A System Design for the Reader of Microwave Radio Frequency Identification

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Abstract— RFID (Radio Frequency Identification) is now attracting many interests for its bright future in commercial and daily use. For the low-frequency (LF, typically 125 KHz) and the high-frequency (HF, typically 13.6 MHz) RFIDs, the Readers have already come into our daily life out of their matured technologies, while the ultra-high frequency (UHF) RFID Readers are still in the process for the reliability and functionality. This paper represents a systematic design of a UHF RFID reader. Received backscatter modulation waves (carrier wave frequency 915 MHz) are directly demodulated to baseband signals using the Zero IF technology. The reader is designed as a quadrature (I/Q) one, which can avoid null points of the received signals [4] and enhance the demodulation sensitivity.

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1. INTRODUCTION

RFID is the short for “Radio Frequency Identification”, which is a generic term for non-contact technologies that supply means to automatically identify people and objects on the basis of radio waves. RFID is, to a certain extent, similar to the bar coding, however, it greatly enhances the data process and acts as a complement to the present existing technologies. RFID covers a wide variety of applications such as the building access control, toll collection, vehicle parking access control, anti-theft system, animal tracking, inventory management and so on [3]. It is widely believed that RFID will supersede bar coding in the following few years.

An operational RFID system typically falls into three parts: an RFID tag (a combination of a microchip and an antenna), an RFID reader, and a host computational system that communicates with the reader [2, 3]. According to the frequency used in an RFID system, there are usually four broad RFID categories: low frequency (LF, usually around 125 and 134.2 KHz), high frequency (HF, usually around 13.56 MHz), ultra-high frequency (UHF, usually around 868 and 928 MHz) and microwave (usually around 2.45 and 5.8 GHz). For tags, there are two major types: the passive tags, which draw their power from the transmission of readers through electromagnetic coupling; and the active tags, which have their own power supplies. This paper introduces an RFID reader that communicates with the passive tags which are much more widespread used. The reader transmits a carrier (unmodulated wave) to the tag and powers up the microchip inside the tag, and then the tag reacts to the reader by transmitting a series of data, the ID. Backscatter modulation is applied in this process, which can be described as follows: the reader transmits an unmodulated carrier and receives a modulated backscattering from the tag [1].

2. RECEIVER DESIGN

The reader is constructed as a quadrature structure whose receiver chain includes I (in-phase) and Q (quadrature) subchains. The block diagram of the reader’s architecture is shown in Figure 1.

The design is based on a direct conversion topology, which is known as “homodyne”, in which received signals are down converted (demodulated) directly from RF to baseband. This requires that the Local Oscillator (LO) must be tuned to and synchronized in-phase with the carrier frequency [2], which is 915 MHz in this paper. Input signals, which has been backscatter modulated by the tag, are usually very weak signals with a power level only measured several decades mV. Thus it is probable that the incoming signals are fully submerged in the relatively more powered carrier. I/Q demodulator is employed in the receiver chain to act as an advantageous component to help improve overall signal to noise ratio (SNR) as well as the LO carrier leakage suppression [2]. The carrier...
Figure 1: Block diagram of UHF RFID reader system.

is generated by an ADI’s ADF4360-7, which integrates an integer-N synthesizer and a VCO. By choosing appropriate external inductors, we get our required RF carrier. LO carrier for the receiver chain goes through a 2-way power splitter that outputs two quadrature carriers — the in-phase (I) channel and the (Q) quadrature channel. Dual matched MMIC amplifier MERA-556 amplifies the two quadrature carriers to a proper power level to meet the requirements for the inputs of the mixers. Consequently, quadrature carrier signals used for I/Q demodulation are acquired.

Consider an RF carrier from VCO

\[ X(t) = A \cos(w_0 t + \theta_0). \]  

Passing through the splitter leads to a \(-90^\circ\) phase shift in one output channel,

\[ X_1(t) = A \cos (w_0 t + \theta_0 - \pi/2) = A \sin(w_0 t + \theta_0), \]  

while other channel is in-phase with the initial RF carrier, i.e.,

\[ X_2(t) = X(t) = A \cos (w_0 t + \theta_0), \]  

where \(X_1(t)\) and \(X_2(t)\) are the two quadrature carriers waves.

Coupling through the circulator, incoming signals are filtered via a SAW filter whose centre frequency is 915 MHz. Another 2-way power splitter is employed to divide the incoming signals into two identical and equal parts without any phase shift. Two mixers with differential inputs demodulate the above signals directly to baseband, as shown in Figure 2. It is seen from the upper waveform that the \(V_{p-p}\) of the baseband signals is only 32.5 mV, which does not satisfy the ADC’s input requirement. Therefore, additional low-noise amplifiers (LNA) are used and the amplified waveform is shown in the lower part of Figure 2.

Figure 2: Waveforms of the demodulation output (Channel 1, \(V_{p-p} = 32.5\) mV) and the LNA output (Channel 2, \(V_{p-p} = 812.5\) mV).
3. TRANSMITTER DESIGN

Most of the passive tags can be read by a reader directly, but some tags must be read according to specific communication protocol. When a reader is reading a tag, it is also providing tags with power, which enables the chips on the tags to work normally. The reader sends out ASK modulated signals, then the chip on the tag derives its operating power from the RF beam transmitted by the reader. The RF beam is received and rectified by the chip. When the tag gets enough energy and the correct commands, it will return its own unique User ID. The reader must send out a continuous carrier wave to provide energy to the circuit on the tag, and the tag transmits its factory-programmed code back to the reader by varying the amount of energy that is reflected from the chip antenna circuit.

The commands signal produced by DSP is modulated in OOK (On-Off-Keying) method, then magnified by power amplifier, and finally emitted by an antenna. All commands are transmitted from the reader to the tags by means of pulse interval encoding, and the average bit rate is 33 kbps.

The output power of Power Amplifier is limited, and generally no more than 1 Watt in USA. A Power Amplifier with a typical output power of 1.2 Watts is used in the system, and a tag in a distance of about 4 meters away from the antenna can access enough energy. A circulator, whose typical isolation is 22 dB and typical insertion loss is 0.25 dB, is used to insulate the transmitter signal and the receiver signal.

4. BASEBAND DESIGN

Baseband chain is composed of ADC, DSP, EEPROM and SRAM. An ADC with two 12 bits channel is used to sample and hold differential input analog signal. Maximum SNR performance will be achieved with the ADC set to the largest input span of 2V p-p, and common-mode voltage of the input signal is easily set to the half of power voltage. The lowest typical conversion rate of the ADC is 1 MSPS. The separate clock inputs for each channel should have a nominal 50% duty cycle and commonly a 5% tolerance.

A DSP is a system controller and baseband processor used for configuring PLL, controlling ADC, encoding, decoding and communicating with PC. The TMS320VC5402 fixed-point, digital signal processor (DSP) is based on an advanced modified Harvard architecture that has one program memory bus and three data memory buses, with 10-ns execution time for a single-cycle, fixed-point Instruction (100 MIPS). It has 4K × 16-Bit On-Chip ROM and 16K × 16-Bit Dual-Access On-Chip RAM, and we use a 64K × 16-Bit SRAM to extend data and program space.

An EEPROM is included for storing system programs, and communicating with the DSP through Serial Peripheral Interface (SPI). The DSP bootloader is used to transfer codes from the external source EEPROM into internal program memory following power-up. This allows codes to reside in slow, non-volatile memory externally, and be transferred to high-speed memory to be executed. The EEPROM clock rate is set to 400 kHz for a 100 MHz device.

5. CONCLUSION

We have introduced the detailed structure of a UHF RFID reader that functions well experimentally. For the receiver chain, Zero-IF demodulation is incorporated, as well as quadrature I/Q channels. The designed system proves a good operational structure as data signals have been received and exposed as the above schematics.
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