The Application of the CMA Blind Equalization in UHF RFID System

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Abstract

The "Gen2" specification for UHF passive RFID system released by EPC global has been paid great attention in recent years. A Gen2 tag derives its power from the RF wave emitted by a Gen2 RFID reader and responds reader's interrogation command with its modulated backscatter signals. The readability of a Gen2 tag is often influenced by the problem of multipath fading and inter-symbol interference (ISI). In the paper, the Constant-Modulus blind equalization algorithm (CMA) is used to reduce the bit error rate (BER) of RFID transmission and to strengthen the channel adaptation capability. The CMA blind equalization algorithm is of low computational complexity, easy real-time realization and good convergence performance, which made it suitable for the request towards the computation of RFID system. Compared with the method without using any signal processing, the proposed algorithm is of lower BER and better channel adaptation capability, which is confirmed by computer simulation.

1 Introduction

The RFID technology originating from the radar technology is a kind of recognition technology which uses wireless channel to realize two-way communication. Its practicable operation frequency is established in the criteria of industry, science, and medical service (ISM), which is mainly divided into low frequency (LF), high frequency (HF), the ultra-high frequency (UHF) and the microwave (MW). Its LF and HF system technology has already matured and the application of their product is quite widespread. But the UHF RFID technology based on the radar back scattering communication principle has just aroused concern in recent years and become the hot point of research. This technology is mainly for the digitized commerce. It can realize the automatic identification, the long-distance real-time monitor and the management. The characteristics of UHF RFID are long working distance from several centimeters to several dozens meters, big information content up to several kilobyte, well secrecy and small antenna size and so on. Its main application field is train recognition, long-distance recognition, container recognition, automatic charge system and so on.

Although some UHF RFID systems had been put into use, the problem of multipath interference [1~3] and the inter-symbol interference (ISI) [4] have been disturbing its application in industrial field continuously.

2 The principle of RFID system

A typical RFID system consists of the reader, the tag and the central processing system (CPS), as shown in Figure1. Its fundamental operation principle is that a reader emits radio frequency (RF) signals in a certain frequency through an antenna. When the RFID tag is in the interrogation zone of the reader, its antenna produces induced current. In this way, the tag obtains the energy to be activated and transmits information to the reader. After the reader has received the signal from the tag, it demodulates and decodes the signal in turn, and then delivers the datum to the CPS. According to the logic computation, the CPS judges the validity of the tag and then makes corresponding processing and controlling based on the different setting and sends out the command signal at last. After the tag has received the command from the reader, the datum demodulation part of tag demodulates the datum from the RF pulses and delivers this datum to the control unit on tag. The control unit receives order and then performs memory, transmission or other operations. Readers in all RFID systems can be reduced to two fundamental functional blocks: the control unit and the HF interface unit. The HF interface unit structures the transmitter and receiver. The reader's control unit performs the following functions

(1) Communication with the CPS and the execution of commands from the CPS,
(2) Control of the communication with a tag,
(3) Signal coding and decoding;

In more complex systems the following additional functions are available

(4) Execution of an anti-collision algorithm;
(5) Encryption and decryption of the data to be transferred between Tag and Reader;
(6) Performance of authentication between tag and reader.

The control unit is usually based upon a microprocessor to perform these complex functions.

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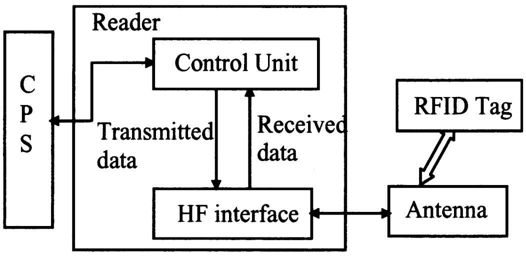

Fig.1 Block diagram of RFID system

Hsin-Chin Liu et al [1] proposed a method which can solve the problem of low recognition rate in passive UHF RFID system standing to the "Gen2" protocol. To deal with the influence of multipath interference to the recognition rate of "Gen2" tag, they proposed the multi-carriers passive UHF RFID system, namely the CWE operating at 915MHz provides continual electromagnetic wave energy to tag and transceiver operating at 917MHz. This method alleviates effectively the multipath interference and ISI, expands the operating scope of passive UHF RFID system by improvement at reader part. Marcel Kossel et al [2] proposed circular polarization modulation which can reduce demodulation complexity and power consumption. Additional coding of the circular polarization modulated data can reduce transmission errors because of the inversion of polarization at multipath propagation. Jin MITSUGI et al [3] proposed the tag probe, namely a power measurement antenna at the position of tag attached, can monitor and get to know the real-time environment and then establish a countermeasure to improve the tag readability.

The essential idea of above methods is to increases the energy of tag deriving from the electromagnetic wave by making improvement at reader part or the tag part, by which solves the ISI. But all RFID standards or protocols put strict limit to the radio frequency power. Therefore, in this paper, the CMA blind equalization algorithm is introduced to the RFID system to solve the ISI problem.

3 Blind equalization algorithm

As an adaptive equalization technology, blind equalization algorithm utilizes the prior information of transmitted signals to equalize the channel character without referring to raining sequence to maintain work. Blind equalization algorithm can make the output sequence to approach the transmission sequence as far as possible, compensate effectively the non-idealized character of the channel, overcome the ISI, reduce the error rate and improve the communication quality. In this paper, CMA blind equalization algorithm is used, which is of low computation complexity, easy real-time realization and good convergence performance and cost function only being relative to amplitude of received sequence but the phase , so it is insensitive to the carrier phase. In this paper the CMA blind equalization algorithm is implemented in the control unit of the reader. It equalizes the signal demodulated by the HF interface, re-establishes the counter-channel to counteract the interference of the ISI and reduces the error rate. Figure 2 shows the blind equalization principle block diagram of RFID receiver. Based on Gen2 protocol, the signal $u(n)$, using the back scattering modulation, send out by the tag, pass channel and arrive HF interface of reader. After being demodulated by HF interface, the signal $x(n)$ is sent into blind equalizer. The output sequence $\hat{x}(n)$ is transmitted to the CPS, after being decoded by the control unit.

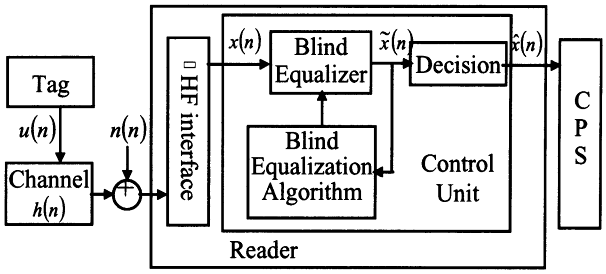

Fig. 2 Blind equalization principle block diagram of RFID receiver

Nowadays, the classics blind equalizer uses mainly finite tap transversal filter, as shown in Figure 3.

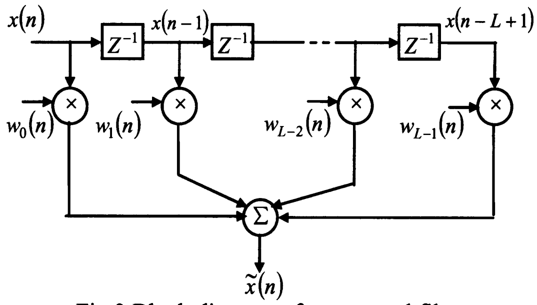

Fig.3 Block diagram of transversal filter

The input sequence vector $\mathbf{X}(n)$ of the transversal filter is

$$\mathbf{X}(n)=[x(n),\ x(n-1),\ \cdots,\ x(n-L+1)]^T \tag{1}$$

The weighting vector (or called coefficient vector) $\mathbf{W}(n)$ of filter is as follows

$$\mathbf{W}(n)=[w_0(n),\ w_1(n),\ \cdots,\ w_{L-1}(n)]^T \tag{2}$$

The output $\tilde{x}(n)$ of transversal filter may be represented as

$$\tilde{x}(n)=\sum_{i=0}^{L-1} w_i(n)x(n-i)=\mathbf{X}^T(n)\mathbf{W}(n)=\mathbf{W}^T(n)\mathbf{X}(n) \tag{3}$$

Where, L is the number of order of transversal filter.

The cost function of CMA is

$$J(n)=\frac{1}{2}\left[\left[|\tilde{x}(n)|^2-R_2\right]^2\right] \tag{4}$$

Where, $R_2=E\left|\hat{x}(n)\right|^4 / E\left|\hat{x}(n)\right|^2$

According to the steepest-descent algorithm, the weight iterative formula of CMA algorithm can be obtained as

$$\mathbf{W}(n+1)=\mathbf{W}(n)-\mu\nabla \tag{5}$$

where

$$\nabla = \frac{\partial J(n)}{\partial \mathbf{W}(n)} = 2\left[\tilde{x}^2(n) - R_2\right]\tilde{x}(n)\frac{\partial \tilde{x}(n)}{\partial \mathbf{W}(n)} \tag{6}$$

$$\frac{\partial \tilde{x}(n)}{\partial w_i(n)} = x(n-i) \tag{7}$$

where, $\frac{\partial \tilde{x}(n)}{\partial w_j(n)}$ is the scalar form of $\frac{\partial \tilde{x}(n)}{\partial \mathbf{W}(n)}$ and μ is the step of iteration。

4 Simulation results

The modulation depth defined by Gen2 protocol is 80%~100%. Different modulation depth for a certain RFID system can result in different system performance. The smaller the modulation depth is, the stronger of the power emitted by reader is, and the more the activating or the working power obtained by the tag. So the probability of the tag to be activated or identified is larger. However, the tag identification ratio is related with the BER. The bigger modulation depth is, the easier the envelope of "1" or "0" levels are distinguished. So the BER will be reduced. Figure 4 and Figure 5 show the 80% and 100% modulation depth respectively.

The modulation depth is defined

$$M = \frac{A-B}{A+B} \tag{8}$$

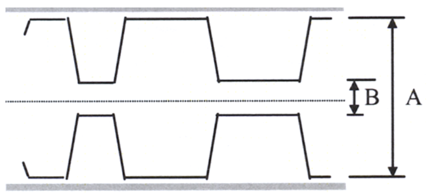

Fig.4 80% modulation depth

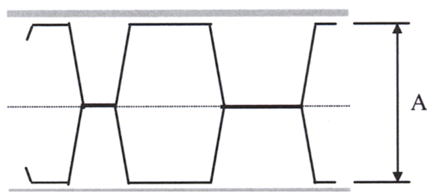

Fig.5 100% modulation depth

In the paper, the algorithm proposed will be simulated under two modulation depths respectively. As shown in figure 10, the BER of algorithm using 100% modulation depth is lower than that of using 80%.

A discrete channel model can be described by the channel pulse response [6]

$$H(z) = \sum_{i=0}^{M} a_i z^{-i} \tag{9}$$

Where, τ_i is the time delay of the i^{th} path, a_i is the discount of the i^{th} path, M is the path number. (Typical value of RFID system is 2~6).The input sequence uses the 2PAM signal, the order number of transversal filter is 5, the iterative number is 10000. The transmission function of channel used in the simulation is

$$H_1(z) = 0.15 + 0.85z^{-1} + 0.25z^{-2} \tag{10}$$

$$H_2(z) = 0.2 + 0.85z^{-1} + 0.25z^{-2} \tag{11}$$

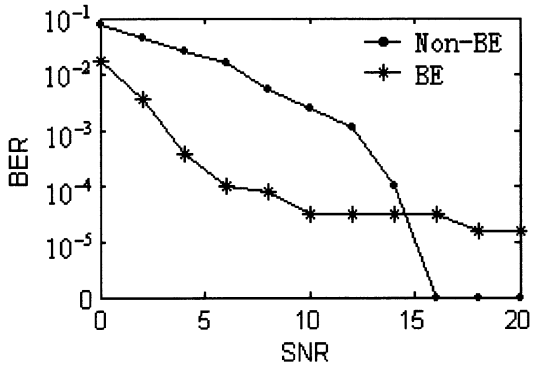

Fig.6 BER in $H_1(z)$ channel under 100% modulation depth

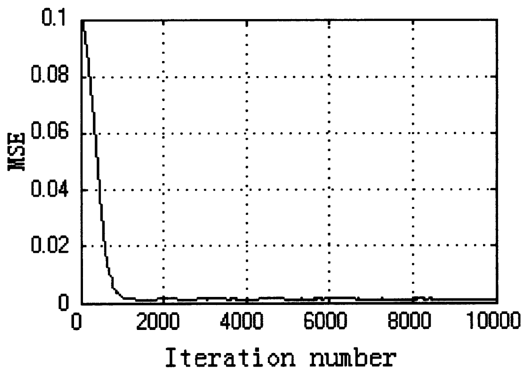

Fig.7 convergence curve of blind equalization algorithm in $H_1(z)$ channel under 100% modulation depth

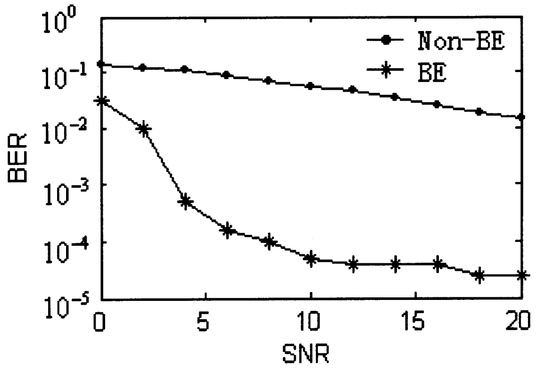

Fig. 8 BER in $H_2(z)$channel under 100% modulation depth

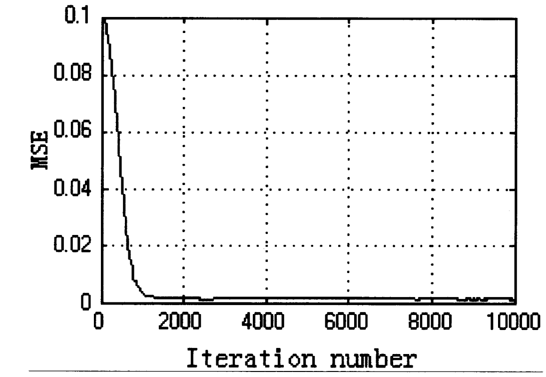

Fig.9 convergence curve of blind equalization algorithm in $H_2(z)$ channel under 100% modulation depth

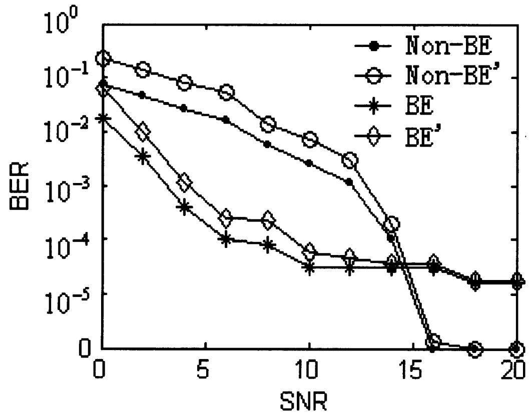

Fig.10 BER in $H_1(z)$ channel under two modulation depth

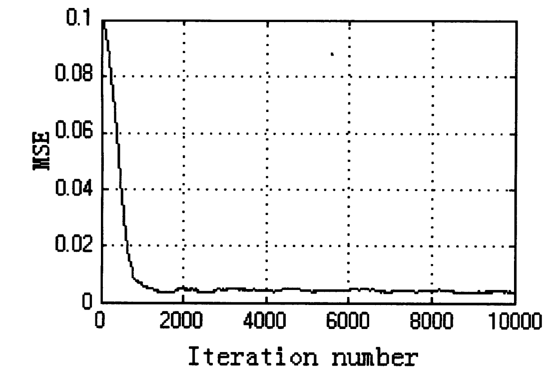

Fig.11 convergence curve of blind equalization algorithm in $H_1(z)$ channel under 80% modulation depth

The "BE" denotes blind equalization algorithms and "Non-BE" denotes no signal processing method is used under 100% modulation depth. The "BE'" denotes blind equalization algorithms and "Non-BE'" denotes no signal processing method is used under 80% modulation depth.

5 Conclusion

According to the simulation curve obtained, the algorithm proposed has following merits

(1) The error rate is lower and the convergence rate is faster under the low signal-to-noise ratio situation.

(2) As is shown in Figure 8, without any signal processing used in the channel $H_2(z)$, the error rate is higher than 10^{-2} all along, and communication fails. While using blind equalization algorithm, when SNR is bigger than 8, the error rate is always under 10^{-4}, communication can be done. Therefore the algorithm proposed is not only suitable for the simple channel but also suitable for a more complex channel.

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