Chapter

RFID in Libraries: Automatic Identification and Data Collection Technology for Library Documents

Timoshenko Igor

Abstract

The chapter describes the main features of the use of the radio-frequency identification (RFID) technology in library activities. The technical capabilities of RFID equipment for unique identification of library documents in information systems for various purposes are shown. The questions of development of library technologies due to the full-featured use capabilities of automatic and radio-frequency identification systems in libraries are presented. The possibility of development of library RFID systems in the direction of the concept of Electronic Product Code (EPC) through the modification of the regulatory framework on the basis of existing harmonized standards is considered. It is shown that this approach to the formation of the regulatory framework will create conditions for increasing the availability of RFID technology for libraries. Development of library RFID systems in the direction of the Internet of things (IoT) concept will significantly increase the integration of the traditional library collections, along with electronic documents, in the modern information space. This will increase the availability of printed documents to readers and contribute to development of library technologies towards development of a global integrated system of library and information support for human activities. This will allow libraries themselves to integrate more fully into the global information space, at the next stage of development of information technologies.

Keywords: RFID, radio-frequency identification, ILS, integrated library system, library automation, EPC, electronic product code, internet of things, IoT

1. Introduction

The issues of integration of automated information systems into the surrounding world as well as its effective use for information support have become important. Automatic identification and data capture technologies play a paramount importance in this. These technologies include bar code, biometric, and radio-frequency identification. Bar-code and radio-frequency identification (RFID) is widely used in library information systems of ABIS. Of these, radio-frequency identification has a significant functional advantage over bar code identification. It is radio-frequency identification that has the potential to contribute to development of library technologies. RFID technology is now firmly established in the life of modern libraries.

For library RFID systems, the main accounting object is the document of the library collections, which has a material carrier of information. These documents primarily include printed publications, which now form the basis of the book stock collections in most libraries. The electronic publications increased the availability of information for users and, at the same time, was a serious challenge for the traditional document collections and traditional library technologies. Radio-frequency identification technology allows increased mobility of traditional documents in the electronic information space.

Full-featured use of RFID system capabilities enables development of library technologies through the use of existing experience and the latest achievements in the field of automatic identification and object management.

In these circumstances, the actual task is to understand the experience, fixing it as generally accepted rules and standards, the implementation of which can ensure further development of both RFID technology and library work technology.

2. History of RFID systems in libraries

The first attempts to introduce radio-frequency identification technology in libraries began in the mid of 1990s. A pioneer in this field was "3 M" company (USA), which since the end of 1960s started to produce and install radio-frequency EAS systems in libraries and since the beginning of 1990s started production of radio-frequency identification devices for libraries. 3 M company announced the first project of school library automation, based on RFID, in 1994, and in the 2000s, several thousand libraries in Europe and the United States had already implemented RFID technology. A lot of practical experience has already been accumulated by this time [1].

Most of the projects used RFID equipment of companies such as 3 M, TAGSYS, and FEIG Electronics of 13.56 MHz band. Commercial attractiveness of implemented projects brought to this market a large number of new participants, among which, along with specialized companies, there were many commercial IT companies of a wide profile working with RFID systems in the field of warehouse logistics. This fact can explain the emergence of RFID library projects based on UHF equipment (860–960 MHz), which is an alternative to the equipment of "traditional" library HF band (13.56 MHz).

In Russian libraries, the technology of radio-frequency identification appeared somewhat later [2]. First, the RFID library project was implemented by "ANTIVOR" company on the basis of Russian ILS "IRBIS64" in the library of the graduate management school of St. Petersburg state University, in 2007 [3].

The first full-featured project implemented in a large Russian library on the basis of Russian RFID-equipment was a research project implemented in 2008–2009 by non-commercial partnership "International Center of Technology Transfer " (NP "ICTT"), in cooperation with the "GPNTB of Russia" library [4]. The project used the equipment of HF band, appropriate for library conditions and is claimed in foreign libraries.

3. Regulatory framework of RFID library systems

Widespread use of RFID systems in libraries required systematization of the acquired experience. The first library standard for application of RFID technology appeared in Denmark in 2005 [5]. This standard has been directly supported

by many countries of the world, and in 2011 Technical Committee ISO/TC 46/SC 4 has established a system of international standards ISO 28560, representing a group of three standards, under the general title "Information and Documentation. RFID in Libraries." Adopted standards defined the main technical parameters of library RFID systems, as well as the structure and protocols of data exchange with library automation systems. Later, in 2014, the system of standards was revised and a fourth part was added to it. The new standard part was defining the use of UHF band RFID equipment (850–960 MHz) in libraries.

Currently, the international standard ISO 28560 set consists of four parts. To date, all four parts of the standards system have been introduced into the Russian standardization system as identical to international standards.

ISO 29560-1 [6] standard defined data elements used in the cataloging of documents in library collection, which can be placed in the memory of RFID tags and is used for automation of technology operations in libraries. The entire set of 26 items is given, of which only two items are required—the "Primary Item Identifier" and the "Owner Institution (ISIL)". The ISIL code is defined in the ISO 15511 [7] standard. Both identifiers represent in the aggregate the "International Library Item Identifier" (ILIL), defined in ISO 20247 [8]. Libraries are invited to decide of specified elements what should be used, based on the needs and capabilities of their automation system. Data elements are presented without specifying the location in the label memory. In general cases, labels may have different organization for different types. There are also no defined encoding conditions in which data can be represented. These conditions are defined in the following parts of the standard.

ISO 29560-2 [9] standard defines the way of placing of data elements, defined in the first part, in the tag memory, based on standard rules of coding of the object identifier structure defined in ISO/IEC 15962. Standard data element placement rules allow for flexible encoding of variable-length data and different formats. Their application allows the use of RFID tag resources with the greatest efficiency. The data encoding rules in this standard can be applied for any type of labels.

ISO 29560-3 [10] standard is based on the principles set out in the Danish national standard and on the experience of its use in other countries. Data structures presented in the standard are focused primarily for HF (13.56 MHz) band type labels conforming to ISO/IEC 18000-3 [11] Mode 1 standard. Such type of tags includes NXP company labels of ICode SliX specifications. User memory of these labels has a capacity of 112 bits and is divided into 28 blocks of 32 bits available for reading and writing by special commands of RFID reader. Other types of radio-frequency labels are considered in terms of their compatibility with the base type.

Data element allocation principles, defined in ISO 29560-3 standard, are based on a fixed data structure consisting of several blocks. In total, four types of data blocks are defined, of which only the "Basic block" is obligatory for programming, which is a rigid structure, consisting of fixed length fields.

The "Basic block" contains data elements, defined in the first part of the standard as mandatory:

- Primary item identifier
- Owner institution (ISIL)

as well as data elements defined in the first part of the standard as optional:

- Type of usage
- Set information

which have acquired the status of mandatory under this standard.

Additional "Structured Extension Blocks" are used to store data elements from full set that are not included in the "Basic block". The standard defines 5 types of structured blocks of which the formats are determined by their different purposes in the technological system of the library.

Data allocation principles, defined in the third part of the standard, are not compatible with the rules set out in the second part and they are more stringent. Data compression algorithms are not used in coding; different data elements can be represented in different codes. In general, it can be said that data coding based on the rules of the third part of the standard is less rational than the rules presented in the second part. Adoption of this standard is due to the fact that coding based on the rules of the Danish model became a de facto international standard for libraries long before, and such an international standard was adopted by ISO TC46/SC4 Technical Committee. A large number of libraries in many countries around the world use RFID equipment of HF range, and a huge number of documents were marked with labels encoded according to the rules of the Danish data model. Change to other label types and encoding methods is currently a challenging practice task. This situation is supported by main manufacturers of specialized library equipment. Using UHF RFID equipment in libraries is not popular now, despite the significant advantage of UHF technology in "non-library" areas related to logistics.

The fourth part of the standard (ISO 29560-4 [12]) appeared later than previous three parts and was adopted in 2014 only. The standard defines the rules for placement of data elements presented in the first part of the standard, consistent with coding rules defined in the second part. This part of the standard has been added to allow selection of different frequency bands of RFID equipment, between HF (13.56 MHz) defined in part three of the standard and UHF (850–960 MHz), conforming to ISO/IEC 18000-63 [13], for libraries. Data structures presented in the standard are focused on RFID tags having a block memory organization defined in the EPC global Inc. standard as "Class 1 Generation 2" (EPC C1g2). [14].

The logical memory structure of the radio-frequency labels defined in the fourth part of the standard consists of four blocks, of which only two are available for reading and writing library data elements: "01" (EPC memory) and "11" (User Memory).

For EPC memory block the standard defines the possibility of recording a Unique Item Identifier (UII), composed of the "Primary Item Identifier", the "Application Family Identifier" (AFI), and, all or selectively, two data elements: the "Owner Institution (ISIL)" and the "Set Information".

These data elements in various combinations occupy the entire memory block, and the format of their record does not correspond to the format of the standard EPC code. The presence in memory of a "Unique Item Identifier", in non-EPC format, is determined by the value of a fixed bit in the memory block (bit 17hex = 1), located directly in front of the AFI byte area.

For user memory block, the standard defines the ability to write a set of optional data elements, which is a subset of the set defined in the first part of the standard. The choice of data elements to be written to memory can be arbitrary from a given set and is determined by technological needs of the library.

In general, we can say that the fourth part of the standard defines coding rules applicable to labels with a memory structure corresponding to the EPC "C1g2"

specification. In this case, the structure of the "Unique Item Identifier" placed in the EPC memory area is not compatible with EPC code format. This makes library RFID systems based on the fourth part of the standard alternative to EPC systems.

Emergence of ISO 28560 systems of international standards was an important step towards the development of RFID library systems. At the same time, while analyzing the content of the standard, it should be noted that its existing parts are not fully consistent with each other, which is a consequence of the historical situation of the use of RFID technology in libraries. Coding principles defined in the second part are not compatible with coding principles presented in the third part. The third and fourth parts of the standard describe incompatible systems. This inconsistency creates difficulties in the further development of RFID technology in libraries.

4. Principles of identification for library items in the library RFID systems

RFID systems use a unique numeric code stored in the memory of radio-frequency tags as an identifier. The degree of uniqueness of the code is determined by the functional needs of the automated systems in which it is used. The main requirement for the identification of code formation is its uniqueness within the boundaries of a specific system.

In the first projects of library RFID systems, a UID code of the radio-frequency label was often used as a unique identifier of accounting objects. The use of this type of identifiers in the library automation system can only ensure their uniqueness. The UID value is set during chip manufacturing; it is constant, and its structure is determined by needs of radio-frequency label manufacturers. In addition, RFID systems based on UID have significant limitations associated with existing library technology: the impossibility of identification of group accounting items in the case of application of non-inventory registration technology for documents and in the case of accounting of document sets of the book stock collections.

The use of radio-frequency labels in the RFID library system, compatible with ISO 28560 standards, involves the use of a rewritable memory area of the label to accommodate structured data, which includes data elements defined in the ISO 28560-1 standard. One of the mandatory data elements is the "Primary Item Identifier" unique for each document instance in the collection of one library. An arbitrary value, that meets the requirements of the ILS, can be assigned for this element. In this case, it is possible to identify the RFID system of group accounting items, such as the publication, as well as sets of documents. The mandatory data block is supplemented by the "Set Information" element for support of accounting of document set. The block is present by the structure of "total set/part number" elements. In addition, if document identifier is located in the rewritable memory, it becomes possible to structure it in order to support functionality of the general system by means of the RFID system.

The ISO 28560 standard defines the length of the primary item identifier as 16 bytes. If you use one byte to display a single character, you can number 10000000000 (10 quadrillion) instances of documents with direct decimal numbering. If you use alphabetic characters to form an identifier, this number of unique combinations will be much greater. Libraries with such collections of printed publications currently do not exist, and in the foreseeable future their appearance is not expected. This code space redundancy can be used to place additional information in the ID code. It can be used to extend functionality of the RFID library system. The primary item identifier must be a structure, each element of which provides a

unique identification of the section of the library collection on its hierarchical level. All elements together make up the code of the primary item identifier, which must be unique within the library collection.

Entering into the primary item identifier of additional data elements is suitable for RFID systems that support automation of technological processes related to inventory, with varying degrees of autonomy from library OPAC. These data encoding method give an additional value to the identifier, and it can complement the standard method for writing data elements to the radio-frequency label memory, as defined in ISO 28560-3, 4. Such encoding methods can get faster response of the RFID system by reducing and simplifying read operations for user memory. Also it can be useful, for example, in the case of use of RFID system equipment or ready-made third-party software modules that do not fully implement functions of data elements encoding, according to ISO 28560.

It is advisable to choose data items, which are used in automation of technological operations by means of the RFID system, for encoding the primary item identifier. In addition, selected data items must also remain unchanged, because the primary item identifier must remain the same throughout the life of the document in the library collection. The "Book number" and the "Set information" data items can be used for automated verification of the book stock collections.

The book number data item indicates document location in the library store. Inserting these data item into the code structure of the primary item identifier may be efficient, if it is unchanging for document and based on unchanging classification characteristics. For example, in the case of semantic arrangement of the book stock collections, it can be compiled on the basis of library classification tables (indices UDCC, DCD, etc.) or on the basis of library collection identifier classification (ISCI defined in ISO 27730 standard [15]). In the case of formal arrangement, such features may be the book format (size and accession arrangement), document type, author number, year of publication, etc.

The book number is used in library processes, related to automated inventory, but it can also be used in other processes, for example, in document pre-ordering systems and to automatically determine possible delivery time of ordered documents from storage location to issuing location.

Entering book index into the structure of the primary item identifier is available for the collection of a separate library, since different libraries may apply different systems of collection arrangement, and formats of book index can vary.

The primary item identifier provides unique codes only within the local integrated library system. To ensure the uniqueness of several libraries, the standard defines an additional data item—"Owner Institution (ISIL)". The ISIL code is the International Standard Identifier for Libraries and related organizations. Its format is defined in ISO 15511 standard as a data structure that consists of ISO 3166-1 country code (alpha-2 type) [16] and organization identifier as an alphanumeric element that identifies library in the national identification system.

The procedure for using the ISIL code to identify library documents is defined in the international standard ISO 20247. This standard defines the International Library Item Identifier (ILII) as a structure, consisting of two elements:

- ISIL or ISCI identifier
- Local item identifier

The ISCI specified as a possible element of the ILII structure is a standard collection identifier and it is defined in ISO 27730 standard. Structurally, the ISCI represents ISIL code with extension in the form of a supplementary collection identifier.

Collection is defined in the standard as a logical group of one or more resources. Collections can also be logically or physically grouped or separated, i.e. a collection can be part of one or more other collections and/or can consist of one or more sub-collections. Collection can be an archive reading room, a digital collection of electronic resources, or OPAC of the library. Collection may consist of documents, combined on a semantic basis and located in different physical sections of the book stock store (in accordance with the type of arrangement adopted in the library) or in different sections of the virtual repository for electronic document collections. The need to use the ISCI collection identifier in the RFID system is entirely determined by the configuration of the technological system of a particular library. If you want to store it in the label data structure, the part of code that extends the ISIL code can be written to the internal code field of the Alternative Owner Institution defined as a data element in the ISO 28560-1.

In general, data structure, presented in the international standard ISO 20247, defines the method of forming identifier of the library item, which provides its unique identification on the scale of several libraries and several countries.

5. Unique identification of library documents in radio-frequency identification systems for various purposes

Automated identification of library document participating in a particular technological operation involves reading data from the tag memory located in the RFID reader working area. At the same time, radio-frequency labels of the same type as the library ones, but not those, can fall into the reading zone. Besides, if library documents are borrowed (or documents are transferred to another library through the interlibrary lending system), they could fall into the reading area of non-library RFID systems for various purposes using the same type of radio frequency tags outside the library. Unauthorized radio-frequency tags in the working area of the RFID system may reduce performance or interfere with the normal operation of the system, for example, to cause malfunction of the accounting system of material objects or to cause false triggering of the system that performs anti-theft functions.

To implement the mechanism of radio-frequency tag selection of the same type in the working area of RFID reader to minimize time of data transmission and exclusion from data exchange of tags that are not included in the system, the Application Family Identifier (AFI) is used.

The AFI is specified by a one-byte code, which is often found in the system memory of the RFID tag. The values of the AFI for various RFID applications are defined by ISO/IEC 15961-2 standard [17]. The hexadecimal "C2h" value is defined for use in libraries. The specified value must be assigned to radio-frequency label of library document located in the area of RFID reading systems for various applications outside library. In this case, they will be ignored or, if necessary, identified as library documents. The "C2h" value can be assigned to the label as a permanent one, at the stage of marking library document, or assigned at the registration of issuing document to reader or in the Interlibrary loan (ILL) system. In this case, when registering return of document, the AFI can be assigned as the "07h" value ("in storage" as defined in ISO/IEC 15961-3 [18]), and it can be used in the RFID library system to implement electronic article surveillance (EAS) functions.

To implement the selection mechanism of the same type of library radio-frequency labels in the RFID reader working area with different data encoding, the Data Storage Format Identifier (DSFID) is used. The DSFID value must be assigned a label at the stage of marking the library document and remain unchanged for the

entire period of use of the data recorded in the memory of the label. DSFID values for use in library radio-frequency identification systems are defined in the ISO/IEC 15961-2 standard as follows:

- "06h" for tags encoded according to ISO 28560-2.
- "3Eh" for tags encoded according to ISO 28560-2.
- "1Eh" and "5Eh" values can be used for migration from radio-frequency tags that do not meet the requirements of ISO 28560 standards.

Document of library collection, labeled by RFID tags, may be subject of accounting in the technological system of not the library assignment, for example, in the accounting system in the warehouse of printing house or warehouses, and as a part of transport units in the logistics system for delivery of documents to warehouses of trading organizations or libraries. In addition, documents circulating in the ILL system can be identified in automated mail service systems. For enabling the use of labeled library documents in automated RFID systems, non-library application, data structures written to the label memory must be correctly interpreted by all systems. This possibility is achieved through harmonization of standards, governing the data exchange in systems of different applications.

In library RFID systems that are compatible with the set of standard ISO 28560, for compatibility of library systems with systems of global supply the "Identifier of a trade item GS1" data element can be used, which is optional and is placed in the additional block of the tag data structure, encoded according to ISO 28560-3 rules. Specified data element may contain the Global Trade Item Number (GTIN) [19], assigned by GS1 organization to identify products in the supply chain, which is part of the EPC code system. Unfortunately, encodings provided in ISO 28560 standards are not included in the EPC set of standards currently. Thus, radio-frequency labels of library documents cannot be identified in automated EPC systems operating within the existing standards.

6. Unique identification of library documents in the EPC identification system

Now the global technology of contactless identification on the basis of shaped coding and radio-frequency identification in the world applied for marking of goods and transport units exists and develops. The contactless identification is a basis of automation of account at promotion of production from producer to consumer in the systems of warehouse, transport logistics, and trade. Technology of contactless identification represents a set of compatible technologies developed under the general name of electronic product code (EPC).

The concept of EPC was proposed and developed in the early 2000s by the specialized scientific center for automatic identification "Auto-ID Center" created on the basis of the Massachusetts Institute of technology. Later it was published by the international organization "EPC global, Inc.". The very name "EPC" is a trademark of this organization. Currently, the concept of the EPC is developed by international organization GS1, which has its offices in a number of countries.

The EPC is a numeric identifier unique to each material object to be accounted. Currently, the most commonly used standard code types are of 64-bit and 96-bit lengths. There is also a 198-bit code standard, and a 256-bit code standard is being developed. The total length of code determines the possible length of data fields

and, as a consequence, the width of the code space and freedom of choice of data presentation formats.

All information about objects identified by EPC code is available to organizations within a single Global Data Synchronization Network (GDSN), which allows obtaining data about identified objects by their EPC codes. Currently, there is a migration of data from the GDSN network to the Trusted Source of Data (TSM) network, which is a project of the GS1 organization and is designed for two-way exchange of information for users. The GDSN network acts as a source of data for TSD network aggregators.

The EPC concept is supported by manufacturers of RFID equipment. Currently, market offers a wide range of equipment—radio-frequency tags and readers operating in the UHF range (850–960 MHz). Similar HF band equipment (13.56 MHz) is poorly represented, although it is supported by normative documents at the level of international standards [20]. The technical ability of using such equipment in RFID library systems is defined in ISO 28560-4. Use of the same type of equipment in the systems of warehouse, transport logistics, and library RFID systems, with the possibility of modification of identification codes within the existing standards, gives the principal opportunity to integrate RFID library systems with existing, as well as emerging in various fields, EPC identification systems, combined in the TSD network. This integration will allow multiple uses of a single radio-frequency label at all stages of the movement of printed documents, from their production in the printing house to the end user, not only through trade organizations, but also through libraries. The ability to exchange information about library documents in the TSD network with other participants in this process can significantly expand functionality of library automation systems based on radio-frequency identification. For example, such integration is allowed to improve and automate processes of increasing library stock collections, as well as the processes of document exchange in the ILL system, etc. To implement this possibility, it is necessary to harmonize the standards governing the formats of data presentation in library RFID systems with the set of EPC standards.

The format of the structure of data recorded when marking a library document in the memory of an EPC type label is defined in ISO 28560-4 standard. This format is based on the data of elements, defined in ISO 28560-1, and on the coding principles, defined in ISO 28560-2, with significant differences from the encodings, included in the EPC set of standards, and is not supported by EPC systems.

For RFID systems, compatible with EPC standards of the Serial Global Trade Item Number (SGTIN) system is applied [21]. The SGTIN code is a data structure that corresponds to the general structure of the EPC and consists of a standard heading and the following three elements:

- "Company prefix"—the company identifier of the vendor/owner in the GTIN format is assigned by the GS1 organization. Format is incompatible with the similar in purpose ISIL identifier used in the libraries.

- "Product code" - a generic product identifier in the GTIN format.

- "Serial number" - identifies a specific instance of the product.

First two code elements uniquely conform to standard GTIN code, used in bar coding, and replace elements of the codes EAN and UPC previously used in Europe and the United States. Code GTIN may have a standard length of 8, 12, or 13 characters. The international standard numbers for books (ISBN) and periodicals (ISSN) could be submitted in code GTIN-13 since 2007. For them, the dedicated codes in the table of regional GS1 codes are applied:

- 977—periodicals (ISSN)
- 978 and 979–books (ISBN)

According to ISO 28560-4 standard, when publication is marked with an EPC type radio-frequency tag in the early stages of the supply chain dedicated, the entire "01" tag memory block (EPC memory) must be overwritten by the library value unique identifier of the accounting item with AFI byte. Information about EPC code is lost, and thus, the label ceases to be recognized in EPC systems. The possibility of its return to such an automated system, for example, when delivered to recipient through a transport company or a postal service or when it enters the sales network, is associated with the need to restore the EPC code in its memory, which will lead to the loss of "library" information.

For implementation of this possibility for printed publications, it is possible to mark them, at the initial stage of the supply chain, when printing, by radio-frequency EPC tags with SGTIN code. In this case, the "company prefix" and "product code" values can contain a standard ISBN or ISSN code and are assigned to the label by publisher. The serial number value is also assigned by the publisher and can be a data structure defined locally in the printing house. Assigned values can be used for automation of technological processes, as well as for transportation and storage of publications. Serial number field can be reassigned when such documents arrive to the library. In this case, the serial number can also be structured in accordance with the technological requirements of library cataloging.

To illustrate the possibility of placing the library structure of data elements defined in ISO 28560-1 and ISO 28560-2 in the EPC SGTIN format, the following calculations can be made. The total length of the reassigned "serial number" field for different types of EPC labels can be from 36 to 180 bits. This field can contain data elements that make up unique identifier of accounting object (UII) according to ISO 28560-4, which includes the following elements:

- Primary item identifier—16 bytes
- Set information–2 bytes
- Owner institution (ISIL)—11 bytes

Of these elements, the ISIL code can be placed in a user memory block, so the total length of UII without AFI byte will be 18 characters. When encoding according to the rules of URN Code 40, the overall length code with AFI byte will be 12 bytes. Thus, the total length of the entry in serial number field, together with the added byte value of the AFI application family, will be 104 bits. The resulting field size does not exceed the maximum possible size of the "serial number" field of the SGTIN-198, which is 140 bits.

This example is an illustration only and shows the principal possibility of placing a unique identifier of a library document in the structure of EPC code, which allows us to talk about integration of the integrated library systems and systems based on EPC standards. This possibility can be realized when using radio-frequency EPC labels in the supply chains with an EPC memory block capacity sufficient to accommodate the SGTIN-198 code. It will also require modification of the regulatory framework for the use of radio-frequency identification in libraries in terms of ISO 28560-4 standard, which defines rules for the use of specialized EPC RFID equipment in libraries. The possibility of realization of such extension of regulatory base

of library RFID systems has ripened today and follows from the general logic of development of information systems and, in particular, library systems of radio-frequency identification.

7. The development of universal library HF/UHF RFID systems

In radio-frequency identification systems operating on the principles of EPC, there is currently no alternative to use equipment of UHF range, the work of which is defined by ISO/IEC 18000-63. The use of such equipment is fundamentally possible in library automation systems. This fact is reflected in ISO 28560 library standards. There are two standards defining operation of library RFID systems: ISO 28560-3—for HF systems, and ISO 28560-4—for UHF systems. The presence of two standards gives libraries an opportunity to choose the type of equipment for their automation system. Rules for placing and encoding data elements in the memory of radio-frequency labels defined by these standards are significantly different and are compatible only at the level of nomenclature of data elements presented in ISO 28560-1. Provisions given in the ISO 28560-2 are applicable only to RFID systems corresponding to the fourth part and are not applicable to systems based on the third part of ISO 28560. The reason for this is that RFID equipment of different frequency ranges—HF and UHF—is incompatible and that does these systems alternative to each other.

The use of UHF equipment based on the EPC concept in libraries is hampered by a number of factors; one of the most significant factors is the impossibility of a "smooth" migration from HF technology to UHF due to their complete incompatibility at the level of applied radio-frequency labels and readers. Thus, the choice of frequency range for the RFID library automation system uniquely determines the type of equipment that should be purchased by the library. The choice of equipment determines the overall configuration of the system and specialized software that is integrated into ILS. Subsequent migration to other equipment is practically impossible, because it is also associated with the re- or additional marking of library documents with radio-frequency labels of another type, since existing RFID readers are compatible only with labels of their frequency range.

The solution to this problem is possible by creating universal RFID systems that work with radio-frequency labels of both bands. Such a way requires a lot of efforts of software and hardware developers, which is associated with significant financial costs. Such costs are reasonable under the condition of payback due to widespread introduction of radio-frequency identification in a large number of libraries.

A common problem of widespread introduction of radio-frequency identification technology in libraries at present is the relatively high cost of equipment and availability only to libraries with good sources of finance. This is equally true for both HF and UHF systems. The cost of such equipment consists of two main components: the cost of RFID readers and the cost of radio-frequency tags. The share of radio-frequency tag cost in projects is growing rapidly with increasing library stock collection. For libraries with the collection of more than 100,000 document copies, to be labeled, the share of tags is already determining the cost of the RFID automation project.

Drastic cost reduction for the use of radio-frequency identification technology is possible due to repeated use of radio-frequency labels at several stages of product life cycle in the supply chain, from manufacturer to consumer. For libraries, this means that in order to reduce the cost of RFID library systems, printed publications must be marked with radio-frequency tags in manufacturer's printing house. Labels should be used to automate manufacturing, warehousing, and delivery processes. This is the main direction of development of automatic identification systems

based on the EPC concept. Libraries will receive such documents already marked with EPC-type labels that carry information identifying a document as an object of accounting in the global EPC network. The use of such tags in RFID library systems will eliminate the need for libraries to purchase them independently, but the system must support work with tags, used in EPC systems. In other words, the library RFID system must be integrated into a global identification system, based on the EPC concept. Taking into account the fact that the EPC system is currently working with labels of UHF band, for most libraries with the book collection, marked with HF markers, such possibility will appear only in connection with appearance of universal systems that work with tags of both types.

The emergence of universal systems is dictated not only by needs of libraries. There are a number of areas, where use of HF radio-frequency labels is preferred due to physical properties of electromagnetic waves. Increased penetrability of working field of the HF readers allows more efficient reading of labels located inside the objects of accounting or inside package. Relatively small range of HF tags, which is essentially possible, makes them preferable in systems with high information security requirements. At the same time, inclusion of such systems in the global identification system significantly expands their functionality.

The universal systems are still a matter of the future, but their emergence is already supported by existing international standards. If we consider the recent history of the regulatory framework of radio-frequency identification technology over the last ~15 years, we can see a clear trend of transition of existing centers of standardization, from statement of current situation in the market of RFID equipment, to creation of a regulatory framework that determines and stimulates further development of technologies in the direction of integration of RFID systems of similar types.

Without going into the background history, we can say that in the beginning of 2000s, two standardization centers, working on basic RFID standards for logistics tasks, were formed in the world:

- Joint Technical Committee ISO/IEC JTC1 "Information technology" /SC 31 "Automatic identification and data capture techniques" developed by the group of standards ISO/IEC 18000 for all types of RFID equipment, including HF and UHF.

- "EPC global Inc." organization is promoting the concept of electronic product code as a single identifier for all automatic identification systems, including RFID systems, and proposed a standard for manufacturers of UHF equipment "EPC UHF Class 1 Generation 2".

The existence of two different standard groups that determined operation of similar types of devices and were incompatible with each other was a significant obstacle to development of RFID systems. None of them was fully supported by equipment manufacturers. From two ranges that are most used in practical fields, HF and UHF leading manufacturers of HF equipment (including library equipment) were guided by ISO/IEC 18000-3 Mode 1 standard and manufacturers of UHF equipment by EPC C1g2. Use of equipment of a particular range in specific areas was determined by their characteristics and limitations arising from physical properties of electromagnetic waves. In addition, the logical structure of labels of these ranges was significantly different from each other. This fact, along with the difference in frequency ranges, made HF and UHF systems alternative to each other.

The first step towards harmonization of two standardization trends was made by ISO/IEC JTC1. In 2006, a supplement was added to the existing ISO/IEC 18000 group of standards and an ISO/IEC 18000-63 standard was adopted, which defines a data exchange protocol between UHF RFID devices, compatible with the protocol EPC C1g2.

The next step was the development in 2011, by the GS1 international organization together with EPC global Inc., of a standard "EPC Class 1 HF", which defined EPC protocol concepts for HF RFID equipment. The new standard was supported by ISO/IEC JTC1/SC31 by adopting a similar supplement "Mode 3" to ISO/IEC 18000-3 standard.

At present, we can talk about the existence of a regulatory framework for production and use of RFID equipment, specialized for operation in automation systems, based on the concept of EPC and operating in both frequency bands [22]. In this case, RFID readers of both types will have the same functionality, and radio-frequency tags will have a similar logical structure, described in the following international standards:

- HF band—ISO/IEC 18000-3 Mode3 (EPC Class 1 HF)
- UHF band–ISO/IEC 18000-63 Type C (EPC C1g2)

The existence of a common regulatory framework for production and use of RFID equipment in the most popular frequency bands provides a fundamental opportunity to implement the original EPC concept: using a single electronic product code to identify objects of accounting in RFID systems of various specializations, including library.

The ability of "transparent" work of the EPC RFID system in two ranges, along with the use of EPC tags, requires use of double-frequency RFID tag readers. Creation of such tag readers is a highly technical task. The first step in this direction was made by FEIG Electronic company, which began production of "ID ISC. PRHD102 HF/UHF" [23] mobile readers in 2013, which supported simultaneous operation in HF/UHF bands. The RFID reader cost of this model is approximately 20% higher than the cost of a similar UHF range reader.

Despite the presence of a dual band RFID reader, its use in the proposed generic library system today is not possible, as it does not support working with HF tags like ISO/IEC 18000-3 Mode 3 (EPC Class 1 HF). In addition, until today it is the only dual-band RFID reader in the market, and readers of various types are required to create RFID library systems.

The possibility of producing label EPC HF band appeared in 2013, when NXP Semiconductors company started production of ICODE ILT type chips [24], which comply with ISO/IEC 18000-3 Mode 3 (EPC Class 1 HF). On the basis of these chips it is possible to produce library HF labels of EPC type, but until today such labels are not presented in the market and are not used in RFID systems.

From the aforesaid, it is visible that emergence of universal RFID library systems today is problematic. Developers of RFID systems face the problem of lack of necessary equipment in the market: tags and readers, and manufacturers are in no hurry to invest in establishing production of new equipment due to the lack of created sales market. Current situation remained very similar to that of the 1990ths for the whole radio-frequency identification technology.

Implementation of the large RFID system project, with the use of HF band EPC tags, can change the situation in an area where use of this band labels is advisable along with UHF labels. Within the framework of such a project, developments can be made, further commercialization of which can change the situation in the market. Implementation of such project at the level that ensures its economic efficiency is possible only for large commercial or state organization. RFID library systems occupy a very modest place in the total number of RFID systems and unlikely will be able to meet their needs of the required scale project.

Participation of libraries in the overall development of automatic identification systems may be in their integration into the supply chain of printed publications,

from publisher to reader, along with trading organizations. To do this, RFID library systems must support the EPC concept, and it will make a notable contribution to the development of this concept. Such support requires the development and expansion of the regulatory framework that defines principles of application of RFID equipment, designed for EPC systems, in libraries.

Participation in development of the global EPC network will be useful for libraries. The fundamental difference between libraries and book-selling organizations is that documents of library collection are transferred to users for a limited period, with their subsequent return to the library storage system. At the same time, libraries provide users with advanced opportunities to search for necessary information. Integration of ILS into the global EPC identification system, using services of the Trusted Source of Data network can significantly expand the search capabilities of ILS not only for users of library services, but also for library acquisition services. Inclusion of marked documents of library collections into information space of automated systems, based on EPC standards, can significantly increase their mobility in delivery services of the ILL system in the future to provide the widest possible range for access to the library's holdings through widespread use of new information technologies, with using technologies of automatic identification and item management.

8. Integration of library RFID systems into the network of Internet of things

At present, the Internet of Things (IoT) concept is actively developing. This concept involves creation of a computer network that combines physical objects equipped with means to interact with each other and with ambient medium. Great importance in this network is given to artificial intelligence systems, managing processes and excluding human participation from certain actions and operations. Establishment of such a network is possible only on the basis of standardization of information exchange principles. An important place in development of the IoT concept is taken by technologies of automatic identification, and among them the technology of radio-frequency identification has a leading value. The concept of EPC as the global identification system participates in general development of the Internet of Things [25].

IOT network can be represented as a virtual space consisting of objects identified in a standard way, and there are used standard communication channels. Within the frame of such a surrounding, there may be many functionally localized information systems that interact "transparently" with each other. Library documents may participate in such systems. This can significantly extend the functionality of library automation systems. The development of IoT systems with library functionality may partially replace functions of specialized library automation systems. The central place in localized IoT systems is taken by humans, who determine the purpose of activity in any area. The system actively involves information for the program to achieve this purpose and making conditions for its implementation. Information support is a key condition for any kind of human activity. Participation of systems of the IoT in information support means that the system itself will define information needs of people, to select and provide sources of necessary information which are in the area accessible for them.

Such an area is the global information system which has included information objects identified in a standard way. These objects may be electronic documents and printing editions marked by radio-frequency tags identified in the global system of identification. The system can determine nearest location of available copy of

desired edition independently, and even it can order its delivery to the required place as the location of necessary publications can be both, trading organizations and libraries. For libraries, this will mean that the number of users of their information services, along with a person, will include expert systems of artificial intelligence. This requires that library document collections exist in the global system of automatic identification and in information space of the IoT network.

The development of IoT as a new communication technology is very fast. Today, such systems are already widely used in automation systems of mass production as Industrial Internet of Things. Mass appearance of such systems in the consumer sphere is predicted in 5–10 years. Such systems already exist in space of electronic information resources in the Internet environment. These are the so-called WEB 3.0 systems, the concept of which was formed in the mid of 2000s [26]. Now they exist as technological platforms for formation of content of the smart websites. Inclusion of physical objects into operational space of such systems, which may include library documents, will mean exit of WEB 3.0 systems from Internet virtual space to the real world and transition to IoT systems. This transition is directly related to automatic identification technologies and, to a large extent, to development of radio-frequency identification technology.

The development of library systems of radio-frequency identification in the direction of the EPC and the Internet of things concepts will allow including traditional printed documents, which make up a large part of the library stock collections, in digital information space, along with electronic documents. This will increase accessibility of printed documents to users and promote development of library technologies. This will allow libraries to integrate more fully into global information space at the next stage of development of information technologies as a global integrated system of library and information support of human activities and take a worthy place in the modern information society.

9. Conclusion

The appearance of radio-frequency identification technology is associated with the development of microelectronics and computer technology. This technology is also the general direction of automatic identification technology development, which allowed effective use of the computer technology in a wide range of applications. The use of first bar-code and then radio-frequency identification in libraries has significantly improved the traditional methods of servicing readers.

The emergence of electronic documents was the next step in the development of information technology, which allowed libraries to go beyond reading rooms to the limitless expanses of the Internet. The new opportunities have become a serious challenge for traditional documents of library collections, which are significantly inferior to electronic documents in access speed. There were ideas of a total elimination of paper books, but such forecasts do not sound today. The market for paper books has been growing in recent years, which means that paper books have found their place in the modern world. Increasing the availability of paper books in the electronic information space is a very urgent task today.

Printed documents now are a significant part of the library collections around the world. The use of radio-frequency identification technology in libraries together with the concept of the Internet of things will allow including "traditional" printed documents in the digital information space along with electronic documents. This will contribute to the development of library technologies and will allow more fully integrate libraries in the global information space at the next stage of development of information technologies.

Author details

Timoshenko Igor
Russian National Public Library for Science and Technology, Moscow, Russian Federation

*Address all correspondence to: timigor@gpntb.ru

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