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# The Right UHF RFID Tags for Libraries – Criteria, Concern and Issues

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## 1. Introduction

In the logistics industry, UHF RFID has been widely deployed. Information and guidelines on the selection of the right tags for the different logistics applications are abundant. However, when it comes to the library arena where the use of UHF RFID is just in its infancy stage, such information is relatively scarce and sporadic. While the tag selection criteria for the logistics industry may also be applied to the library field, there are indeed fundamental differences between library business and logistics operation that libraries must take the initiative to formulate their own selection checklist.

In this chapter, the Run Run Shaw Library at the City University of Hong Kong (*hereafter the CityU HK Library, or the Library*), attempts to share its experience on tag selections based on the research and studies that it has performed in the past few years. The pilot test on the use of UHF RFID in a selected small collection in the CityU HK Library has proved to be successful and the Library is now planning for large-scale implementation of the technology for its entire collection to improve overall service efficiency. As the collection contains over one million items, selecting the right tags that are reliable and sustainable in the long term is crucial. Research and studies in this regard therefore continue through (i) naturalistic evaluation and tests of different tags purchased or borrowed from the suppliers, and (ii) peer discussion with other libraries and UHF RFID practitioners in different occasions such as seminars and conferences and (iii) review of related literature.

By providing an overview of the different criteria, concerns and issues that the CityU HK Library has come across when evaluating different UHF RFID tags, the authors intend to create a momentum for more discussions to go on which for sure will benefit all who are also interested in deploying UHF RFID in their libraries.

## 2. Lessons learnt from the stories of barcodes and tattle tapes

For libraries, the basic issues behind any material check-in and check-out transactions are (i) item identification and (ii) security. There must be a means good enough for each book to be accurately identified so that the circulation status specific to each book can be recorded, mapped with the patron record concerned, and then reflected in the Integrated Library System. There must also be a mechanism good enough to safeguard the book from being illegally removed out of the library without going through the proper check-out procedures. For decades, libraries have been using barcodes and tattle tapes to handle the two issues.

RFID technology, however, has emerged recently with its capability to handle both item identification and security in an all-in-one manner. What more is, the contactless nature of the technology enables multiple book identification and thus can greatly improve loan transaction efficiency. The memory of RFID tags makes RFID more than just an identification technology but a data carrier that can keep track of the circulation status of the item concerned to ensure security and to store other necessary item information that facilitates collection management.

Since HF RFID was first deployed in libraries a decade ago, RFID technology has drawn the interests of many libraries. While the number of libraries adopting RFID technology is on the rise, nonetheless, many libraries are still stationing in the electro-magnetic domain of tattle tapes and barcodes observing the trend. At least this is the case in Mainland China and Hong Kong.

For many libraries, the decision to migrate to a new technology hinges not just to the capability of the technology concerned, but cost-benefit analysis and return on investment. A study called “*RFID Implementations in California Libraries: Costs and Benefits*” conducted in 2006 (Engel, 2006) surveyed different California public and academic libraries and provided an outline with different categories of possible costs and benefits for libraries to consider when planning RFID adoption. The report mentions that a large cost associated with the adoption of RFID is the expense on tags. Apart from the tag costs, tagging itself is also very labour intensive. New equipment, although costly, is comparable to the electro-magnetic systems currently in use in many libraries (Engel, 2006).

Since the survey was conducted in 2006, in fact the prices of tags have dropped, but migrating to a new technology still involves huge investment. To many libraries, barcodes and tattle tapes are still better choices because they have been in place for many years and have proved to be reliable, functional and stable. Adopting a new technology, however, involves risks and a lot of sunk costs in terms of technology research, product evaluation and testing, staff training, as well as new service development and planning.

After all, barcodes are widely recognized means of identifying items (*though they do need lines of sight and support single item identification for each scan only*). Standards for barcodes have been well established and barcode scanners of almost any brand name can be tuned to read any barcode schema and thus there is no interoperability issue for resource sharing among libraries. (*The different RFID data models used in different systems however create obstacles for interoperability in the case of RFID tags as explained later in this chapter.*) Thus, without ensured interoperability and cost savings, many libraries are hesitant to change to any new technology. Thus, even though the 2-D barcodes nowadays have presented another possible choice for libraries to upgrade their barcode system so as to store more item information for books, very few libraries, if any, have chosen to do so. (*Some libraries, however, have adopted 2-D barcodes in other contexts, such as enriching holding information on library catalogues, providing web links to users on promotional brochures and alike.*) Although 2-D barcodes are comparatively newer technology, they are not backward compatible. Scanners for the traditional 1-D barcodes cannot read 2-D barcodes either. To change, it means hardware replacement and thus capital investment. So, if the traditional 1-D barcodes are good enough to store the basic information (*in most cases, the unique accession number of the book concerned*) to support any circulation transactions, why do the libraries need to bother about changing their 1-D barcodes to 2-D barcodes, not to mention about RFID tags?

For the case of tattle tapes, the common product specifications and requirements as well as the aggregate demand across different libraries have created the possibility for group

purchase to drive the costs down. For example, among all the university libraries in Hong Kong, there are regular joint tendering exercises for bulk purchase of tattle tapes. The discount secured can be up to 30%.

The lessons learnt from the stories of barcodes and tattle tapes is that for UHF RFID technology (*despite its strengths and potentials to enhance library operations*) to be widely adopted among libraries, standardization, interoperability, aggregate demand supported by common product requirements are the necessary conditions to drive the costs down to ensure value for money. Moreover, efforts and sunk costs involved in technology research, evaluation and testing should be minimized through experience sharing among libraries.

At the CityU HK Library, studies and experiments on the use of UHF RFID in the library context have been carried out for years since 2007. After all, choosing the right tags is important as the tags are the souls that RFID-enable the books to make them identifiable throughout the RFID process. The performance of the RFID system hinges very much on the performance of the tags. For the UHF RFID hardware, the investment is basically one-off, though replacement may be necessary in a few years' time because of maintenance and system upgrade purposes. The expenses for tags with good performance, however, can be more significant when compared to the costs associated with the first-time one-off investment in hardware, especially when the collection to be converted is big. Moreover, the demand for tags is recurrent and ongoing throughout the years as the collection expands annually and so do the expenses. Similar to the case of tattle tapes, should libraries be able to agree on common requirements to ensure standardization, interoperability and compatibility, the aggregate demand will guarantee quality and sustainable supply of UHF RFID tags as well as the opportunity for consortial purchase to bargain for bigger discounts and long-term cost savings.

### 3. UHF RFID pilot test and long term implementation for the CityU library

When the National Library Board of Singapore first introduced RFID into their libraries in 1998, HF RFID was the only available technology and thus has naturally become the *de facto* choice by the system developers at that time. But then as technology emerges, UHF RFID has presented to libraries a possibly much cheaper and more powerful choice. The CityU HK Library thus joined hands with the Wireless Communication Research Centre (RCW) of the University in 2007 to form a project team (*hereafter, the CityU HK Library Project Team or the Project Team*) to look into the use of UHF RFID in the library environment. To compare the performance of HF RFID and UHF RFID, however, is not the intention of the authors (Ching & Tai 2009). Instead, based on the UHF RFID pilot test carried out at the CityU HK Library, this chapter discusses the criteria, concerns and issues behind the selection of the right tags for libraries that would also like to use UHF RFID.

In April 2008, the CityU HK Library selected its Semi-Closed Collection<sup>1</sup> as the site to carry out a pilot test that involved real users. UHF RFID applications of the beta version developed by the Library and RCW were put in the Collection for users to check-out and check-in books by themselves. The applications, being called the “EasyCheck System”, include the EasyCheck Units (self-check machines), the EasyReturn Units (self-return machines) and the EasyDetect Gates (security detection gates). They have been well-received by the users and thus are still in

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<sup>1</sup> The Semi-Closed Collection consists of some 7,000 course-related library books that are for short loans (5 hours or 1 day) to students.

operation inside the Semi-Closed Collection till now. Studies and experiments, however, carry on as the Library is planning for large-scale implementation in the whole Library. In particular, the Project Team strongly felt that choosing the right UHF RFID tags is important if the utility and performance of the UHF RFID System is to optimize. Thus, tests have been performed with many different brands of UHF RFID tags.

#### **4. Criteria, concern and issues behind UHF RFID tag selection**

In the logistics industry, tags are for one-off use only. When the pallets/ cases/ items reach the end of the logistics chain, leaving the retailing line and settle in the hands of the customers, in most cases, the tags will be discarded together with the packaging. Nonetheless, for libraries, the tags have ever-lasting roles in the book circulation transactions, perhaps until the books concerned are withdrawn from the collection. Tags in libraries need to go through repeated check-in and check-out processes throughout the years and its anti-theft capability must last as long as the books concerned are still part of the library collection. Moreover, tags in libraries serve at the item level. Almost every book bears a tag and that constitutes to a dense tag environment. What complicates the case is the production life cycle of tags. With the rapid development in the UHF RFID technology, not just the readers are evolving, tags are also kept upgrading. Libraries cannot guarantee that they can use the same brands or the same models of tags throughout the years because of tag evolution. Thus, the dense tag environment will be one with a mixture of tags. Compatibility of tags of different generations to the same machines acquired years ago is a concern.

Other well known issues that libraries may consider also include compliance with regulatory standards, data model, interoperability among libraries, shapes of tags, read range and distance, physical mounting issues such as adhesive, position, orientation, suitability of the selected tags for efficient reading by foreseeable new applications (e.g. smart shelves) and so on. All these different considerations have something to do with the business nature of libraries and also the unique local situation and environments, or even loan rules of different individual libraries. Moreover, unlike the logistics industry where the major concern is smooth flow and tracking of pallets/ cases/ items throughout the supply chain, libraries' concern extends to customers' perception and transaction experience. Thus user behavior and expectation are determining factors too.

Since 2007, the CityU HK Library Project Team has been testing with different UHF RFID tags from different vendors. All the tags concerned are passive tags. Table 1 provides a snapshot of the tags that have been tested so far. To protect the interest of the tag suppliers and companies concerned, the brand names of the tags concerned are represented by the English alphabets only. The most distinctive features of the tags are listed in the table. The country of origin and also the EPC memory size of the tags are also provided.

Results and observations from the tests have provided valuable information to the Project Team for long term implementation of UHF RFID in the whole CityU HK Library. It is hoped that by sharing the findings, the other libraries that are also interested in adopting UHF RFID can benefit too or at least reduce their sunk costs in product testing and evaluation. To choose the right tags, the Project Group recommends that libraries concerned should pay attention to the following areas:

1. Standard Compliance
2. Data Models and Interoperability
3. Tag Memories

4. Form Factor, Orientation and Position of Tags
5. Interferences
6. Product Life Cycle and Compatibility

Tag	Description	Country	Memory size (EPC)
A	A general-purposed inlay intended for use by a wide variety of applications	US	96
B	Strong read range and provides a durable antenna that can withstand more physical abuse than a traditional dipole antenna due to its increased antenna surface	US	240
C	Comes with both EPC memory and user memory	China	EPC: 96 bits User: 224 bits
D	Powerful read performance with best in class reading capabilities for RF friendly contents at FCC frequencies. 240 bits EPC memory with an option for additional 512 bits of user memory	US	240
E	An Item-level inlay designed for best edge on performance, especially in close proximity to other tagged items	US	96
F	Offers far-field performance on RF-friendly materials & metals in a compact form factor	US	96
G	A general-purposed inlay intended for use by a wide variety of applications	US	96
H	Orientation sensitive to minimize cross-talk in dense reader environments	US	96
I	With a breakthrough antenna design that enables more reliable read/ write functions in item level applications where tags may be stacked with millimeters of each other	US	240
J	Orientation insensitive inlay coupled with powerful read range performance. Ideal for reading randomly orientated tags like baggage tagging and pallet tracking	US	96
K	With better performance on items with metal	US	96
L	Orientation-insensitive, with high performance for pallet- and case-level applications.	US	96
M	Long and thin antenna which are long enough to prevent shielding of signals by human hands	Korea	96
N	Tailored, high-performance product for item level use. Reliable reads/ writes when tags are in close proximity to each other.	US	240
O	Cost-efficient, high-performance product for a wide range of supply chain management and apparel applications.	US	96
P	Near field tag which is able to be detected by far field antenna. However, the tag cannot be read when it is too closed to the far field antenna, some distance is required.	US	96
Q	Designed for item level tracking and can be read in both near and far fields. Orientation insensitive with superb performance in dense tag environments.	US	96

Table 1. Tags that have been tested and tried out by the Project Team of the CityU HK Library

## 4.1 Standard compliance

### 4.1.1 Technical standards

The very basic consideration is compliance to standards. It is important that the selected UHF RFID tags should comply with existing and emerging standards so that they can be formatted and are readable by any RFID readers that have also incorporated the ISO standards. ISO18000-6 (UHF Generation 2 Standard) has been developed for UHF RFID. According to the EPC Global specifications (EPC Global, 2008), UHF RFID uses “EPC Gen2” standard as the air interface, standard protocol to communicate with readers and tags. It defines the frequency range, commands, memory bank and protocols for tags and it has been approved and included in the international standard organization (ISO 18000-6C).

### 4.1.2 Frequency band

As RFID makes use of radio waves, the technology is subject to governance by the radio telecommunication ordinance of each individual country. The UHF RFID bandwidths stipulated by different countries, however, are slightly different and sometimes incompatible. The following are some examples:

- The European Union defines 865 - 868MHz as the UHF RFID bandwidth in Europe.
- The Federal Communication Commission (FCC) of the US stipulates 902 - 928 MHz for their country.
- For Singapore, only frequencies between 923-925 MHz are allowed for UHF RFID applications.
- For China, the State Radio Regulation Committee (SRRC) under the Ministry of Information Industry (MII) has approved bandwidths in the 840.25 to 844.75 MHz and 920.25 to 924.75 MHz ranges to be used by UHF RFID tags and interrogators. Each band is divided into 20 channels, each consisting of 250 kHz of spectrum.
- For Hong Kong, the RFID restriction is less tight. The Office of the Telecommunications Authority (OFTA) has stated that for UHF RFID, the bandwidths are 865 – 868 MHz and/ or 920 – 925 MHz. The Telecommunications Ordinance (Cap 106) has set out the technical requirements for RFID equipment operating in these frequencies.

The tags that the Working Group has tested so far (see Table 1) can support frequency range from 865MHz – 925MHz and thus should have no frequency compatibility issue. However, caution should still be taken by libraries to ensure that their selected tags support the UHF RFID frequency bandwidth of the country or region where they belong to.

## 4.2 Data models and interoperability

Data models define the requirements for data elements and structure on the RFID tags and are somehow related to the standardization issue too. To ensure interoperability which is essential for interlibrary loan and resource sharing among libraries, data stored in the tags must be readable and usable by all libraries concerned irrespective of the UHF RFID system that they are using, whether the system comes from company A or company B. Therefore, data model standards are the keys to interoperability.

However, this has not been the case for HF RFID ever since it was first adopted by the libraries in Singapore a decade ago. Standard data models for HF RFID emerged only recently<sup>2</sup> when libraries started to realize that proprietary ways of formatting the tags have

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<sup>2</sup> Different HF RFID library data model standards at the national level have emerged recently. They include data models from Denmark, the Netherlands, the UK and Finland that are examples of fixed

deprived them of the flexibility to use the equipment from any vendor they want. For libraries that have been using proprietary systems for years, changing the vendor or adopting the new data model standard means re-formatting all the old tags. (*This is possible only if old tags are compatible to the system of the new vendor, or otherwise, all items concerned will need to be re-tagged*). This is contrary to the case of barcodes mentioned earlier. For barcodes, standards have been so well established and observed that basically libraries can buy any scanner from any supplier and be able to read barcodes of any schema such as Code 39, codabar, U.P.C. and so on.

Therefore, while UHF RFID is making its way into the library arena, libraries should take the opportunity to first compromise on the data model standards. So far, there is no ISO standard stipulating the UHF RFID library data models. However, instead of accepting whatever proprietary data models that the vendors may propose, libraries should present their own specifications to ensure vendor independence. Such specifications should at least be a consortial consensus among libraries that will have interlibrary loans among themselves, or preferably, a regional or national data model standard. Specifications as such are critical to the choice of tags as sufficient tag memory to support the data model standard concerned is a must.

Therefore, libraries should first make up their mind on the data model that they will adopt before making their tag selection or starting their tag conversion exercise. Once a certain data model is formatted in the tags, it cannot be easily transformed and rewritten. The following is what the CityU HK Library has experienced during its pilot test.

#### 4.2.1 Data model used in the pilot test

When the CityU HK Library launched its EasyCheck System in its Semi-Closed Collection in 2008, the prevailing EPC memory size of UHF RFID tags available in the market was 96 bits only. Moreover, no other reference cases were available in Hong Kong as the CityU HK Library was the only pioneering library trying out UHF RFID in Hong Kong at that time<sup>3</sup>. No regional or international UHF RFID library data model standards could be identified either. Therefore, the Library has come up to its own proprietary data model which is a fixed length one of 12 bytes (96 bits).

The table below shows the structure of this 12-byte data model. The fixed length structure ensures that each data element is given its designed memory address to enable speedy identification of data location even without a precursor. However, the “fixed” approach also means lack of flexibility and the limited tag memory of 96 bits leaves no room for the Project Team to reserve space for additional data elements that other libraries may find necessary if they are to adopt the same data model. Thus, the 12-byte data model as outlined below is tailor made for the CityU HK Library only to suit its local circumstances and may not be suitable for other libraries. This in the long run can be an obstacle to interoperability if every other UHF RFID library devises its own proprietary data model.

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memory models. Other examples are data models from Australia and the US which are examples of flexible memory models (ISO/ IED 15962 encoding). ISO 28560 as an international standard which consists of 3 parts to provide general guidelines on the data elements and incorporate both the fixed memory approach and flexible memory approach came into place only in 2010.

<sup>3</sup> The Library of the Chinese University of Hong Kong, later on, also conducted a pilot test on UHF RFID during January to May 2010.



Offset	Length	Field
0	1 byte	Institution / Organization
1	1 byte	Library Branch / Location
2	1 byte	Classification
3	7 bytes	Barcode
10	2 bytes	CRC16

Table 2. The 12-byte proprietary data model used by CityU HK Library during its pilot test in 2008

#### 4.2.2 Data model for library-wide implementation – the recommended standard

What added light to the situation, however, is the fact that the Moore's Law, (Moore, 2011) coined by the Intel co-founder Gordon Moore in 1965, also applies to UHF RFID tags. Within the few years since the CityU HK Library started its pilot test, the memory sizes of UHF RFID tags have been increasing yet with lower and lower costs. This has provided the Project Team the opportunity to re-plan the data model for future long term implementation of UHF RFID in the whole CityU HK Library. As tags of 240 bits or even larger EPC memory sizes are now available in the market, the Project Team can re-consider adopting a more flexible data model that can cater for more scenarios and possibly fits all UHF RFID libraries. Nonetheless, so far there is still no regional or international data model standard for UHF RFID. Therefore, modeled on ISO28560, the recently announced international data model for HF RFID, and with reference to the recommendations from the National Library of China on the adoption of ISO28560 by Chinese libraries, the Project Team has attempted to devise a data model standard specific to UHF RFID. Based on the ISO28560 data element table, the Project Team proposes that the starting block of the UHF RFID data model be as follows:

Offset	Length	Field
0	2 byte	Overhead
2	4 byte	Primary ID
6	3 byte	Owner Library
9	X bytes	Reserved (Title)
.....	.....	Reserved (set information)
.....	.....	Reserved (Type of usage)
.....	.....	Reserved (call no.)
.....	.....	Reserved (barcode)
28	2 bytes	CRC16

Table 3. Starting block of the proposed UHF RFID data model based on ISO28560

The lessons learnt from the stories of barcodes and tattle tapes as well as the evolution history of the data model standards for HF RFID have enlightened the CityU HK Library Management on the importance of standardization and interoperability. The data model so proposed by the Project Team should also be a regional consensus if not international. Thus, discussion and exchange of ideas with different stakeholders are the essential next steps.

In March 2010, the CityU HK Library, together with the Shanghai Jiao Tong University and the Tsinghua University, formed the *Higher Education Libraries "UHF RFID Application" Working Group (hereafter, the Working Group)*. In a meeting held in August 2010 organized by the Working Group, representatives from different libraries in Mainland and Hong Kong

gathered together in Shenzhen, PRC, to discuss UHF RFID data model standardization. Then in March 2011, a conference called *The Development and Best Practices of UHF RFID Technology Applications*<sup>4</sup> co-organized by the Working Group and GS1 Hong Kong<sup>5</sup> involved not just participants from the library arena, but UHF RFID practitioners and organizations with expertise in standards to discuss and share ideas on standardization and best practices. The conference has created the nurturing ground for a regional UHF RFID data model standard to gradually emerge for libraries in Mainland China and Hong Kong. It has also provided a platform for libraries to collectively convey their needs and requirements to the UHF RFID practitioners.

The Project Team has a high hope that not long there will be a consensus on the UHF RFID data model, at least among the JULAC (*Joint University Libraries Advisory Committee*)<sup>6</sup> university libraries in Hong Kong. In fact, collaboration among the JULAC libraries in Hong Kong has already had a long history and for the adoption of UHF RFID, a few meetings have been held among the JULAC library directors in late-2010 to discuss the possibility of seeking external funding for collaborative implementation. This has naturally paved the way for adopting a common data model standard among the JULAC libraries.

#### 4.3 Tag memories

As mentioned earlier, the UHF RFID data model so proposed by the Project Team was modeled on ISO28560 for which the 96-bit EPC memory size of the first generation UHF RFID tags is not sufficient. However, the development of UHF RFID Gen2 tags has been fast paced. Tags of 240 bits EPC memory are now available and some brand names even claim to have 496 bits. Moreover, apart from EPC memory, some suppliers can also provide an extendable memory that reaches 512 bits in their tags. Therefore, storage capacity is no longer an issue. What important rather is the choice of data elements.

Among the dozens of data elements outlined in ISO28560-1, libraries are to choose their own sets of data. The Project Team recommends that “primary item identifier” (*the unique identification of an item inside the Library and this usually is the accession number*) and “owner library (ISIL)” be the mandatory elements. Based on the description in ISO28560-2, libraries

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<sup>4</sup> The conference called The Development and Best Practices of UHF RFID Technology Applications co-organized by the Higher Education Libraries “UHF RFID Applications” Working Group was held in Shenzhen, PRC, on 18 March 2011. The conference has attracted a total of 134 participants from Mainland China and Hong Kong. Participants include 88 librarians from 29 academic libraries, 29 UHF RFID practitioners and users from 17 companies, and 7 representatives from the National Library of China, the Hong Kong Public Library and GS1 Hong Kong. Details about the conference are available at: [http://www.cityu.edu.hk/lib/about/event/rfid\\_conf2011/index\\_e.html](http://www.cityu.edu.hk/lib/about/event/rfid_conf2011/index_e.html)

<sup>5</sup> Background about GS1 Hong Kong is available at:

<http://www.gs1hk.org/en/hkana/gs1/aboutgs1/profile.html>

<sup>6</sup> Details about JULAC is available at <http://www.julac.org/>. JULAC members include libraries of the following universities:

- The Chinese University of Hong Kong
- City University of Hong Kong
- Hong Kong Baptist University
- The Hong Kong Institute of Education
- The Hong Kong Polytechnic University
- Hong Kong University of Science and Technology
- Lingnan University
- The University of Hong Kong

have the flexibility to choose any other data elements that suit their local operations and circumstances. However, libraries should be cautious that the amount of data elements that they choose to include into the tags will affect the memory size and thus, the storage capacity of the tags they will need. The natural logic is that the more data a library would like to store in the tags, the larger the tag memory it will require. Moreover, between EPC memory and user memory, libraries will also need to decide what data elements are to be housed in the EPC memory and what data are to be housed in the user memory. In this regard, the reading speeds of different memory banks in the tags should also be taken into consideration.

#### 4.3.1 Tests on reading speed

In terms of storage capacity, the different brand names of tags (see Table 2) that the CityU HK Library has tested so far are mainly of two types. The first type comes purely with EPC memory only and the second type comes with both the EPC memory bank and the user memory bank in a single tag.

The intention of the tests performed by the Project Team was to find out how different the reading speed can be for tags with different memory sizes. Test 1 compared the reading speed for tags with different EPC memory sizes (*96 bits versus 240 bits*) from a selected brand name (Brand I). Comparing tags from the same brand name ensured that all other possible deviations due to the difference in suppliers could be minimized. Test 2 compared the reading speed of tags with different memory combinations (*EPC memory versus EPC memory plus user memory*), again from the same brand name only, though this brand name (Brand II) is different from the brand name used in Test 1.

For Test 1 and Test 2, both the 1-tag scenario and the multi-tag scenario (*10 tags have been involved*) have been examined. For both scenarios, the one tag or the ten tags concerned were read 100 times and the reading speed of each time was recorded. Table 4 and Table 5 show the results.

For Test 1 (see Table 4), when there was only one tag involved, the average time required for the reader to successfully read the data in the 96-bit EPC memory tags and the 240-bit EPC memory tags were 0.123 second and 0.126 second respectively. The difference has been insignificant. When ten tags were being read together, the average time required then became 0.193 second and 0.227 second for the two types of tags, meaning that when more tags were involved, the reading speed for the 240-bit EPC memory tag dropped, in this case, by 0.034 second. However, this 0.034 second was indeed minimal and even not noticeable by human beings during the transactions.

Reading Times	1-Tag scenario		10-Tag scenario	
	96 bits	240 bits	96 bits	240 bits
1	0.121	0.120	0.193	0.221
...	0.123	0.130	0.188	0.226
100	0.128	0.126	0.201	0.231
<b>Average (Seconds)</b>	<b>0.123</b>	<b>0.126</b>	<b>0.193</b>	<b>0.227</b>

Table 4. Reading speed for tags with different EPC memory sizes (96 bits versus 240 bits) from a selected brand name.\*

\*Comparing tags of the same brand name ensures that all other possible deviations due to the difference in suppliers could be minimized.)

For Test 2 (see Table 5), under the 1-tag scenario, the average time required for the reader to successfully read the data from the tags that provide EPC memory (96 bits) only was 0.103 second while that for the 10-tag scenario was 0.199 second. The difference is still less than one second. However, for the tags with both EPC memory (96 bits) and user memory (224 bits), the average reading speed for one tag was 0.492 second while that for reading ten tags together was 5.227 second which was more than ten times that of the 1-tag scenario. This in fact is an expected result by the Project Team as the reader used for the test provides only simple commands that support programming and reading of either the EPC memory alone or both the EPC memory and user memory together because the user memory cannot be separately read without mapping to the EPC memory to ensure correct association to the corresponding tags. Therefore, whenever the user memory is to be read, the reader must first read the EPC memory and thus requires longer reading time, though it is still a matter of a few seconds. The Project Team has tried out two other readers of the popular brand names and the same reading behavior was observed.

Reading Times	1-Tag scenario		10-Tag scenario	
	EPC 96 bits	EPC 96 bits + User memory 224 bits	EPC 96 bits	EPC 96 bits + User memory 224 bits
1	0.108s	0.519s	0.331s	5.279s
...	0.106s	0.500s	0.202s	5.039s
100	0.100s	0.480s	0.180s	5.389s
<b>Average (Seconds)</b>	<b>0.103s</b>	<b>0.492s</b>	<b>0.199s</b>	<b>5.227s</b>

Table 5. Reading speed for tags with different memory combinations (EPC memory alone versus EPC memory plus user memory)\*#

\* Comparing tags of the same brand name ensures that all other possible deviations due to the difference in suppliers could be minimized

# The reader used during the test only provide simple commands to support programming and reading of either the EPC memory alone or both the EPC memory and the user memory together because the user memory cannot be separately read without mapping to the EPC memory to ensure correct association to the corresponding tags. With readers that support programming and reading of the EPC memory and the user memory separately, hopefully the reading speed for the user memory can be improved.

The tests involved tags from two different brand names only (*Tags from Brand I for Test 1 and tags from Brand II for Test 2*) and thus the sampling size may not be big enough for any authoritative conclusion. Moreover, when more and newer readers are involved as the technology evolves, the read rates can be different too. The tests therefore simply serve as preliminary references for libraries to select memory sizes for their tags and to decide on which memory is to be used for different data elements.

For the case of CityU HK Library and for the adoption of the UHF RFID data model standard recommended earlier (modeled on ISO28560), the Project Team will put data elements that are more transaction critical into the EPC memory. With the primary item identifier (*mandatory and for the CityU HK Library, it is the accession number*), all other bibliographic information of the library item concerned will be readily retrievable from the Integrated Library System (ILS). Thus the primary item identifier must be read instantly in

the first place for any check-in or check-out transaction to take place. It is therefore transaction critical and should be written in the EPC memory for speedy identification. As for owner library (ISIL), the Project Team strongly feels the need to have it mandatory too in view of the interlibrary loan and HKALL<sup>7</sup> transaction activities among the JULAC libraries. This data element enables libraries to quickly identify the ownership of the items concerned during the resource sharing processes and is therefore recommended to be written in the EPC memory too.

#### 4.4 Form factor, orientation and position of tags

RFID tags consist of three components, namely, the integrated circuit (IC), antenna and substrate. The IC is connected to the antenna that is deposited or printed on the substrate. Even with an identical IC, tags with different antenna geometry will display completely different properties and behaviors. Tag antenna designs determine the frequency at which the tags concerned operate. They affect tag performance in terms of read range and orientation sensitivity. Also, as antenna is the largest component of a tag, its geometry impacts the form factor of the tags in terms of size and shape. However, just as much as how the antenna geometry requirements affect the form factor of the tags, form factor requirements appropriate to different applications also impact on antenna designs (Imprinj, 2005). For different purposes, the selected tags should exhibit a size and shape appropriate to the items to be tagged. Therefore, tags come in different sizes, shapes and forms. Generally speaking, larger tags with larger antennas support operations that require a long read range and are less orientation sensitive. On the contrary, for situations where only smaller tags can be used, the antenna geometry that conforms to the smaller form factor of the tags must also be compact and small, thus sacrificing the read range and orientation insensitivity. Of course, the extent of the shortfall in the tag performance also depends very much on the abilities and skills of the tag antenna designers.

For libraries, the size of the tags to choose depends very much on the types of materials to be tagged, how the tags are to be mounted on the library materials and the read range required in the real operational environment. This will have something to do with the relative distance between the tags to be read and the reader antennas that reside in the self-check machines and the detection gates. While choosing tags of a larger form factor seems to be advisable given its longer read range and less orientation insensitivity, libraries still need to practically consider if the tags would be too sensitive that a very large buffer area will be required to keep users with non-checked-out books in hands distant from the gates in order not to cause any false alarms. Of course, the power of the readers at the detection gates can be tuned down, but this will sacrifice security.

Moreover, libraries must also note that the tag masking phenomenon may occur when tags overlay each other in a stack of thin books. When tags mask each other, either one or both of the tags may become unreadable (Butters, 2008). Large tags may stand a higher chance of overlaying with each other when tagged at book covers (either front or back). Moreover, large tags may be too visible and easily subject to mutilation when noticed by naughty users.

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<sup>7</sup> Based on a common on-line catalogue running on a server hosted in one of the JULAC libraries, HKALL seamlessly connects the library automation systems of all university libraries in Hong Kong and allows staff and students to request and borrow materials of the other local university libraries directly.

For the case of the CityU HK Library, the UHF RFID tags that the Project Team has used in its pilot test were of an optimal size with a dimension of 72mm x 30mm. The Semi-Closed Collection where the pilot test was conducted is a very small room of about 75sq.m. only. The self-check machines, the self-return machines and the security detection gates are all in proximity. For instance, the security detection gates are only 4.5 meters away from the nearest bookshelves. Therefore, the Project Team must be even more cautious when choosing the tags. Different tests have been performed to ensure that the size of the buffer zone required around the detection gates is kept to a minimum and at the same time the self-check machines can read the most number of tags when books are placed on top of them so as to maximize the benefit of multiple item identification at the check-out process. In the Semi-Closed Collection, the UHF RFID tags have been placed at the back covers of books with a book plate of 150mm x 100mm on top to act as a camouflage to hide the tags from the scene (Photos 1 and 2). To reduce the tag masking probability, during the tagging process, tags have been randomly placed in four different positions behind the book plates. However, the additional book plates mean additional costs and labour.



Photo 1. In the pilot test conducted by the CityU HK Library, UHF RFID tags were randomly placed in four different positions at the back covers of the books. The photo shows one of the selected positions.

In fact, some suppliers do provide long and narrow UHF RFID tags that resemble the shape of the traditional tattle tapes. These elongated tags can be put along the book spines, thus reducing the tag masking probability and also making the tags less visible to the users. These certainly are advantages. However, users usually hold the books on the spines and libraries must therefore be cautious enough to test beforehand to ensure that shielding of the spines by human hands will not affect the readability of the tags, especially in the case of the detection gates.

The Project Team chose to place the tags at the back cover of the books because, to maximize the read range, the tag orientation needs to match that of the reader antennas in the self-check machines. In the Semi-Closed Collection, the reader antennas lay flat horizontally

inside the machines and they are circularly polarized ones that are supposed to be less orientation sensitive. However, tests conducted by the Project Team reveal that, even with circularly polarized reader antennas, when tags are placed on the book spines and exhibit a perpendicular orientation to the reader antennas, the read rate is far from satisfactory. When books with tags on the book covers are laid flat on the self-check machines and thus sharing the same orientation as the reader antennas, the read rate is much better and the read distance is long. The long read distance enables users to check out more books in any one go<sup>8</sup> and thus capturing the benefits of UHF RFID. *(Long read range, however, may generate a concern on misread if the detection area goes beyond the expected one. While the power of the reader antennas can be tuned to adjust the read distance when needed, the Project Team has also put in place a shielding mechanism in the self-check machines to guide the radio waves to go upright instead of sideways so as to safeguard against misread.)*



Photo 2. The tags were then covered by a book plate.

Nonetheless, on the book shelves, when books are read by hand-held readers, the test results present a different story (Photo 3). Books with tags on the spines are more readily identifiable by the handheld readers when compared to books with tags on the covers. This is because when books are vertically placed on the shelves, tags on the spines share the same orientation as the reader antennas in the handheld scanners while tags on the covers exhibit a perpendicular orientation. Handheld scanners are tools for stock taking and locating missing items on shelves. Some UHF RFID practitioners are developing smart shelves to provide similar functions in an automatic way. The performance of the smart shelves may possibly be related to the relative position and orientation between the reader antennas on

<sup>8</sup> In the Semi-Closed Collection, however, users are allowed to borrow up to 5 volumes of books at any one time. This is because materials inside the Collection are course-related and thus of very high demand. The restrictive loan rule ensures that every student gets a fair chance of using the books. However, the longer read range provides the CityU HK Library the flexibility to allow users to borrow more in one go when the general circulation collection is involved in the long term library-wide implementation of UHF RFID in the whole library.

the shelves and the tags on the books too. Smart trolleys and automatic book dispensers are examples of other foreseeable applications that many people have been talking about. Libraries forward-looking enough that will consider adopting these innovative applications in the future may also need to take into consideration the possible requirements of these end-use applications when selecting their tags at the present moment.



Photo 3. When books are vertically placed on the shelves, tags on the spines share the same orientation as the reader antennas in the handheld scanners while tags on the covers exhibit a perpendicular orientation.

#### 4.5 Interferences

It is a fact of physics that metal reflects radio waves and water absorbs them. This makes tracking metal products and those with water content difficult in the logistics field. In the library environment, with the exception to the media collection which usually constitutes only a small part of the entire collection, the main subjects to be handled are mainly books. Therefore, to many people, interferences caused by metal and water seem not to be the problems for libraries. However, this is not the case.

To add elegance and a sense of luxury to the books, many publishers put metallic gold or silver printing on the book covers. To add varieties to the contents, some books contain CDs as the accompanying materials. All these are metallic elements that will cause interferences to the readability of the tags. For cases as such, libraries will need workarounds such as placing the tags sideways at positions that do not overlap with the metallic prints or, in the extreme case, sending the books to the binders to have the metallic covers replaced. For the CDs accompanying materials, they can be detached from the books concerned for separate handling.

As for water, it is rare that books or library materials will contain water, but humans do. As mentioned earlier, for books with spine tags that are not long enough, there are chances that human hands may shield the tags making them less sensitive to radio waves.

However, while metal and water have a detrimental effect on radio waves, the two factors are not necessarily negative with regard to the application of UHF RFID in libraries. In the



library setup, given the long read range of UHF RFID, it is important that radio waves are confined only to the designated area and distance appropriate for the purposes intended. For example, as discussed earlier, for the self-check machines in the pilot test of the CityU HK Library, the radio waves are expected to go only upright in a distance long enough to allow the most number of tags/ books to be identified in any one go. To ensure that the waves go far but not wide, the Project Team has made use of metal to provide shielding around the reader antenna (Photo 4).



Photo 4. In the pilot test conducted in the CityU HK Library, the UHF RFID reader antenna is laid flat horizontally inside the self-check machines. The radio waves must go far upright to ensure the reading of the maximum number of books. However, the waves are not supposed to go wide to scan the books sideways as well. Any cases like that are misreads and must be rectified. The Project Team thus has made use of metal to provide shielding around the reader antenna and the result is good.

#### 4.6 Tag production life cycle and compatibility

Usually, the biggest investment on tags takes place during the first-time conversion of the entire collection; the subsequent annual requirements will depend on the expected growth in the collection every year. To buy additional tags for the growing collection, it is natural that libraries will tend to buy the same tags as what they have used during the first-time implementation (*unless the tags have proved to be a wrong choice*). The following is the experience of the CityU Library during its pilot test.

In the Semi-Closed Collection where the CityU Library carried out its pilot test on UHF RFID at the operational environment involving real users, all the 7,000 volumes of books were tagged with UHF RFID tags of Model A from Producer X acquired through vendor Y. (*To protect the interest of the parties concerned, the authors prefer calling them with English alphabets.*) The model was the final choice after a series of tests and careful consideration and has proved to be a correct choice. In the first purchase, the Project Team acquired 10,000 tags

so that a stock of some 3,000 tags could be reserved for future use at least for the first two subsequent years before any further requisition was required. Materials in the Semi-Closed Collection are course-reserved materials. The Collection is subject to reviews and changes every semester according to changes in the curricula and the teachers' requirements. Books considered no longer relevant will be removed and returned to the general circulation collection while new items will be added in. Therefore new UHF RFID tags must be ready for new members in the Collection every semester. Everything has been so far so good until early-2010 when there were just several hundred tags left and the Project Team found it necessary to order more before the stock ran out.

The natural response was then approaching Vendor Y to buy more UHF RFID tags of Model A from Producer X again. However, the Project Team was told by Vendor Y that Producer X has ceased the production for tags of Model A. Only limited stocks were available and when they ran out, the Project Team must find substitutes. This has not been anticipated by the Project Team. Choosing tags of another model will mean creating a "mixed-tags environment" in the Semi-Closed Collection and also a series of tests to ensure that the reader antennas in the self-check machines, the self-return machines and the detection gates are compatible to the newly selected tags and at the same time do not upset the performance of the old tags. Consequently, UHF RFID tags of Model B from the same producer were selected as the substitutes. However, to start with, occasional misreads (though not too many) at the self-check machines and the detection gates were reported. That was rare when there were just tags of Model A in the Collection. The "Mixed-tags environment" did cause some concerns. Given that the relative distances between the different components in the RFID processes have been fixed in the Collection, what the Project Team could do was to adjust the power of the reader antennas. Through trial and error, the reader antennas were finally tuned to become just optimal for both the old and new tags.

The lesson learnt from the experience is that tags do have their production life cycle. While the tag specifications from the vendors claim that their tags can be used up to 10 years or more or the read/ write times being 100000 times, they are talking about the life spans of the tag ICs and tag antennas. No matter how long lasting the tag ICs and antennas can be, the fact is that the tag model itself may not have a very long production life span depending on the producer's different manufacturing considerations. Libraries should not expect that they can stick to the tags of the same model forever for the collections despite the "claimed" life span of the tags. Libraries must be prepared to face a "mixed-tags environment" in the long run and be cautious to ask for compatibility guarantee from the tag providers as well as the RFID system providers. In fact, the same will apply to the reader antennas too. Because of wear and tear and system upgrade, machines will be upgraded or changed. Backward compatibility is therefore a must.

## 5. Conclusion

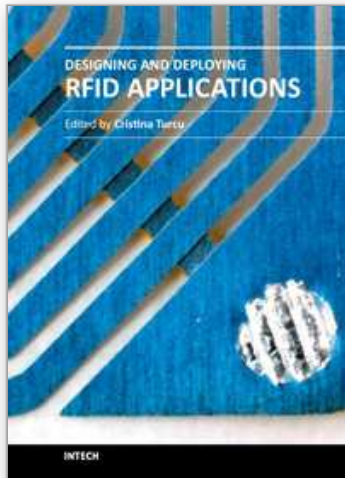
The compatibility issue discussed above has highlighted the fact that libraries are now playing a rather passive role in terms of UHF RFID product development. Apart from compromising on the data model to be used (*if libraries are collaborative enough*), libraries do not have much influence on what the UHF RFID practitioners are offering as the demand generated from each individual library is indeed too small when compared to the transaction volumes in the logistics industry. In fact, while the operational environment that each library is facing can be quite unique, the nature of the transactions to be

enhanced by UHF RFID is by and large similar. This provides a very good necessary condition for common specifications and requirements to be identified and thus aggregating the demand to make it large enough for libraries to influence the decisions of the suppliers as a consortial entity.

Moreover, it is important that experiences and test results are shared so that libraries learnt from each other to reduce the sunk costs and reserve more investigation time for newer findings. Libraries should play a more proactive role to work with the UHF RFID practitioners so that the latter know well what libraries are expecting and find it less risky to develop more innovative UHF RFID solutions for the library arena. When UHF RFID starts to transform library services, libraries together should act early enough to ensure that they can get the best out of it.

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## **Designing and Deploying RFID Applications**

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Radio Frequency Identification (RFID), a method of remotely storing and receiving data using devices called RFID tags, brings many real business benefits to today world's organizations. Over the years, RFID research has resulted in many concrete achievements and also contributed to the creation of communities that bring scientists and engineers together with users. This book includes valuable research studies of the experienced scientists in the field of RFID, including most recent developments. The book offers new insights, solutions and ideas for the design of efficient RFID architectures and applications. While not pretending to be comprehensive, its wide coverage may be appropriate not only for RFID novices, but also for engineers, researchers, industry personnel, and all possible candidates to produce new and valuable results in RFID domain.

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