Development of an identifier analysis algorithms to account for the movement of material flow in space transport systems

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Abstract. In modern space transport systems, the extremely urgent task of a unified identification and labeling of goods for various segments. One of the main tasks to be solved in the process of organizing the movement of cargo for delivery to the International Space Station is the organization of operational management. The article discusses international standards for identification and hardware implemented on the basis of radio frequency identification technology. The cargo movement system should have modules for cargo traffic planning, which is currently not the case. In addition, an important task in organizing the operational accounting of the material flow of goods is the realization of the possibility of a single information exchange between the various segments of the space system, which in turn involves the use of standardized methods and means. The article discusses the technology of automatic identification in relation to the space industry, the basic standard documents and provides a new developed algorithm for the analysis of identification codes of cargo data for the space transport system.

Viewing the space branch, the most trendsetting technologies that exist in the world nowadays will be taken into consideration. One of the most important tasks that must be solved during the flow of cargo to the ISS management process is the organization of operational control, which in turn is divided into two elements: thread scheduling of objects and effective flow control. Planning, inventory of the flow of cargo and flow control are difficult tasks because several entities have an influence on flow management formation of the objects to be supplied. There must be a very fast reaction stochastic events, which afterward require executive decision-making.

Accounting for a material flow should be based on standardized procedures, but due to the complexity of processes and configuration of goods, it is necessary to develop new more productive commodity accounting systems. The cargo tracking system should combine all transport and storage operations, solve the problem of determining the movement of cargo both on earth when forming, checking completeness, and directly on the ISS in space. The cargo movement system must have cargo flow planning modules, which are not available at the moment [1]. Besides, an important task in organizing operational accounting of material cargo flow is to implement the possibility of unified information exchange between different segments of the space system, which in turn involves the use of standardized methods and tools.

To implement the proper level of planning quality, as well as to improve the efficiency of flow management, there are several methods and tools for implementing the task. One of the methods is to...
Use automatic object identification systems. The means here is the technology of radio frequency identification (hereinafter-RFID). Undoubtedly, the technology of radio frequency identification is an innovative technology in the instrument industry and the space industry. In this case, RFID is a tool for organizing supply chain management at all levels to implement identification, monitoring, accounting, and planning of the flow of objects. The flow of objects refers to the cargo flow consisting of the necessary equipment and life activities for supplying to space on the ISS.

In a simplified form, the technology contains such tools as a set of radio frequency tags, RFID readers, and the implementation of a database of identifiable objects.

RFID tags are classified according to the following characteristics [2]:

- power method;
- memory type;
- frequency;
- range.

Regarding the method of nutrition, the labels can be passive, active or semi-passive.

Passive tags do not have an active battery in their structure. The required charge for the label is projected by the reader.

Passive tags in the 860-960 MHz and 2.4-2.5 GHz bands transmit the signal by modulating the reflected carrier frequency signal. The reader antenna emits a carrier frequency signal and receives a modulated signal reflected from the tag. Passive tags in the 13.56 MHz band transmit the signal by modulating the load of the carrier signal. Each label has an identification number [3]. Passive tags can contain rewrtable non-volatile memory. The range of 13.56 MHz tags is 1-200 cm, and tags operating in the 860-960 MHz and 2.4-2.5 GHz range is 1-10 meters.

Active tags [4] are supplied with a power supply, which allows them to work at a greater distance than passive tags, but active tags are large in size and have a limited service life, determined by the power supply device. Also, active tags can be equipped with additional electronics, such as temperature, humidity, etc., and thus actually acquire the property of a sensor.

Active tags work independently of the reader since they have a separate power source. Active tags, with their power source, can also generate an output signal of a higher level than passive tags, allowing them to be used in environments that are more aggressive for the radio frequency signal:

- in water (including people and animals that are mostly made up of water),
- in metals (ship containers, cars),
- for long distances in the air.

Most active tags allow you to transmit a signal over distances of hundreds of meters with a battery life of up to 10 years.

Semi-passive tags [4] (also called semi-active) are similar in purpose to passive tags (they begin to emit a signal only at the request of the reader), but they have an independent power supply.

By the type of memory used, tags are divided into [4]:

- read-only tags,
- tags with the ability to record once
- rewrtable labels.

Data is written to read-only labels by the manufacturer during manufacturing.

Labels that can be written once have a memory block that can be used by the programmer to write data once.

Rewritable labels have memory available for multiple write-reads.
According to the operating frequency, the tags are divided into [4]:

- low-frequency;
- high frequency;
- ultra-high frequency;
- microwave.

As the base frequency increases, the speed of information exchanges between the reader and the tag increases. This feature allows, for example, using tags with longer key lengths that provide a higher level of data protection.

By range, tags are divided into:

- near-field identification (up to 20 cm);
- identification medium (20 cm - 5 m);
- long-range identification (more than 5 m).

The reading range «table 1» is determined by the frequency of the RFID tag, its type, and the size of the reader's antenna.

**Table 1. RFID tag reading range [5].**

| Range          | Frequency |
|----------------|-----------|
| 125-134 kHz    | Up to 1 m |
| 13,56 MHz      | Up to 1 m |
| 860-960 MHz    | Up to 15 m|
| 2,45 GHz       | Up to 100 m|

The use of radio frequency identification systems in space is regulated by the CCSDS 881.0-M-1 standard "Spacecraft Onboard Interface Services-RFID-Based Inventory Management Systems. Magenta Book" [6]. This document provides instructions for developing systems of this class. We recommend using ultra-high-frequency tags with an operating frequency of 860,960 MHz (ISO/IEC 18000-6 standard). This standard regulates the single entry of RFID tags and their multiple reading. In turn, CCSDS 881.1-B-1 "Spacecraft Onboard Interface Services-RFID tag encoding specification. Bluebook" [6], is a standard used for encoding RFID tags. This standard contains both the representation structure of the encoded label and the table of characters used for encoding.

The peculiarity of this standard equipment is that in some countries it is forbidden to work on some frequencies from the specified range, so depending on the country, readers are used either at 860 MHz or at 960 MHz, while tags can work with both types of readers.

When an object is identified, the radio frequency tag transmits the binary code of the RFID reader, which uses the encryption keys to decode the information and receives an identification code, which is then compared with the archive of identification codes in the database. If the database is set to match the identification data, it is considered that the object has been identified and full information about the object has been obtained. Otherwise, the object is not identified.

For successful identification of the object, both decoding of the received information and analysis of the received data after decoding are necessary.

Another important task when creating a new RF tag for an object is to verify that the identity data of the programmable tag is correct relative to the data that will be written to the tag ID database.

According to the CCSDS standard, the RFID tag stores information about five data fields in a binary system, with 96 bits allocated for implementation «figure 1».
In the database, information about the object is stored in a hexadecimal system using 24 characters. Figure 2 shows an algorithm for analyzing the correspondence of the encoded RFID tag data with the database of object identifiers.

**Figure 1.** Bitwise display of RFID tag data fields [6].

**Figure 2.** Algorithm for analyzing RFID tag data.
Verification of data compliance consists of several stages. First, each structural field is decoded and assembled, and then the label ID is assembled as a whole according to the information representation order rules. Multi-stage, in this case, allows you to implement parallel execution of functions for analyzing the received data when identifying an RFID tag. Thus, if there are cases associated with non-standard data representation, the system stops decoding the rest of the field data and provides information about the problem decoding node, which in turn significantly saves time for analyzing the received data.

The use of radio-frequency identification is a promising technology in the space industry, which can significantly improve the ability to manage cargo traffic.

Accounting, monitoring, and effective planning of objects are the key parameters whose effectiveness affects the viability and effectiveness of cosmonauts' tasks. These parameters in a complex technical system will be presented at a high operational level due to the use of this technology.

The cargo tracking system based on this technology will allow us to combine all transport and storage operations, solve the problem of determining the movement of goods both on earth during the formation, verification of completeness, and directly on the ISS in space. The cargo movement system will solve the problem of planning cargo flows.

The use of radio-frequency identification will allow realizing the efficiency of work on each section of the supply chain, which in turn will allow reallocating the operational management capacity to other important aspects of space flights.

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