter of the coupler, and Γ_2 stands for reflection coefficient at port 2. The principle of the self-jammer cancellation is shown in Fig. 2. By tuning the Γ_2 and Γ_4, the sum of the three vector components in (1) can be zero, and at this point, the self-jammer is canceled completely.

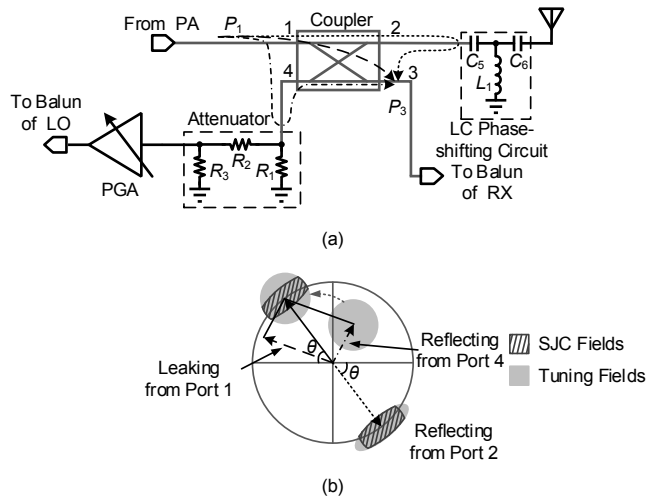

Fig. 2. The vector diagram of self-jammer cancellation principle.

IV. System Realization

The entire UHF RFID reader module includes one RF/Analog front-end circuit board and a digital baseband one, which are connected through a flexible printed circuit (FPC) line, as shown in Fig. 3. The thickness of the RF/Analog front-end PCB is 1 mm with four laminates, while the digital baseband circuit board is 2 mm thick with 12 laminates. The circuit boards used low cost FR4 with dielectric constant of 4.2. The two boards are encapsulated in a sandwich stack to reduce the size of the reader module. The final reader module packaging structure is shown in Fig. 4, and its volume is 70×60×15 mm^3, which is only one fifteen of the volume of commercial reader R420 (188×175×30 mm^3).

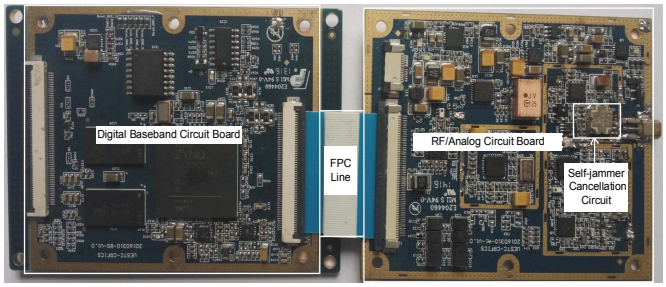

Fig. 3. The photo of the PCB boards of UHF RFID reader module.

Fig. 4. The encapsulation of the UHF RFID reader module.

V. Results and Analysis

The designed UHF RFID Reader Module was tested and analyzed. The isolation between the port 1 and 3 of the directional coupler is measured and shown in Fig. 5. When the output port of the reader module connects a 50 Ω termination load and an antenna respectively, the isolation in 920 ~ 925 MHz frequency band is better than 42 dB and 40 dB correspondingly, and the best isolation is about 65 dB (when connected the antenna) at the center of the designed frequency band. This high isolation indicates the self-jammer is canceled well.

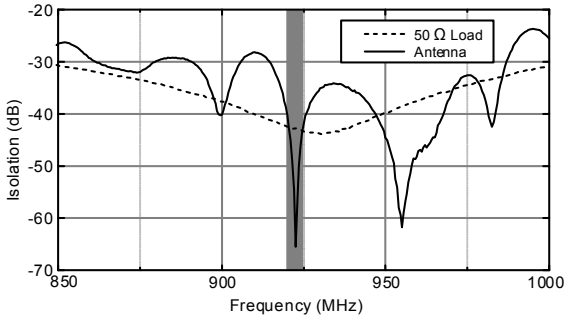

Fig. 5. The isolation of the transimitting and receiving paths.

The measured spectrum of the DSB-ASK modulated transmitting signal is shown in Fig. 6, which is to meet the requirements of the UHF RFID spectrum template. In addition, the saturation output power of the transmitter is 29.6 dBm.

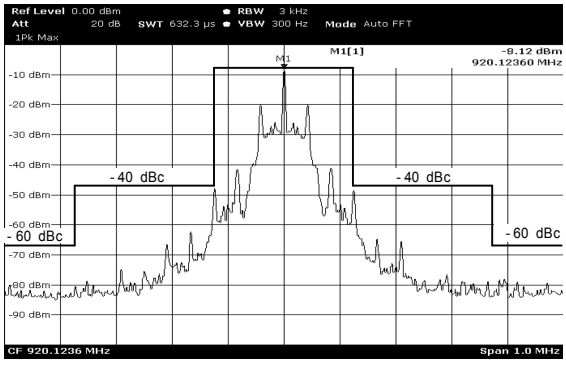

Fig. 6. The measured spectrum of the transmitting signal.

The differential output signal waveform of the baseband VGA is shown in Fig. 7 when the reader module inventorying

the E41B tag, which is one of Impinj's commercial tags supporting the international standard ISO/IEC 18000-6C, and the inventory range is about 15.8 meters. Meanwhile, the inventory range reaches to 17 meters for the tag with the Chinese standard GB/T 29768-2013.

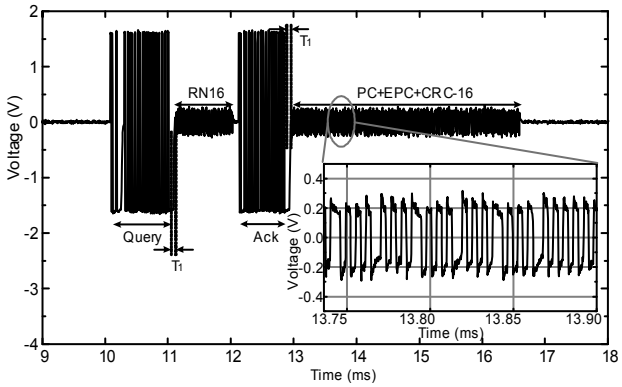

Fig. 7. The differential baseband output signal waveform.

VI. CONCLUSIONS

In this paper, an UHF RFID reader module based on discrete component is designed and realized, which supports the international standard ISO/IEC 18000-6C and the Chinese standard GB/T 29768-2013. A simple LC tuning circuit is added at the output of the directional coupler to enhance the isolation of the transmitting and receiving paths markedly. The miniaturization of the designed reader module is realized by using a sandwich-stack encapsulation with the volume of $70\times60\times15$ mm^3. The test results show that the multi-protocol reader module with high performances is suitable for middle and long distance RFID applications.

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