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The Performance Analysis Using Multiple Beams for RFID Warehouse Management System

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Abstract—In **order to enhance the efficiency of supply chain, Radio frequency identification (RFID) technology is used to label every cargo. Logistics center (warehouse) is the important node in supply chain. The RFID application in warehouse is complicated. The environment influence and multi-tags collision would make the reader lost targets. It is desired to raise the detect accuracy and detect speed of RFID reader. In this study, we propose multiple antenna beam former algorithm based on SDMA (Space Division Multiple Access) theory to get rid of the multi-tags interference in warehouse with RFID technology. The simulation results show that proposed algorithm can enhance the detect accuracy of RFID reader. It will become an effective tool in warehouse management. Further more, the RFID reader using multiple antenna beam former algorithm will save energy.**

Keywords-RFID; multiple antenna; beam former; inteferance

I. INTRODUCTION

The characteristics of modern logistics are high-quality services, exactly information. With the development impact of globalization on international trade, more effectively way to control and track the merchandise is needed in supply chains. Radio frequency identification (RFID) is an automatic identifications method. RFID systems use radio waves to transmit information from an integrated circuit tag through a wireless interchange to a host computer [1]. In warehouse management system, RFID could improve the mean of data collection, avoid the errors of labor work, decrease the labor cost and process time[2]. Warehouse management using RFID becomes hot research field in modern logistics because of it's management process is very complexity and process effective is low. RFID application in warehouse could enhance the veracity and integrality of cargo information in supply chain.

Barcode is the traditional way to manage single unit in the warehouse. RFID becomes the new instrument to substitute the barcode. Compare the RFID with barcode, we can found some merits of RFID technology. The barcode need touch scanning and time consuming. The RFID provides the function of wireless sensor to identify simultaneously more products than the traditional barcode scanner [3]. The characteristics of barcode and RFID technology are analyzed, and the results are listed in Table 1. From the Table.1, the analysis results indicate that the RFID has many advantages, which has a potential ability to improve logistics chains, but the disadvantage is the higher than barcode.

TABLE I. THE CHARACTRISTICS OF RFID AND BARCODE

Item	*RFID*	*Barcode*
Line of Site	Not required (in most cases)	Required
Read Range	Passive RFID: Up to 25 feet Active RFID: Up to 100's of feet or more	Several inches up to several feet
Read Rate	10's, 100's or 1000's simultaneously	Only one at a time
Identification	Can uniquely identify each item/asset tagged	Can typically only identify the type of item (UPC Code) but not uniquely
Read/Write	Many RFID tags are Read/Write	Read only
Technology	RF (Radio Frequency)	Optical (Laser)
Interference	Like the TSA (Transportation Security Administration), some RFID frequencies don't like Metal and Liquids. They can cause interfere with certain RF Frequencies.	Obstructed barcodes cannot be read (dirt covering barcode, torn barcode, etc.)
Automation	Most "fixed" readers don't require human involvement to collect data (automated)	Most barcode scanners require a human to operate (labor intensive)

RFID is applicated in warehouse. When RFID reader faces multiple tags, the phenomenon of interference and collision around tags is often occurs. Some anti-interference approaches have reported to handle the problem, such as, TDMA, FDMA. The approaches are not easy to realize in RFID system. In this study, based on the approach of smart antenna [5-8], we proposed an algorithm of antenna beam forme. Promising simulation results are achieved. Multiple antenna beam former can increase the received SNR and decrease the interference. It could be a feasible way to

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resolve the collision problem in the multiple tags warehouse environment.

The rest of this paper is organized as follows. Section II gives a brief description for the RFID warehouse environment. Section III introduces the model of multiple antenna beam former, and a simplest delay-and-sum beam former algorithm. In section IV, our numerical simulation results are shown. In section V, some conclusions are drawn.

II. RFID WAREHOUSE ENVIRONMENT

In warehouse management system based RFID, there are often existing many tags around the RFID reader. RFID reader emits rays to tags, and receives signal from tags. The simplified model is depicted in Figure 1. In this complicated tags density environment, RFID Reader may suffer the serious noise interference. Improving the SNR in desired tags direction and weaking the interference from other tags will be a feasible method to guarantee communication reliability of RFID reader in density tags.

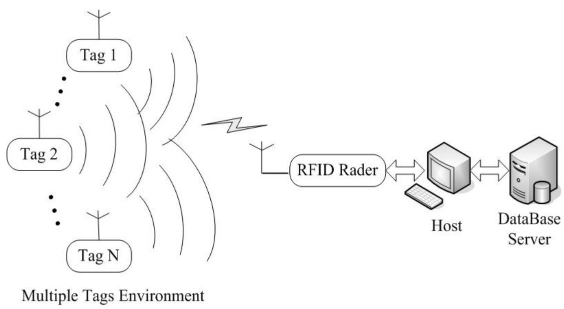

Figure 1. RFID multiple tags communication model.

III. MULTIPLE ANTENNA BEAM FORMER

The approach of multiple antenna beam former has been applied in many fields, especially in MIMO system and smart antenna system. The MIMO system utilizes the space signal's independence to achieve diversity gain, while the smart antenna system utilizes the correlation received space signal to obtain the SNR gain. Here, we adopt the signal correlation theory to steer beam pattern to the desired direction. Multiple antenna beam former uses the signal correlation to realize beam former, which can decrease the interference and enhance the power efficiently. From the above analysis, the smart antenna beam former technology is more suitable to decrease interference in RFID warehouse environment. The structure is illuminated in Figure 2. It contain antenna, A/D (D/A), array weight adjuster which control by digital signal processor (DSP).

There are many beam former algorithms are studied [9], such as adaptive Null Steering algorithm, adaptive beam former algorithm, *etc*. The main structure can be depicted in Figure 2.

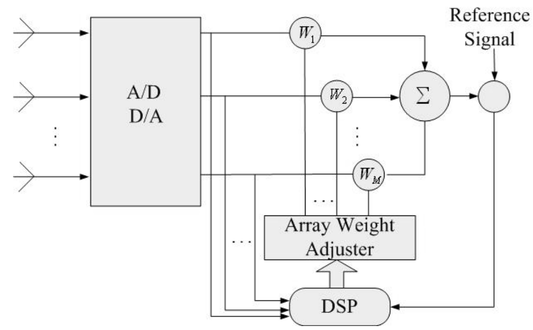

Figure 2. Multiple antenna beam former structure

The array weight $w(i)$ can be defined as follows

$$w(i)=\begin{bmatrix} w_1(i) \\ w_2(i) \\ \vdots \\ w_M(i) \end{bmatrix} = \begin{bmatrix} 1 \\ \exp(-j\frac{2\pi}{\lambda}d\sin\theta_2) \\ \vdots \\ \exp(-j\frac{2\pi}{\lambda}(M-1)d\sin\theta_i) \end{bmatrix} \quad (1)$$

where, λ is the wavelength, d is the antenna element spacing, θ_i is the direction of received beam. We only concern the 2-D uniform linear array (ULA) with M antennas element.

A. *The ideal beam former pattern*

We design the smart antenna beam former beam pattern, as depicted in Fig.3. This ideal model can be view as the tags distributed in warehouse. The whole distributed space are divided in several subspace through SDMA, then the interference is weaken more efficiently when the tag at the main lobe region through switcher module. The space is divided is several subspace with $2\pi/N$, each subspace has its mainlobe in the look direction of θ_i , see Eq 2. The ideal smart antenna beampattern through the antenna array is shown in Figure 3.

$$\theta_i = \frac{2\pi i}{N} \qquad i \in [0,\ldots,N-1] \quad (2)$$

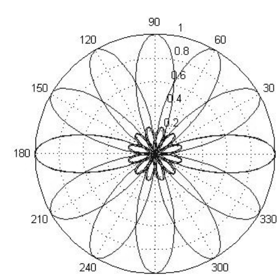

Figure 3. The ideal beam pattern

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B. Delay-and-Sum beam former algorithm for RFID

The delay-and sum algorithm [9,10] is the simplest algorithm for Space-Time processing. This beam former is done through coherent reception of amplitude and phase of the signal received from each antenna elements array. It has some merits including (1) the prior information is unnecessary, and (2) the approach is easy to realize. We assume the received of signal with same amplitude, and only have the phase difference. The algorithm structure can be depicted in Fig.4. where, $s(t)$ is the received signal, $n(t)$ is the background noise, $e^{j\omega\theta}$ is the phase shifter.

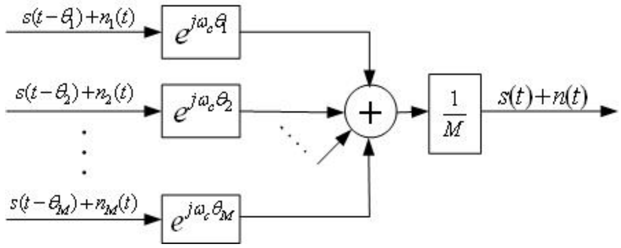

Figure 4. The delay-and-sum beamformer algorithm structure

There are N narrow band far field signals impinging on the *i-th* second user. The received signal $s_i(t)$ can be express as

$$s_i(t) = m(t)\exp[j(2\pi f_0 t + \frac{2\pi d(k-1)}{\lambda}\sin\theta_i)] \quad k \in [1, M] \quad , \tag{3}$$

where $m(t)$ is the complex modulating function of received signal, the f_0 is carrier frequency, θ_i is the phase jitter.
Thus, the input array signal vector *s(t)* is formular as

$$s(t) = [s_1(t), s_2(t), \ldots, s_M(t)]^T . \tag{4}$$

The array weight vector of delay-and-sum algorithm is

$$w(i) = [w_1(i), w_2(i), \ldots, w_M(i)]^T = \frac{a(\theta_i)}{M}. \tag{5}$$

The output of the beam former is

$$y(t) = w(i)^H s(t) . \tag{6}$$

Thus, the output power of processor can be express as

$$P = E[y(t)y^*(t)] = y(i)^H R_s y(i) = P_s , \tag{7}$$

where P_s is the signal power, and assume the received signal at different antenna element can reach whole synchronous, R is the signal of correlation matrix, it can be define by

$$R_s = E[s(t)s^H(t)] = \begin{bmatrix} E\left[S_1^2(t)\right] & E\left[S_1(t)S_2(t)\right] & \cdots & E\left[S_1(t)S_M(t)\right] \\ E\left[S_1(t)S_2(t)\right] & E\left[S_2^2(t)\right] & \cdots & E\left[S_2(t)S_M(t)\right] \\ \vdots & \vdots & \ddots & \vdots \\ E\left[S_1(t)S_M(t)\right] & E\left[S_2(t)S_M(t)\right] & \cdots & E\left[S_M^2(t)\right] \end{bmatrix} . \tag{8}$$

In similar way, aimed at the zero and variance σ_n^2 AWGN, the noise is uncorrelated at the different antenna. The output noise average power is M times less than on each user, it can be written as:

$$P_N = E[n(t)n^*(t)] = w(i)^H R_n w(i) = \frac{\sigma_n^2}{M} , \tag{9}$$

where the noise correlation matrix is *Rn*, see Eq 10.

$$R_n = \begin{bmatrix} E[n_1^2(t)] & E[n_1(t)n_2(t)] & \ldots & E[n_1(t)n_M(t)] \\ E[n_1(t)n_2(t)] & E[n_2^2(t)] & \ldots & E[n_2(t)n_M(t)] \\ \vdots & \vdots & \ddots & \vdots \\ E[n_1(t)n_M(t)] & E[n_2(t)n_M(t)] & \ldots & E[n_M^2(t)] \end{bmatrix}, \tag{10}$$

where, the multiple antenna beam form array gain is defined as the ratio array output SNR to the single antenna element input SNR, the gain G is

$$G = \frac{SNR_{Multiple\ antenna}}{SNR_{signle\ antenna}} = M . \tag{11}$$

Based on above-mentioned results, the delay-and-sum beam former algorithm can reach M times SNR gain at the mainlobe direction, and the beam former algorithm dose not need *prior* information and complex computation. It is noted that can decrease the interference from other direction. In particular, the method can control received SNR at different in warehouse environment.

IV. NUMERICAL SIMULATION AND DISCUSSION

In a warehouse environment, there are various tags placed in different direction. RFID reader can detect these tags. To ensure the correlation requirement between the element of smart antenna, in our simulation the d/λ=0.5. Our desired tags are located in the direction at the 0° azimuth angles. The simulation results is illuminated in Figure 5. show that the number of antenna array $M = 4,8,16$ respectively, beampattern performance.

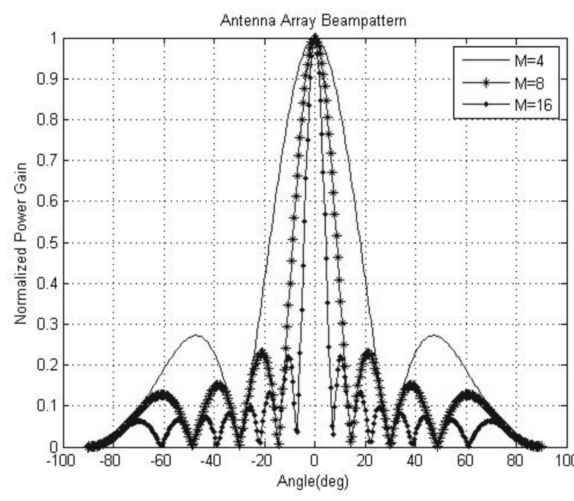

Figure 5. The antenna array beampattern

In Figure 5, the performance of smart antenna Array Beampattern characteristic is tested using Delay-and-Sum algorithm. With the increasing of the element of smart antenna the main lobe is narrow down, and it becomes more directional, and sidelobe is low down. It means that the antenna power coverage range concentrate to the 0°. On the other hand, the power is suppressed and the array gain. The average suppressed about 70%, so it has powerful to apply in the multiple tags warehouse environment for reducing interference. When the azimuth angle vector is driven to the desired direction, the interference from other direction can be weakened.

V. CONCLUSIONS

In this study, a multiple antenna beam former algorithm is proposed to reduce the interference and collision of multiple tags in warehouse environment. The simulation results show that the method can decrease the interference from other direction tags, and increase the SNR more efficiently in desired direction. The beam former algorithm is easy to realize. Using this approach, RFID reader can detect tags more accuracy and quickly.

In real warehouse environment, multiple RFID readers and tags placed in different direction. Various instruments and tools make the environment more complicate is complicate. Proposed approach of multiple antenna beam former becomes potential effective tool for solving multi-tags interference. Especially, the algorithm can be used to track the moving tag. It has potential useful for RFID field, and it is the future research aspect.

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