Detection of a weak tag signal for the ISO/IEC 18000-6 Type B RFID System

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ABSTRACT

In UHF RFID systems output power is limited by the strict regulation to prevent interference to other equipment. The restriction of transmitted power at the reader results in a very weak backscattered tag signal. The weak tag signal may be therefore significantly affected by noise. To efficiently detect the weak signal in noisy environment and thus successfully extract the tag information, we present a simple detection method using a correlator. In addition, for symbol timing recovery in RFID systems with various symbol durations, a bit - duration estimator is proposed. The improvement achieved by the proposed methods in detection techniques leads to enhance the enhanced identification performance of the RFID reader. Simulation results show that the proposed method works well even in low SNR conditions.

Keywords: RFID, AWGN, correlator, tolerance

1. INTRODUCTION

In 900 MHz radio frequency identification (RFID) system, passive (battery-free) tags get the only power of the electromagnetic field received form the reader for data transmission between tag and reader [1]. Hence, the operation of tags is highly dependent upon power consumption and thus limited to be low-power processes. In addition, since the regulations such as Part 15.247 of Federal Communication Commission (FCC) restrict the radiation power of the reader, the backscattered signal power of tags can not avoid being very weak [2]. The weak power of tag signals may be a cause of the detection failure of the reader in noisy environment.

High tolerance margin for the symbol timing specified in the ISO/IEC 18000-6 Type B air-interface is another potential obstacle of the reader's operation because the reader has to spend much time in extracting bit data from the received signal with unknown bit duration [3]. Additionally, in RFID systems a lot of tags respond to the reader's request at once. The resulting signal appears to be very complicated and thus the reader may not differentiate a collided signal of multi-tag from a noisy signal of only one tag. In this case, the reader fails to read tag data and perform false-alarm even after successful collision arbitration.

In this paper, to overcome the above two problems of the noise effect and the symbol timing error and then improve the performance of the RFID reader, we present a noise-reduction method using a correlator and a bit duration estimator using preamble defined in the standard.

The paper is organized as follows. In section 2, detection problems are addressed in a weak tag signal with high tolerance under noise environment. Then, we present methods to reduce noise effect and estimate bit duration for timing recovery in section 3. Section 4 shows simulation results. Finally, we conclude the paper in section 5.

This work was supported by the Regional Research Centers Program (Research Center for Logistics Information Technology), granted by the Korean Ministry of Education & Human Resources Development.

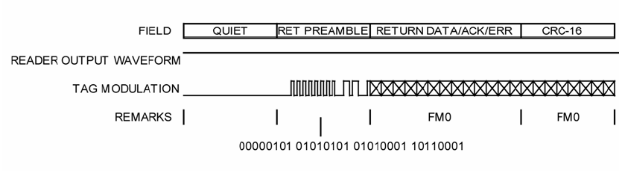

Fig.1: *Sample response packets for GROUP_SELECT.*

Table 1: *Return link parameters*

Data Rate	Trlb	Tolerance
40 kbps	25 μs	+/- 15%

2. DETECTION PROBLEMS OF A WEAK SIGNAL

Figure 1 shows one example for the tag response, which consists of the following fields: Quiet, Return Preamble, Data fields, and Cyclic Redundancy Code (CRC)-16. Data are coded using the FM0 technique and the return link bit time (Trlb) meaning one symbol period, as specified in Table 1, is allocated to each bit to be sent [3].

Generally, under the ideal channel condition, data signal from a tag is received in a reader without any distortion. We can therefore easily detect a tag response signal and extract data. Under noisy channel condition, however, a data signal from tag is distorted by various noises [4]. Fig. 2 shows an example of a distorted signal which seems to be different from in bit duration the ideal tag signal shown in Fig. 1. Therefore, a typical reader cannot decode the tag response signal. This means that a reader needs much time to achieve a tag's UID.

Fig.2: *An example of a response with a distorted preamble.*

Fig.3: *An Example of a valid response.*

In addition, the standard of UHF RFID Type B permits a high tolerance in bit duration which may cause a symbol timing error [3]. For example, figure 3 shows a valid received signal. If we sample the backscattered signal every 12.5 μs which is the half of typical one bit duration, we cannot get any information. Since exact bit duration of the received signal, as shown in Fig. 4, is approximately 23.86 μs, we shall adjust sampling instant to extract valid data.

It is important to reduce time for tag identification in RFID systems for various potential applications with this respect. As the above two problems have to be solved. To achieve this goal, we propose a simple method to reduce noise effect using a correlator and to estimate the bit duration using a correlator output.

3. PROPOSED DETECTION METHOD

Fig. 5 shows a proposed method which is mainly composed of two parts. One is a correlator and the other is a bit duration estimator. The correlator executes cross correlation of a known reference signal and a received signal. The noise effect is reduced in the correlator output. This noise reduction makes the reader robust to noise

Fig.4: *Received signal with -4.6% Tolerance.*

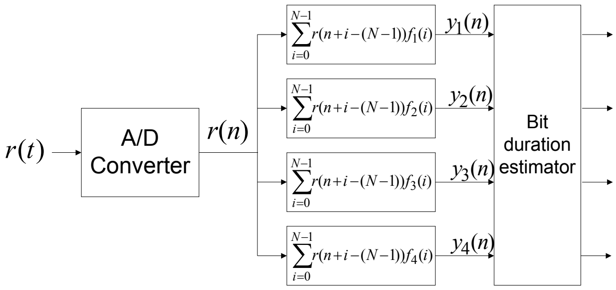

Fig.5: *Structure of a proposed detection method.*

even at low SNRs. We shall show it in section 3.1. Next, a bit duration estimator is adopted to prevent missing a tag response signal due to high tolerance of bit duration. Since we can estimate bit duration using a correlator output, we adjust appropriately sampling instant. We shall explain this method in detail in section 3.2.

3.1 Correlator

Suppose a received signal $r(n)$ is passed through a parallel bank of 4 cross correlators which basically compute the projection of $r(n)$ onto the 4 basis functions $\{f_k(i)\}$. Basis functions which are used in this paper are shown in table 2. The correlator output $y_k(n)$ is

$$y_k(n) = \sum_{i=0}^{N-1} r(n+i-(N-1)) f_k(i) \qquad (1)$$

Table 2: *Bases parameters*

	Bit duration	Tolerance
Basis 1	21.25 μs	- 15%
Basis 2	23.75 μs	-5%
Basis 3	26.25 μs	5%
Basis 4	28.75 μs	15%

Since $r(n)$ is a sum of transmitted signal $s_m(n)$ and noise $v(n)$, we rewrite equation (1) as

$$y_k(n) = \sum_{i=0}^{N-1}[s_{mk} + v_k]f_k(i) \quad (2)$$

where

$$s_{mk} = \sum_{l=0}^{N-1} s_m(n+i-(N-1))f_k(i) \quad (3)$$

$$v_k = \sum_{l=0}^{N-1} v(n+i-(N-1))f_k(i) \quad (4)$$

Here n, i and N denote time index, filtering index and the number of filter taps, respectively. The signal is now presented by the vector $\mathbf{s}_m$ with components s_{mk}, $k = 1,2,\ldots,L$. Their values depend on which of M signals was transmitted. The components $\{v_k\}$ are random variables that arise from the presence of additive noise [5]. If N approaches infinity in time interval T, we rewrite equation (1), (2), (3) and (4) as

$$\int_0^T r(t)f_k(t)dt = \int_0^T [s_m(t)+v(t)]f_k(t)dt \quad (5)$$

$$s_{mk} = \int_0^T s_m(t)f_k(t)dt, \qquad k = 1,2,\ldots,L \quad (6)$$

$$v_k = \int_0^T v(t)f_k(t)dt, \qquad k = 1,2,\ldots,L \quad (7)$$

In fact, we can express the received signal $r(t)$ in the interval $0 \le t \le T$ as

$$\begin{aligned} r(t) &= \sum_{k=1}^{L} s_{mk}f_k(t) + \sum_{k=1}^{L} v_k f_k(t) + v'(t) \\ &= \sum_{k=1}^{L} r_k f_k(t) + v(t) \end{aligned} \quad (8)$$

The term $v'(t)$, defined as

$$v'(t) = v(t) - \sum_{k=1}^{L} v_k f_k(t) \quad (9)$$

is zero-mean Gaussian noise process that represents the difference between the original noise process $v(t)$ and the part corresponding to the projection of $v(t)$ onto the basis functions $\{f_k(t)\}$ [5]. Since the signals $\{s_m(t)\}$ are deterministic, the signal components are deterministic. The noise components $\{v_k\}$ are Gaussian, since each component can be viewed as the sampled output of a linear filter excited by Gaussian noise. Their means value are

$$E(v_k) = \int_0^T E[v(t)]f_k(t)dt = 0 \quad (10)$$

for all k. Their covariances are

$$\begin{aligned} E(v_k v_m) &= \int_0^T \int_0^T E[v(t)v(\tau)]f_k(t)f_m(t)dtd\tau \\ &= \tfrac{1}{2}N_0 \int_0^T f_k(t)f_m(t)dt = \tfrac{1}{2}N_0\delta_{mk} \end{aligned} \quad (11)$$

where $\delta_{mk} = 1$ when $m = k$ and zero otherwise [5]. Therefore, the L noise components $\{v_k\}$ are zero-mean uncorrelated Gaussian random variables with a common variance $\sigma_v^2 = \frac{1}{2}N_0$. Since the noise components $\{v_k\}$ are uncorrelated Gaussian random variables, they are also statistically independent. As a consequence, the correlator output $\{r_k\}$ conditioned on the m th signal being transmitted are statistically independent Gaussian variables [5]. Finally

$$\begin{aligned} E[v'(t)r_k] &= E[v'(t)]s_{mk} + E[v'(t)v_k] \\ &= E[v'(t)v_k] \\ &= E\left\{[v(t) - \sum_{j=1}^{L} v_j f_j(t)]v_k\right\} \\ &= \tfrac{1}{2}N_0 f_k(t) - \tfrac{1}{2}N_0 f_k(t) = 0 \end{aligned} \quad (12)$$

Since $v'(t)$ and $\{r_k\}$ are Gaussian and uncorrelated, they also statistically independent. Consequently, $v'(t)$ does not contain any information that is relevant to the decision as to which signal waveform was transmitted. Hence, $v'(t)$ is not included for decoding the received signal [5].

This means that noise power is reduced in the correlator output. We can therefore improve the SNR using the correlator.

3.2 Estimation of Bit duration

In the previous section we show that all the relevant information is contained in the correlator outputs $\{r_k\}$ [5] and correlator reduces the noise effect. By using this result, we shall introduce a method to estimate bit duration using the correlator output to determine a sampling instant.

To estimate bit duration, we select basis for the correlator first. Since we know preamble pattern defined the standard, we can use the 3rd bit of the preamble as a basis. Adopted basis is already shown in Table 2. Next by using the selected bases, we execute correlation. Figure 6 shows the correlator output using 4 bases when SNR is

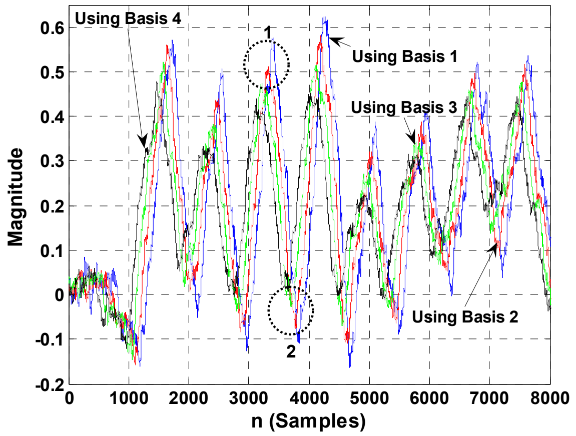

Fig.6: *Correlator output at -15 dB SNR.*

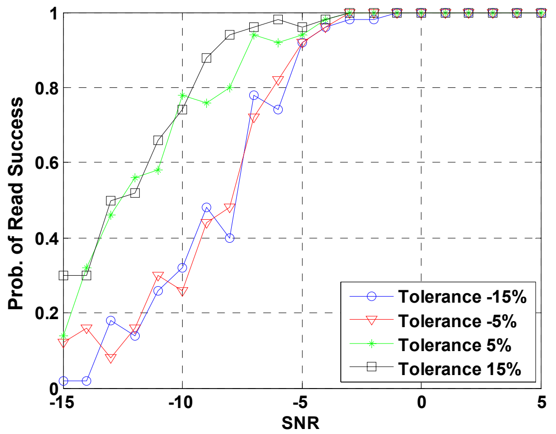

Fig.7: *Performance of proposed method.*

-15 dB and tolerance of received signal is -15%. The positive peak which is marked as a dotted circle with "1" in the Fig. 6 means that low to high bit transition is occurred and the negative peak with a mark 2 means opposite. The difference of two peak times therefore becomes duration of a 'high' state. Since the 'high' state time is a half of one bit duration, we can estimate the time instant for data decoding. Under the ideal channel condition, we can easily estimate a sampling instant using only one state transition. In low SNR, however, accuracy of a sampling instant is deteriorated by noise effect. To prevent degradation of estimation performance, we use 8 transitions in the head of a preamble. We can measure 8 bit-durations respectively and find sampling start point by using the positive peak time of the correlator output. By averaging the measured bit durations, we can estimate a sampling instant.

Since the correlator improves SNR and the bit-duration estimator provides a sampling instant, we can decode a transmitted signal more accurately

4. SIMULATION RESULTS

We carried out computer simulation to show the performance of the proposed method. We assume that

Table 3: *Simulation parameters*

	Range
SNR	-15 dB ~ 5 dB, increase by 1 dB
Tolerance	-15% ~ 15%, increase by 10%

tolerance uniformly affects each bit of the tag response signal and a channel is an Additive White Gaussian (AWGN) Channel. The ranges of SNRs and tolerance are shown in Table 3. We decode a received signal using FM0 and check the CRC-16 to detect an error.

If there is an error in the decoded data, we can not use the data. Thus, we only count and show the success case. Figure 7 shows the simulation results. We can decode most responses when the SNR is greater than -5 dB. In case that bit duration is expanded (Tolerance 5 and 15%), the proposed method shows a better performance than the opposite case. This is due to the increased margin of error time per bit.

5. COUNCLUSIONS

We present a simple detection method using a correlator and a bit-duration estimator to solve detecting problems of a weak noisy tag response signal for the 18000-6 Type B RFID system. Since a correlator reduces the noise effect and a bit duration estimator decreases a sampling rate required for decoding a noisy tag signal, the proposed method performs well even at low SNR values. In RFID systems it is important to ensure data accuracy and reduce waste time by retransmission, the propose method may be contributed to the performance improvement of RFID systems.

6. REFERENCES

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