RFID Reader Receiver Using Blind Signal Estimation for Multiuser Detection

Sarun Duangsuwan and Sathaporn Promwong

***Abstract*—Radio frequency identification (RFID) is a wireless technology that uses radio backscatter signals to purpose of identify objects. Especially, in the microwave frequency as 2.45 GHz is growing rapidly. Since the physical environment surrounding the propagation path of radio identification is generally difficult to control, the channel characteristics in backscattering are often channel fading. There are two major sources of impairment of the RFID reader is unreadable as the tag signal propagate through channel. Some works provides to use the multiple antennas for both transmit and receive of RFID readers. In this paper, we propose a perspective of blind channel estimation is presented to the RFID reader receiver for multiuser detection. Furthermore, the multiple-input and multiple-output (MIMO) of channel measurement is verified with the multiple antennas at the RFID reader and provides the multiple tags are under test. We also propose a linear receiver to estimate the received signal, where provides a zero-forcing (ZF) and a minimal mean square error (MMSE) in order to estimate the channel state information (CSI) at the reader receiver. Under the signal estimation, we shown the blind order signal estimated so that the reader can adapt as the multiple tag and available the detection simultaneously.**

***Index Terms*—RFID reader receiver, MIMO, blind signal estimation, multiuser detection.**

I. Introduction

RFID is automatic wireless identification technology that under operates in a backscatter radio. Using for a long range of communications in an transportation, access control and toll collection. In particular, RFID is divided by 865-868 MHz in Europe, 902-928 MHz in U.S.A, 952-954 MHz in Japan and recently 2.45 GHz allowed in Thailand. Most requirements are drawn to long distance and impact environment for both the RFID reader and the tag [1]. RFID research community recently started to pay attention on using multiple antennas at either the reader side or the tag side. The reason is that using multiple antennas is an efficient approach for increasing the coverage of RFID, solving the non-line-of-sight (NLOS) problem, improving the reliability of data communications between the reader and the tag, and thus further extending the information carrying ability of RFID. Besides, some advanced technology in multiple transmit and receive antennas can be used to solve the problem of detecting multiple objects simultaneously.

Several works have investigated signal estimation with signal originating from tags such as Khasgiwale *et al.* [2] developed techniques to extract information from communication collision involving passing UHF-RFID tags. They used information from the tag collision on the physical layer to estimate the number of colliding tags. With this additional information they increased the accuracy of tag population estimates. In addition, they have shown that it is possible to recover from collision and correctly read the data of the colliding tags. Knerr *et al.* [3] developed the maximum likelihood estimator for the tag population in EPC class-1 Gen-2 standard. Their method can be used to update the information by reference data, during the data duration, based on the probability level of the current estimate. In Holzer *et al.* [4] presented an improvement of the data frame slot based on frame slot aloha (FSA). Their algorithm is suitable for the application where the tag population type is known in advance. The authors have studied the first half of the data signal and if they find an event with probability they restart the signal. Yu *et al.* [5] proposed an anti-collision algorithm based on smart antenna and used binary tree to search in each sector radiation. They have not studied to recover from collisions. Shen *et al.* [6] presented a practical design of an RFID reader based on software-defined radio that is capable of reading multiple passive tags through joint decoding. They focused on low frequency tags and analyzed the signal constellations of the colliding tags. Mindikoglu *et al.* [7] described how to separate multiple overlapping tag signals using an antenna array in order to spite unwanted signal with blind source separation techniques. So far channel estimation employs post-preamble in [8] which require a training sequence. They achieved an increase of the theoretical throughput but employ more bandwidth for RFID reader. However, these works have been only considered of anti-collision. In practical, then, previous works [9]-[11] presented an extension to simulate of blind channel estimation and also in contrast from Kaitovic *et al.* [12] and [13] MIMO receiver is presented in order to optimize.

In this paper, we present the blind signal estimation in RFID reader receiver. From the advantages of MIMO RFID technology allow many potential in the area of accurate tracking, identifications, it can significantly increase the reliability and throughput. Herein, we distinguish the MIMO receiver to the blind signal estimation. The model of RFID system is based on an indoor scenario under test, in order to estimate the data of the signal by using a higher order statistic (HOS). We consider the new problem of multiuser (tags) signal estimation in the presence of statistically independent interference and noise as illustrated in Fig. 1.

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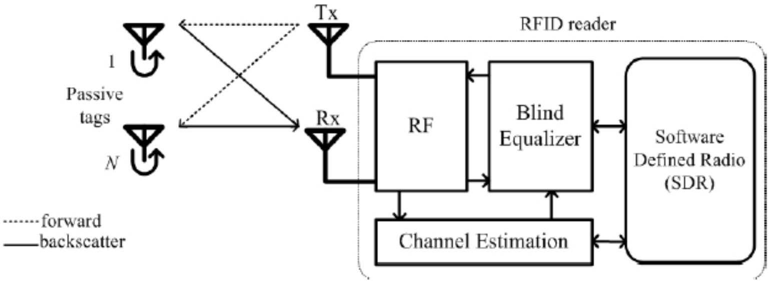

Fig. 1. The proposed of RFID reader receiver for multiuser detection.

The rest of paper is organized as follows: The received signal model and receiver structure are shown in the following Section II. The theoretical in the performance of a MIMO receiver is discussed in Section III. Section IV the proposed channel estimation method is explained. The analysis of the performance is expressed in Section IV. The last section finally concludes the paper.

II. Signal Model

The received signal at the reader is first down converted to the baseband processing. When *N* tags are backscattering simultaneously, the complex-valued at baseband signal can be written as

$$r(t) = \sum_{n=1}^{N}\sum_{m=1}^{M} x_n(t) h_{n,m}(t-\tau_L) + i_m(t) + n_m(t) \quad (1)$$

where $m = 1,...,M$ denotes multiple antenna receiving at the reader, $i_m(t)$, $n_m(t)$ are the complex values of carrier leakage and noise at the m antenna, and $L = (1,2,...,l)$ is different arrival l paths of channel length, respectively. Furthermore, $x_n(t)$ is modulation signal of tag n and $h_{n,m}(t)$ denotes the channel coefficient between readers, the *n* tag and the *m* receive antenna, as shown in Fig. 1. Each channel coefficient $h_{n,m}(t)$ is modeled as the multiplication of forward and backward channel.

According to the received signal of each antenna into a vector, we can rewritten as

$$r(t) = H(t)x(t) + i(t) + n(t) \quad (2)$$

Here, $H(t)$ represented the $N \times M$ channel matrix and $x(t)$ is the $1 \times N$ modulation vector. The terms of $r(t)$, $i(t)$, and $n(t)$ are the $M \times 1$ column vector with the elements $r(t)$, $i(t)$ and $n(t)$, respectively.

Considering the fact that $x(t)$ is real-valued in (4) [11], the received signal described by (2), can be equivalently as

$$\begin{bmatrix} R\{r_m(t)\} \\ I\{r_m(t)\} \end{bmatrix} = x_n(t)\begin{bmatrix} R\{H_{n,m}(t)\} \\ I\{H_{n,m}(t)\} \end{bmatrix} + \begin{bmatrix} R\{i_m(t)\} \\ I\{i_m(t)\} \end{bmatrix} + \begin{bmatrix} R\{n_m(t)\} \\ I\{n_m(t)\} \end{bmatrix} \quad (3)$$

where $\Re(\cdot)$ denotes the real part and $\Im(\cdot)$ denotes the imaginary part of the argument. As the matrix $H_{n,m}(t)$ and $x_n(t)$ are defined, respectively by

$$H_{n,m}(t) = \begin{bmatrix} h_{1,1}(t-\tau_L) & h_{1,2}(t-\tau_L) & \cdots & h_{1,m}(t-\tau_L) \\ h_{2,1}(t-\tau_L) & h_{2,2}(t-\tau_L) & \cdots & h_{2,m}(t-\tau_L) \\ \vdots & \vdots & \ddots & \vdots \\ h_{n,1}(t-\tau_L) & h_{n,2}(t-\tau_L) & \cdots & h_{n,m}(t-\tau_L) \end{bmatrix} \quad (4)$$

$$x_n(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_n(t) \end{bmatrix} \quad (5)$$

III. Proposed Method

For backscatter link, that required optimum receiver. The receiver can be known the channel state information (CSI), in order to exchange the radio functionality such as higher order modulation, adaptive equalization, and channel estimation and so on. In [12] was proposed training-sequence aided for channel estimation method. However, they have been verified in the flat fading not only shown in an imperfect scenario but also require more bandwidth efficient of passive backscatter.

We propose a linear blind receiver (LBR) which does not require special data bits or training-bits and analytic in term of second order statistic (SOS) for RFID signal model as show in Fig. 1. In this paper, we determine $\hat{G}$ is a channel estimator under batch signal processing of linear receiver as expresses.

$$\hat{G}_{zf} = \left(H_{n,m}^{H}(f)H_{n,m}(f)\right)^{-1} H_{n,m}(f) \times R(f) \quad (6)$$

$$\hat{G}_{mmse} = \left(H_{n,m}^{H}(f)H_{n,m}(f) + N(f)\right)^{-1} H_{n,m}(f) \times R(f) \quad (7)$$

where $(\cdot)^H$ is the matrix Hermitial of the channel transfer function, and $R(f) = \int_{-\infty}^{\infty} r(t)\exp(-j2\pi f_c t)dt$ is the spectrum density of the received signal and $N(f)$ represented the spectral of noise is approximated by $|\sigma^2/2|$.

The identification of unknown channels at the blind receiver can benefit from a more order of signal based on higher-order statistic (HOS) from the coordination of source tag.

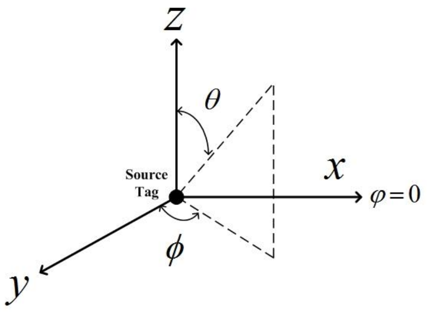

Fig. 2. Coordination of the tag propagates to the reader.

The extended of formulation to HOS estimate the received signal by using tri-spectrum as provides

$$\hat{G}\{\theta,\phi,\varphi\} \tag{8}$$

where $f \cong (\theta, \phi, \varphi)$ represented the spectrum of elevation, azimuth and polarization of source tag, where the assume that $(\varphi = 0)$ is no the mismatch polarization of antenna. The coordinate's characteristic as shown in Fig. 2. Hence, we defined the $\hat{G}$ is the function in term of blind channel estimation based on HOS and we can be written as

$$\hat{G}_{zf} = \left(H^{H}_{n,m}(\theta,\varphi,f)H_{n,m}(\theta,\varphi,f)\right)^{-1} H_{n,m}(\theta,\varphi,f)\times R(\theta,\varphi,f) \tag{9}$$

$$\hat{G}_{mmse} = \left(H^{H}_{n,m}(\theta,\varphi,f)H_{n,m}(\theta,\varphi,f)+N(\theta,\varphi,f)\right)^{-1} H_{n,m}(\theta,\varphi,f)\times R(\theta,\varphi,f) \tag{10}$$

IV. Experiment Result

A. Blind Signal Estimation

In the EPCglobal standard for UHF-RFID a tag response to the *Query* command consists of a preamble followed by a 16 bit-random number or pseudo-random number. Since the preamble is identical for all tags involved in a collision, which is not use for the channel estimation. The bits that follow cannot be used as well. The postpreamble of tag data is described by [12] for useful of the channel estimation. Nevertheless, the postpreamble is wasted more bandwidth and could be occurred more bit error rate in complex scenario. Hence, the postpreamble is performed only in Gaussian scenario and does not have much impact in Rayleigh scenario. The solution one does not require the postpreamble is a blind channel estimation technique.

The most of existing blind channel estimation is developed for a given channel realization with statistical model. We applied to RFID system that is given to estimate the channel of the multiple access interference (MAI).

Consider the source independently in the RFID tags backscattering, we propose to apply Independence Component Analysis (ICA) to design a new linear blind receiver (LBR). The main reason is for using ICA in MIMO-RFID receiver to solve the problem form MAI. In particular, this is because each tag path and each tag transmitted symbol sequence are approximately independent of the other tags. The ICA based on LBR requires $N \geq M$ spatially antennas.

$$\hat{G}(\theta,\phi,\varphi) \cong \frac{1}{M}\sum_{n=1}^{N-1} r_n(t) \tag{11}$$

B. Measurement Setup

The blind signal estimation of the proposed method is investigated though RFID reader as 2.4 - 2.5 GHz frequency band. In an experiment, the RFID reader is provided by the MIMO antennas as a channel dimension $N \times M$. The experiment model has been carried out by the warehouse situation of indoor environment that as shown in Fig. 3 and the parameters setup is shown as in Table I.

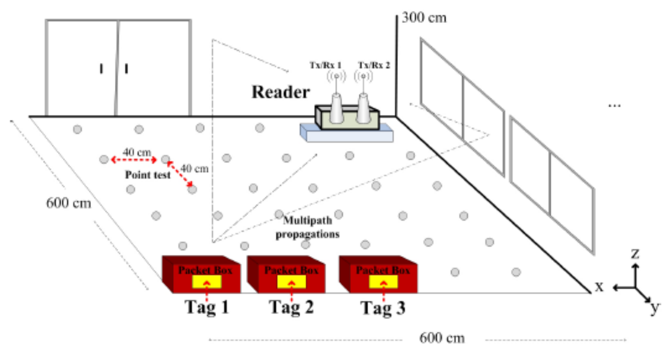

Fig. 3. Experiment model in warehouse scenario.

TABLE I: Parameters Setup

Description	value
RFID standard	ISO 18000-4
Bandwidth	2.4 – 2.5 GHz
Antenna type	Monopole
Antenna gain	3 dBi
Point test	40 points
Transmit power	-20 dBm
Tag standard	EPC Gen-1
Sampling	800
Number of tag	10
Dimension x,y,z (cm)	$600 \times 600 \times 300$

C. Data Processing

First of all, we will have pre-learning the channel coefficient. Secondly, choose the initial separating matrix $H(f)$ and learning spectral density rate $R(f)$. Then, we have carried out by the estimator to minimize the maximum output energy (MOE) of the received signal; this case is well known to cause from the multipath interference power such as self-interfering or channel time-varying in fast fading environment. Then, the procedure of update $\hat{G}(\theta,\phi,\varphi)$ is performed and finally, the received signal after the used of the signal estimator in expression (11) is significantly reduced the variance of the multipath signal.

Fig. 4 and Fig. 5 a comparative overview of the data measurement and blind channel estimation with a MIMO channel are shown. The multiuser receiver batch processing that can preforms to reduce the mean square error (MSE) from the expansion of the channel fading. In order to identify the exact gain of the tag backscatters and focus instead of the behavior of order fading signal this exists to the signal coming out. We found that the extended MMSE receiver is almost perfected the channel estimation which is suppressed from noise variance. With the use of the multiuser receiver batch processing is given to separate the interference plus noise enhancement in the case of multiple tag backscatter simultaneously.

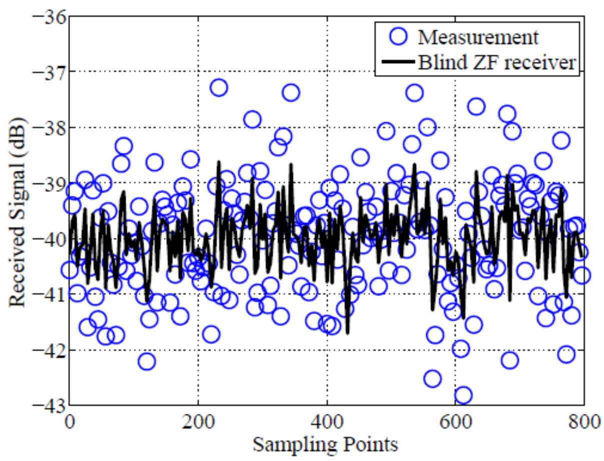

Fig. 4. The result of proposed method with blind ZF receiver.

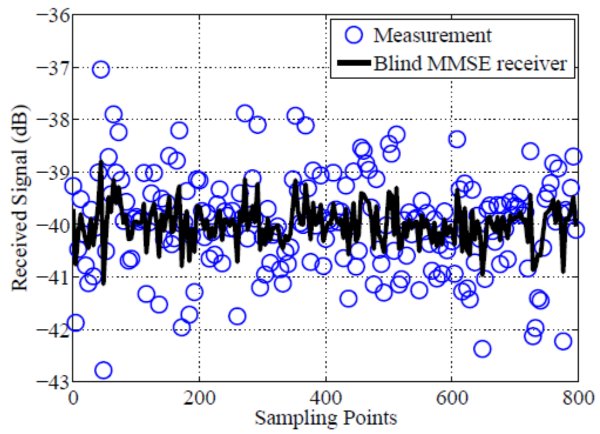

Fig. 5. The result of proposed method with blind MMSE receiver.

Furthermore, we have shown a comparative overview of the expected throughput for the proposed with the possibility to resolve from the results of another works with experimented to 10 tag backscatters are shown in Fig. 6, and Fig. 7, respectively.

The MIMO-RFID receiver is compared with the previous methods as the zero constant modulus (ZCM) and least square (LS) which is proposed in [7] and [12], respectively. The proposed method is to obtain the maximum channel throughput in during 2 tags to 4 tags which is better than all both reference techniques. However, our reader receiver with blind signal estimation, the exact gain is increased to identify the throughput efficiency over the single antenna.

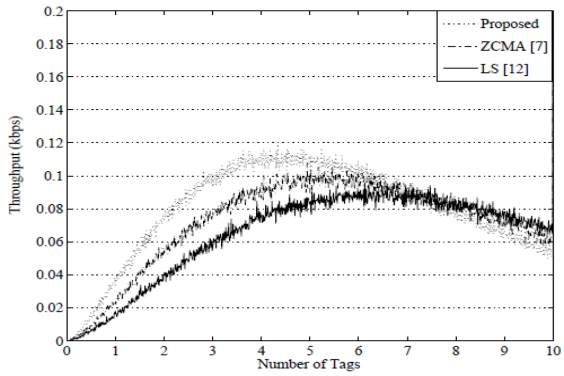

Fig. 6. The throughput of multiuser detection with blind ZF receiver.

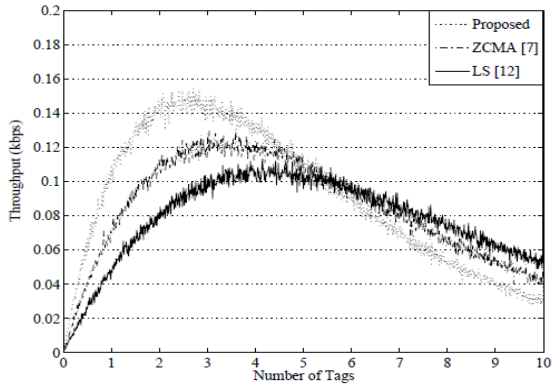

Fig. 7. The throughput of multiuser detection with blind MMSE receiver.

V. Conclusion

In this paper, the experimental of blind signal estimation at the receiver of RFID reader have been proposed. With the multiuser receiver for channel estimation technique is presented. The blind channel estimation not only helps to increase accuracy of the uncertainty in received signal at the receiver from channel varying, but also identity the throughput of channel backscattering. Furthermore, the obtained results show that our proposed method provides to be similar to contribute of the comparison. We have found that blind signal estimation depends on subjective design criteria, it is highly desirable that blind multiuser receiver achieve the same objective for which non-blind receiver are designed. However, this technique is a simple of receiver and provides a low complexity to design the baseband processing of the RFID reader receiver.

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