

EVALUATING THE READING PERFORMANCE OF SEMI-PASSIVE RFID TAGS TO ENHANCE LOCATING OF WAREHOUSE RESOURCES: AN EXPERIMENT DESIGN

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Abstract –

In the supply chain, a warehouse is a crucial component for linking all chain parties. It is necessary to track the real time resource location and status to support warehouse operations effectively. Therefore, RFID technology has been adopted to facilitate the collection and sharing of data in a warehouse environment. However, an essential decision should be made on the type of RFID tags the warehouse managers should adopt, because it is very important to implement RFID tags that work in warehouse environment. As a result, the warehouse resources will be easily tracked and accurately located which will improve the visibility of warehouse operations, enhance the productivity and reduce the operation costs of the warehouse. Therefore, it is crucial to evaluate the reading performance of all types of RFID tags in a warehouse environment in order to choose the most appropriate RFID tags which will enhance the operational efficiency of a warehouse. Reading performance of active and passive RFID tags have been evaluated before while, semi-passive RFID tag, which is battery-assisted with greater sensitivity than passive tags and cheaper than active tags, has not been examined yet in a warehouse environment. This research is in- progress research and it is aiming to perform tests for evaluating the reading performance of semi-passive RFID apparatus to provide an extensive RFID performance comparison for formulating an efficient RFID solution in warehousing environment.

Keywords: Semi-passive RFID tags, Reading Performance, Locating warehouse Resources.

1. INTRODUCTION

During the last two decades, substantial changes have taken place in the warehouses environment as a result of the changes in the environmental factors such as, globalization, technology, international competition and supply chain concepts. Warehousing has become a crucial activity in the supply chain to exceed competitors on customer service, lead –times, and costs (Berg and Zijm, 1999). Also, a warehouse is an essential component for linking the upstream (production) and downstream (distribution) partners in supply chain, and the performance of the warehouse operations, which are either labor- or capital-intensive, not only influences the productivity and operation costs of a warehouse, but also the whole supply chain (Chow et al., 2006).

A warehouse is a crucial component for linking the upstream (production) and downstream (distribution) partners in supply chain, and the performance of the warehouse operations, which are either labour- or capital-intensive, not only influences the productivity and operation costs of a warehouse, but also the whole supply chain (Chow et al.,2006). Thus, information systems such as warehouse management systems (WMSs) were implemented for collecting data of warehouse operations in order to handle warehouse resources and monitor its operations. However, the current WMSs are unable to provide timely and accurate warehouse operations data. Also, incorrect data is inevitably input from time to time as the systems depend heavily on warehouse staff members to put operational data manually or by using bar-code techniques and human error is unavoidable (Sexton, Thomas, and Helmreich, 2000). In addition, the WMSs are incapable of locating accurately the positions of warehouse resources (Shih, Hsieh, and Chen, 2006). Therefore, RFID technology, which is an automatic identification and real-time data collection technique, has been implemented for collecting and sharing data of warehouse operations in order to trace and locate accurately the positions of warehouse resources which will support warehouse operations effectively (Chow et al., 2006; Poon et al., 2009; and Poon et al., 2011). RFID technology uses devices called RFID tags or transponders to store and retrieve data (Lahiri, 2006). There are three types of RFID tags; they are active, passive, and semi-passive tags. Active tags are very expensive, while passive tags are a reasonable solution in short-range applications and have a limited reliability which affects its performance and functionality (Angeles, 2005 and Poon et al., 2009). On the other hand, semi-passive RFID tags have greater sensitivity than passive tags, smaller size and cheaper than active tags (Song et al, 2006). Active and passive RFID tags have been evaluated in a warehouse environment by Poon et al (2009), while, semi-passive RFID tags have not been tested yet in a warehouse environment. This ongoing research will give an overview and will understand deeply the concept of “Warehousing”, “Semi-Passive RFID Technology” which will be defined and interpreted in theory and practice. Both theoretical and empirical studies will be conducted in order to get an overview. The theoretical study will be conducted by accomplishing a research work on relevant literature reviews through a normative literature review.

2. RESEARCH OBJECTIVES:

The theoretical objectives of this research are:

- 1- To give a summary and to briefly display the concept of “Warehousing”, “Semi-Passive RFID Technology”;
- 2- To emphasize on different terms related to warehousing, to examine warehouse operations and the warehousing problems; and
- 3- To examine if the reading performance of semi-passive RFID tags has been evaluated in a warehouse environment.

On the other hand, the empirical study aims to:

- 1- Perform tests for evaluating the reading performance of semi-passive RFID tags in a warehouse environment.
- 2- Provide, based on the test results, an extensive reading performance comparison of all types of RFID tags on the following criteria(Tajima, 2007):
 - The data transmission rates between readers and tags (Higher or Lower);
 - Noise immunity (Subject to noise or better noise immunity);
 - Orientation sensitivity (Greater or less);
 - Number of tags which can be read simultaneously (Fewer or more);
 - And reporting capability (Self or no-self).
- 3- Formulate, with the help of the performance comparison results of these RFID tags, an efficient and economical RFID solution in a warehouse environment. This will enhance locating of the warehouse resources and support warehouse operations effectively.

This paper is organized as follow, in Section 2; we present a literature review of warehouse environments, real-time techniques used for tracking the location warehouse resources, evaluation of RFID equipments in a warehouse environment, and semi-passive RFID tags. Next, we present the evaluation protocol in Section 3. Section 4, is devoted to give a summary of this study.

3. RESEARCH BACKGROUND:

According to (Kaihara, 2003) and (Liu et al., 2005), a supply chain is an important channel for sharing information among all chain parties including, suppliers, manufacturing and storage facilities, distributors and customers for facilitating the core business functions of the production, sale and delivery of a particular product. Hence, the main role of supply chain management (SCM) is to integrate effectively both materials flows and related information between upstream and downstream entities (Soroor and Tarokh, 2006). However, during the last two decades, the enterprises have

changed their production mode from the traditional mass production to the mass customization production in order to facilitate increasing global market competition. Thus, the supply chain processes have been redesigned in order to do new processes that are more efficient and effective which enable supply chain to achieve its competitive advantage. Harmon (1993) indicated that warehouses should be reformulated and automated to achieve high throughput rate, enhance the warehouse productivity, thereby minimizing the order processing cost. In such sense, warehouse operation has become an essential activity in the supply chain to exceed competitors in terms of customer service, lead times and costs (Berg and Zijm, 1999).

The changes mentioned above have had a big challenge on a warehouse management which is the most important function for linking and integrating all the supply chain parties and for ensuring the smooth materials flows within the network (Gu, Goetschalckx, and McGinnis, 2007). With such an arrangement, it is necessary to smooth data sharing and provide the location information of the warehouse resources, such as stock-keeping units (SKUs), pallets and racks, pallet trucks and forklifts, and warehouse staff members, in order to facilitate manufacturing operations, minimize inventory levels, reduce order processing, storage, and transshipment costs, and enhance productivity within facilities (Vogt et al., 2005). Currently, within the existing chain, warehouse management systems (WMSs) have been developed to handle and monitor warehouse resources and operations. However, WMSs are lacking in real-time data capturing and the real working status visualizing as they are using the bar-code-based or manual-based warehouse management (Huang et al., 2007; and Sexton et al., 2000). As a result, the systems can not accurately locate the warehouse resources positions (Shih, Hsieh, and Chen, 2006). Therefore, it is crucial to adopt real-time data management techniques for tracking the real time resource location and status, which increase warehouse visibility and assist warehouse managers to select resources to perform warehouse operations efficiently and effectively (Poon et al, 2009).

3.1 Existing Real-Time Data Management Techniques in Tracking Warehouse Resources Location

There are some real-time data management techniques implemented for smoothing data sharing in the existing supply chain and providing object location information. As far as indoor environment is concerned, different technologies have been developed to locate objects in the buildings such as, Infrared, ultrasonic and radio frequency identification (RFID) technologies (Xu and Gang, 2006). Among those three technologies, RFID is an emerging technology that has been widely adopted in numerous areas in the supply chain activities such as manufacturing, warehousing, retailing, etc., for object identification (Mintchell, 2002; Smaros and Holmstrom, 2000; Vijayaraman and Osyk, 2006). RFID is a generic technology concept that uses radio waves to identify, locate, and track objects (Auto-ID centre, 2002). RFID uses a small tag consisting of an integrated circuit chip and an antenna,

which is capable to respond to radio waves transmitted from the RFID reader . Also, it is capable of sending, processing, and storing data (Wu, Nystrom, Lin, and Yu, 2006). There are three types of RFID tags: (a) active- containing a small battery, (b) passive - draws energy from the transponder and (c) semi-passive - battery powered but requires signal from the transponder for activation (Angeles, 2005).

The following figures show the difference between active and passive RFID power scheme.

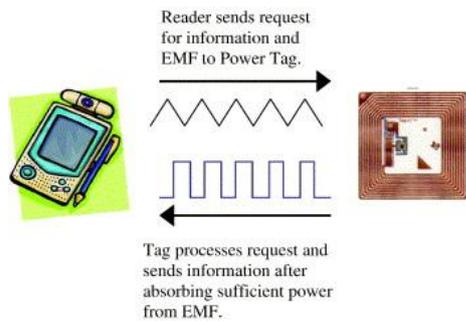


Figure.1. Passive RFID power scheme.

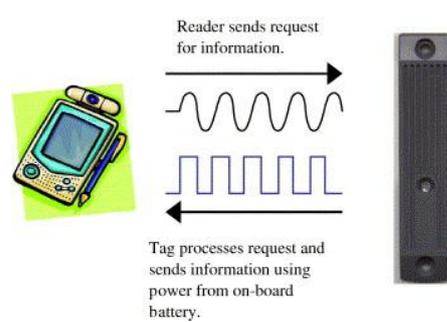


Figure. 2. Active RFID power scheme

Source: Goodrum et al (2006).

In fact, active, passive, and semi-passive RFID tags have many differences. Table. 1. Shows the differences among these tags.

Table 1. Differences among active, passive, and semi-passive RFID tags

Issues	Active RFID tags	Passive RFID tags	Semi-passive RFID tags
Tag power source	Internal to tag	Energy transferred from the reader	Internal power source
Availability of tag power	Continuous	Only when found in the field of the reader	Use their battery to power chip only, require a reader to interrogate them first
Required signal strength from reader to tag	Low	High	Not available
Available signal strength from tag to reader	High	Low	Not applicable
Communication range	Long range(Can be 30 m or more)	Short range(Typically under 3 m)	Long range (This research will find out how much this range is?)
Multi-tag collection	Scanning of thousand of tags from a single reader	Scanning of a hundred of tags within 3 meters from	Not available

		a single reader	
Multi-tag collection	Scanning of up to 20 tags moving at more than 100 miles/hour	Scanning of 20 tags moving at 3 miles/hour or slower	Not available
Sensor capability	Ability to monitor continuously monitor sensor input	Monitor sensor input when tag is powered from the reader	Not available
Data storage	Large	Small	Large
Weight	120-13-g	6-54g	Not available, but they are smaller size (lighter)than active tags
Capabilities	Read/Write	Read only	Read/Write
Operational life	5-10 years	Unlimited	Over than 5 years
Memory	2MB	Up to 16 kb	Not available
Cost (in \$)	100	0.40-10	10-20 /Cheaper than actives and closer to passives
General applications	Suitable for tracking high value items over long ranges; security/personnel access control; asset tracking	Suitable for tracking low-value consumer goods; supply chain tracking;	-Suitable for enhancing the control during cold transport chain of food products, -This research will explore their ability to track warehouse resources?
Performance	-Higher data transmission rates -better noise immunity -less orientation sensitivity - more tags can be read simultaneously - self-reporting capability	-Lower data transmission rates - subject to noise -greater orientation sensitivity - fewer tags can be read simultaneously - no self-reporting capability	This study is to evaluate the performance of semi-passive RFID tags and find out the following performance measures: -How many tags can be read at a time? -How far can they be from the reader (distance effect on their performance)? -The effect of temperature, noise, pressure, and material type on their performance? -How tag placement and antenna number affect the readability of these tags?

Sources: Song et al. (2006); Tajima et al. (2007); Juels & Pappu (2003); Domdouzis et al. (2007); Jedermann et al. (2008); Poon et al. (2009); Speakman and Sweeney (2006).

From the above table, we can see that there still are some missed specifications of semi-passive tags; this research would explore them by evaluating the reading performance of semi-passive RFID tags in a warehouse environment in order to provide a comprehensive FRID performance comparison including all issues of these RFID tags.

3.2 Evaluation of RFID Technologies in a Warehouse Environment

There is a few numbers of experiments which tested the reading performance of RFID equipments in a warehouse environment. The following table shows these experiments.

Table 2. List of publications that conduct case studies and experiments for evaluating the reading performance of RFID tags to enhance locating of the warehouse resources.

Authors	Year	Title
Chow et al. (2006)	2006	Design of a RFID case-based resource management system for warehouse operations.
Poon et al. (2008)	2008	A RFID-Based Location Tracking Scheme for Inbound Operations in Warehouse Environment.
Poon et al. (2009)	2009	A RFID case-based logistics resource management system for managing order-picking operations in warehouses.
Choy et al. (2009)	2009	A design method for configuration and setup of a RFID system in a warehouse.
Wang et al. (2010)	2010	Experimental Study on RFID Performance Factors of Conveyor Belt System Using DOE Methodology.
Poon et al. (2011)	2011	A real-time production operations decision support system for solving stochastic production material demand problems.
Poon et al. (2011)	2011	A real-time warehouse operations planning system for small batch replenishment problems in production environment.

From the above table we can see a list of the publications which evaluated the reading performance of RFID tags in a warehouse environment, apoted RFID tags to locate and track the status of warehouse resource, or mentioned to the importance of RFID tags evaluation in a warehouse environment detailed in the following.

Chow et al. (2006) have performed a case study on RFID technology integration in an actual warehouse environment. They mentioned to some physical setups of active and passive tags needed in order to facilitate the tracking of the warehouse resource location and status in a real-time, but they did

not evaluate the reading performance of these RFID tags before implementation in a warehouse environment.

Poon et al. (2008) have conducted a case study in a real warehouse environment. They have adopted passive RFID tags to locate warehouse resources easily and to obtain a real-time and accurate update of the resources status anywhere at anytime. They aim to determine the appropriate locations for implementation of RFID apparatus in a warehouse. However, they did not test the reading performance of passive RFID tags before the implementation of RFID system in the warehouse environment.

Poon et al. (2009) have performed a case study on RFID technology integration in the Group Sense Limited (GSL) warehouse in order to facilitate the collection and sharing of data in real-time. They aim to formulate and suggest the most efficient RFID solution in warehousing environment the warehouse managers should choose before the implementation process. They have proposed four tests for evaluating the performance of the active and passive RFID devices in that warehouse, namely (i) orientation test (is to determine the horizontal effective RF cover range of the reader), (ii) height test (is to determine the vertical effective RF cover range of the reader), (iii) range test (is to determine the maximum RF cover range of the reader in a horizontal direction), and (iv) material test (is to measure the reading performance of RFID tags when they are placed on the front and back surfaces of various types of products in a warehouse environment). They have found that the reading performance of active RFID tags is better than that of passive RFID tags. Also, it is difficult to implement the active RFID devices for item-level RFID tagging in the warehouse environment due to high implementation cost. So a full passive RFID implementation plan was suggested for implementation in that warehouse. Moreover, the passive large-sized tags are better than the passive middle-sized and small-sized tags, but it is not suitable in tracking forklifts, as the reader is unable to detect the tags which are stuck on the metal.

Choy, (2009) has proposed a design method which combined the methodology of RFID experiment, which has been done by Poon et al. (2009), and arithmetical model for the cost and benefit analysis of RFID set up in order to help warehouse designers to form an RFID configuration and set up in a cost-effective way. This means that he has not evaluated the reading performance of RFID in a warehouse environment, but he has conducted his study based on the results of the RFID experiment of Poon et al. (2009).

Wang et al. (2010) have conducted an experimental study to investigate how the performance factors affect RFID system performance by using Design of Experiment (DOE) methodology. They focused on the following parameters: Tag placement, angle of reader antenna and conveyor speed, and they have achieved these following results. Tag placement, angle of reader antenna and the interaction between them have main effect on read performance. Particularly, they found that it is not true that the

slower conveyor moves, the higher read rate gets. Also, when they set the angle of reader antenna at 15 degrees, they got maximum average read rate overall. However, they have not mentioned to the RFID type used in their experiment. Moreover, there still are some different parameters, which affect the performance of RFID tags, such as material type, temperature, power level of tags,.....etc and they did not investigate them in their study.

Poon et al. (2010) have performed a case study on RFID technology integration in the Mould Manufacturing Company (ABC). They aim to solve many problems in this company such as, defining the actual inventory level and locate the precise location of material handling equipments and SKUs in the warehouse. They mentioned that the four tests proposed by Poon et al. (2009) for evaluating the reading performance of the RFID device in an actual warehouse environment have specific limitations when they are conducted in positions where the tags are either horizontal to or vertical to the RFID antenna. Also, there are no angle tests among those proposed tests (tag angle tests and reader angle tests) which are necessary to determine the relationship between the reading performance of RFID tags and the different tags and reader angles. In other words, tag angle test is necessary because the reading range under different tag angles can be plotted while, reader angle test is important because the reading rate of the tags can be measured when object is moved in front of the antennas at different angles. In addition, the RFID setting, such as the power level of RFID equipment, is fixed. So it is difficult to identify the relationship between the reading performance of RFID tags and the power level. Therefore, they have suggested three additional tests, namely (1) power level- distance level test (It is to determine the effective RF cover range of the reader with a suitable power level), (2) tag angle test [It is to determine the effective RF cover range of the reader when the tag located at specific angle (a)], and (3) reader angle test (It is to determine the effective RF cover range of the reader when the antennas are placed at a certain angle (b)). Besides, two terminologies of E-plane and H-plane were utilized in these tests as parameters to affect the reading performance of RFID tags. According to Balanis (2008), the E-plane is defined as “the plane containing the electric-field vector and the direction of maximum radiation,” while the H-plane is “the plane containing the magnetic-field vector and the direction of maximum radiation”.

The following figures show Power level – distance test, Tag angle test, Reader angle test, and E- and H-plane patterns respectively.

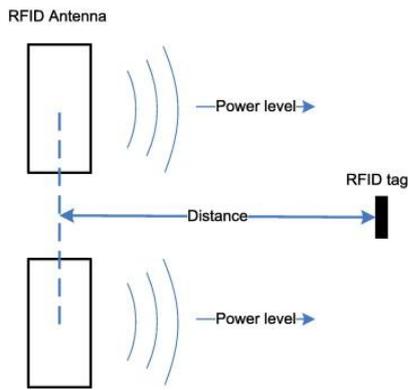


Figure.3. Power level – distance

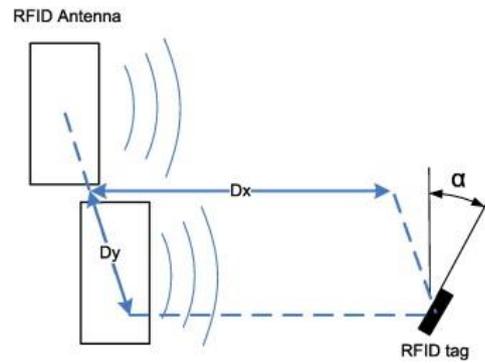


Figure. 4. Tag angle test

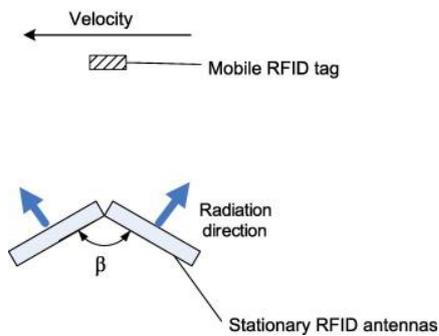


Figure.5. Reader angle test

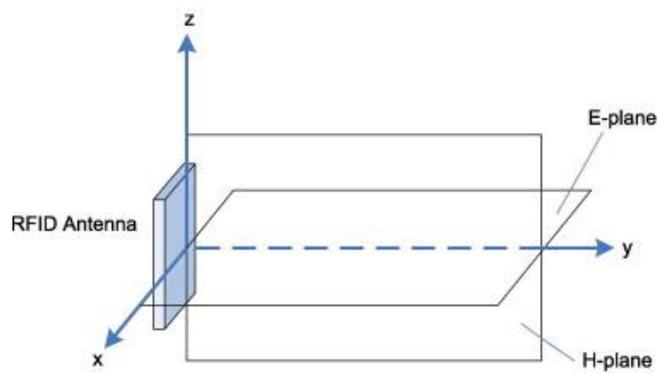


Figure.6. E- and H-plane patterns.

Source: Poon et al. (2010).

Poon et al. (2011) have performed a study on RFID technology integration in a laboratory for collecting real-time warehouse resources information, because it is essential to track the status of warehouse resources, e.g., a forklift, in the form of location and capacity. They have mentioned that before the RFID implementation, it is necessary to evaluate the reading performance of RFID equipments in order to suggest the most effective RFID solution in a warehouse environment. However, they have not evaluate the reading performance of RFID tags and based on Poon et al. (2009) and their tests results, they have adopted passive RFID tags in their study for collecting resources location information in a real-time.

From the literature reviews mentioned above, we can see that just active and passive tags, have been evaluated in these experiments. However, analysing different types of RFID technologies is essential in order ot choose and adopt the most effecient RFID technology. Also, selecting the right technology

for an environment is an important decision factor for organizations to obtain the most out of RFID technologies (RFID journal, March 31, 2003; Angeles, 2005; Poon et al, 2009; and Sarac, et al, 2010). This highlights the need to evaluate the reading performance of semi-passive tags, which have not been examined yet in warehousing environment, in order to report a statistical analysis and provide a comprehensive RFID performance comparison. Resulting in an appropriate reference to help enterprises to select the most appropriate RFID equipment for their actual warehouse.

3.3 Semi-Passive RFID Tags

Semi-passive tags contain an internal power source (generally a thin or printed battery), an antenna, and an integrated circuit (IC) (Angeles, 2005). These tags can bridge the gap between passive and active RFID tags because they have a battery on board that enables them to read from a longer range. Thereby delivering greater reading range and reading reliability than passive tags and offering much of the functionality found on active tags. Also, their prices are lower than active tags and closer to passive tags (Müller, 2008). However, the main differences between active tags and semi-passive tags are that semi-passive tags use their small onboard battery to power the chip only and still use passive response from the tag to the reader. This means that semi-passive tags are incapable of initiating the transmission from their location because they require a reader to interrogate them first. While, active tags use their own battery for both the chip and the transmission of data on the antenna and this enhance their ability to initiate the transmission from their locations (Xiao et al. 2007).

Semi-passive RFID tag is an emergent technology that is being used increasingly in many applications. Recently, Jedermann et al. (2008) examined the spatial temperature profiling by semi-passive RFID loggers for perishable food transportation. For instance, they found that these devices are valuable tools for enhancing the control during the cold transport chain of food products and detecting weaknesses by monitoring environmental variables such as the temperature of chilled food refrigerated products, identifying specific problem areas, and raising alarms. However, these loggers need manual handling due to their low reading range. Similarly, Michigan State University conducted a study by using semi-disposable sensor-enabled RFID tags with data loggers, which are battery-assisted passive tags offering temperature and humidity logging to determine temperature variation in different size refrigerated trailers. They found that refrigerated trailers have micro-climates that exist even when a trailer is correctly loaded. These micro-climates lead to perceivable temperature deviations that had not been forecasted (Bert, 2007). Ford Motor Company also uses semi-passive tags to track parts boxes once they have arrived in their immense assembly plants (Mital and Ives, 2003). Semi-passive tags are also often used in pallet-level tracking or tracking ingredients like automobile parts during manufacture. Furthermore, electronic tollbooths often use semi-passive tags by initiating a

query to these tags which are typically attached to the inside of a car's windshield. By this way it can read an account identifier from the tag when the car passes through a tollbooth (Weis, 2009).

Although semi-passive tags have made a significant contribution to different business environments. However, there still are significant challenges when implementing these tags in various business areas. For example, battery -assisted tags use some battery power to preserve their internal volatile memory but may still depend on the reader's signal to power their transmission. Also, they are more fragile and larger than passive tags (Liu, et al., 2009). Müller. (2008) mentioned that the main challenge of BAP tags is to maximize the backscatter efficiency on the tag side and to provide a high sensitivity on the reader side because BAP tags don't actively send RF power back to the reader. Furthermore, there is a problem of incomplete reading of sensing value stored in the semi-passive sensor tag. So Soohan et al. (2009) presented dynamic resizing of bundle and recovery mechanism for complete reading of semi-passive sensor tag. These techniques improve the reliability of reading process and accelerate the mass data reading .In addition; semi-passive RFID tags have shorter lives because they rely on battery power which only offers a temporary solution due to their finite lifetime. Hence, Lai et al. (2005) conducted an experiment in using ambient vibration energy to power a BAP tag. They found that the ambient vibration energy offers an unlimited life and maintenance free solution in powering BAP tags.

Academics and practitioners have produced much wide ranging literature concerning semi-passive RFID tags innovation since its emergence. Extensive academic debate focused on the benefits of BAP tags and the contribution that this technology could make to overall supply chain performance. Also, they focused on the implementation challenges and the corresponding strategies to enable semi-passive RFID tags in business environment. To date, however, no prior literature has evaluated the reading performance of semi-passive RFID tags in a warehouse environment. This neglected gap will prevent warehouse managers and decisions makers from choosing and implementing the most effecient RFID technology in their warehouses which will affect the operational efficiency of a warehouse. Therefore, this ongoing research aims to perform tests for evaluating the reading performance of semi-passive RFID devices in a warehousing environment. With the help of the testing results, a comprehensive RFID performance comparison will be provided for formulating an efficient RFID solution in a warehouse environment.

4. EVALUATION PROTOCOL

This research is still in progress and it is aiming to utilize a proposed method which will combine the the both methodologies of Poon et al 2009 and Poon et al 2011. This means applying seven tests namely; (1) Orientation test, (2) Height test, (3) Range test, (4) Material test, (5) Power level-distance tests, (6) Tag angles tests, and (7) Reader angle tests. The main reason for choosing this proposed

method because it would provide an extensive reading performance evaluation of semi-passive RFID tags according to various performance parameters.

. It is required to install the semi-passive RFID devices [in racks, forklifts and stock keeping units (SKUs) for real-time data collection] properly before performing these tests so as to obtain reliable experimental results. Also, configuration and setup of a semi-passive RFID System in a Warehouse should be determined. Choy, (2009) has proposed a design method in order to help warehouse designers to form an RFID configuration and set up in a cost- effective way. This proposed method combined the methodology of RFID experiment, which has been done by Poon et al, (2009), and arithmetical model for the cost and benefit analysis of RFID set up. They indicated that there are three tagging strategies for RFID system. They are: 1- Case-level strategy (which is tagging the RFID tag on each case of the products), 2- Pallet-level strategy (which is tagging the RFID tag on the pallet of the products), and 3- Combined mode strategy (which is a tagging procedure that enables $p1$ portion of product using case-level strategy and $p2$ portion of product using pallet-level strategy, such that $p1+p2=1$).

By using case-level strategy, the product has more than one tag, neither miss-tagging nor duplicated tagging exists, but it is assumed that the transaction error of a RFID system will happen. When using the pallet-level strategy, the one-to-one product assessment, the tagged information is reliable and it is assumed to be zero transaction error for the RFID system.

On the other hand, Poon et al, (2009) have suggested the item-level RFID tagging strategy by using passive RFID only as it is difficult to adopt the active RFID devices for item-level RFID tagging in the warehouse environment due to high adoption costs.

So this research will explore all these RFID tagging strategies in order to utilize the most suitable strategy in its experiment in a warehouse environment.

Experiment should be carried out in a warehouse environment. So this research will find out how many experiments should execute and will investigate the potential warehouses and their characteristics so as to choose the most appropriate one to carry out its experiment.

After testing the reading range of semi-passive RFID equipment, comparison should be conducted in order to compare the reading performance of semi-passive RFID tags with active and passive RFID tags in the defined criteria mentioned earlier in this research. This comprehensive RFID performance comparison would provide the most appropriate type of RFID tags for locating accurately the resources in a warehouse environment.

5. SUMMARY/FUTURE RESEARCH

The role of warehousing is changing quickly under the increased pressure to enhance overall supply chain performance. As a result, it is recognized that the Radio Frequency Identification (RFID) Systems in use is the integral part of warehousing operations in order to locate accurately the warehouse resources and obtain the requested high warehouse performance. However, an essential decision should be made on the type of RFID tags the warehouse managers should implement in their warehouses. So this research will evaluate the reading performance of semi-passive RFID tags in a warehouse environment in order to provide an extensive RFID performance comparison. Therefore, the contribution of this research would be of great assistance and guidance for the current users and practitioners of RFID tags in a warehousing environment, planned on implementing RFID tags, or had developed RFID systems.

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