Design and implementation of a RFID-based intelligent tools management system

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Safety is a priority for aviation companies. To ensure aviation safety, consistent maintenance is needed. The maintenance of airplanes requires good technology, and scientific management of maintenance tools help to improve maintenance efficiency and reliability. In this paper, we designed and implemented a Radio Frequency Identification (RFID) based intelligent tools management system for the scientific management of maintenance tools. The intelligent tool car that contains the tools needed for maintenance of airplanes has an enclosed metallic environment. Thus, its structure requires optimization and adjustments to be made before the RFID system can be embedded. RFID tags are then pasted on each tool. Due to the unique signals of each RFID tag, missing tools can be identified. Our experimental results show that the operation of the system is stable and reliable in the complex electromagnetic enclosed metallic environment.

Keywords: RFID Technology; Metallic Environment; Tool Car; Antenna Placement; Tool Management.

1. Introduction

With MH370 aviation accident happened, attention of people gradually focus on the aviation safety. Maintenance is the important guarantee of aviation safety. Mismanagement of tools may result in maintenance errors, which greatly affect flight safety. For example, the lack of tools will seriously affect the efficiency of repair. If tools are accidentally forgot in certain parts of the aircraft, it may also pose a security risk. Therefore, it’s meaningful to use a scientific tools management system in aviation service department.

RFID, an automatic identification technology[1], is widely deployed in security, assets tracking, supply chain management and many other fields from 1990. The advantages of RFID: first, RFID tag can pasted on different items,

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metallic or nonmetallic. Second, the system can use in different environments, liquid or metal. But the performance of RFID system can be strongly effected by environments. Many researches have been conducted to apply the RFID system to different environments. M.Periyasamy etc.[2] assessed and analyzed the performance of 13.56 MHz RFID in metal and liquid environment. C.A Diugwu etc.[3] researched field distributions and RFID reading in metallic roll cages. Xianming Qing etc.[4] studied the proximity effects of metallic environment and applied into the library shelf. On the maintenance tool management, the aircraft repair shops of China Southern Airlines Beijing Branch manage maintenance tools through the bar code management system[5]. ANA and NEC use UHF RFID technology to build the aircraft maintenance tools in and out management system[5]. Scholars have done Many works and related applications in different environments. RFID technology also has been applied in relevant tools management. But less RFID applications are used to tools management in a enclosed metallic environment.

Tools are various, including metallic and nonmetallic tools. And most are stored in a complex closed metal environment. Therefore, with the RFID system embedded in, we design an intelligent tool car which has an enclosed metallic environment.

In this paper, a RFID-based intelligent tools management system is designed and implemented. Section II describes the configuration of tool car. Section III presents the placement of antennas based on the structure. Section IV is software part of the system. Then experimental results are showed in section V. Finally, section VI draws some conclusions.

2. Set Up of Proposed System

The intelligent tools management system is composed of tool car and RFID system. For an ordinary tool car, RFID system can’tt be embedded into it. The structure adjustment is needed. And the main consideration is the installation of antennas and the display panel of PDA.

Figure.1 is the structure of tool car after adjustment. The display panel is installed on the surface of platform for it is very suited to operate and observation the data. However, the installation of antennas is affected by many factors. First, the space of tool car is small so that the installation location is limited. Then, inside of tool car has a complex electromagnetic environment. With these two situations considered, two installation methods are proposed, $antenna_{side}$ and $antenna_{up}$. $antenna_{side}$ represents the antennas mounted on the side of drawer. $Antenna_{up}$ represents the antennas mounted on the above of drawer. Section III will give a detailed description.

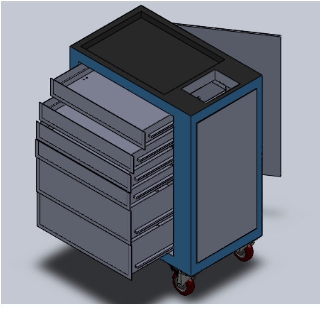

Fig. 1.The structure of tool car

Once the structure of tool car sets up, we build the RFID system. The environment of the drawer is a narrow metallic environment. We select EastAmple E9238 high performance UHF directional slot antenna which is suitable for a narrow signal area. The frequent ranges from 902MHz to 928MHz and the gain is 8dBi. Due to most tools are metal and wood, We choose Omni-ID Fit series tags, including Fit200, Fit210, Fit400, Fit400P, which have small size, high performance and especially suitable to pasted on the surface of tools. These series tags use Alien H3 IC which compliant with EPC Class 1 Gen2 protocol and the frequency range of EU and US. About the reader, we use FN-2184D four-channel UHF RFID reader to improve the reliability and read range. Finally, we build up the whole intelligent tool car. Figure.2 is the framework of the system.

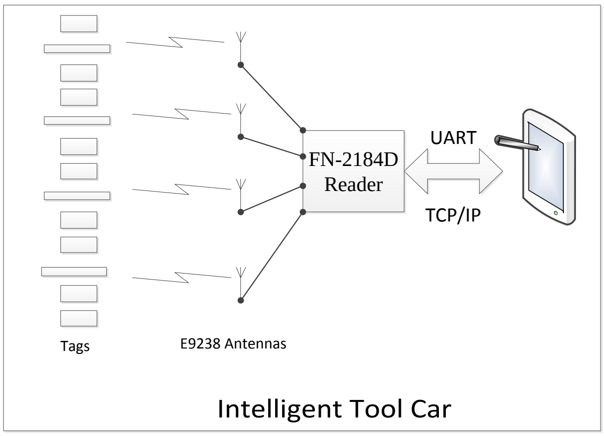

Fig. 2. The framework of the system

3. Alternative of Antennas Placement

Intelligent tool car has a metal environment and metal surfaces are inside the drawers. There are large influence on the antennas which mainly include the absorption and reflection of electromagnetic signals[6]. The portion of High frequency electromagnetic signals which reach the metal surface are absorbed into heat, and another portion are reflected into all directions when they reach the face of a metal target. When the electromagnetic wave reflected by the metal and the reflected wave of tags meet by standing wave, the reflected wave of tags will be weakened, and it will greatly affect the performance of read. According to the radiation patterns of Fit 400 tags, as shown in Figure.3. The read range will change along with the metal size. And when tag is pasted on the small metal sheet, some filed can’t be read. So the mounting and placement of tags will also affect the read performance of system.Since we can’t transform the tags,and tags can only pasted on the area which could not affect the use of tool. as well as the placement of tools is uncertain and the structure of tool car has been determined, so the installation position of the antenna will directly affect the read performance.

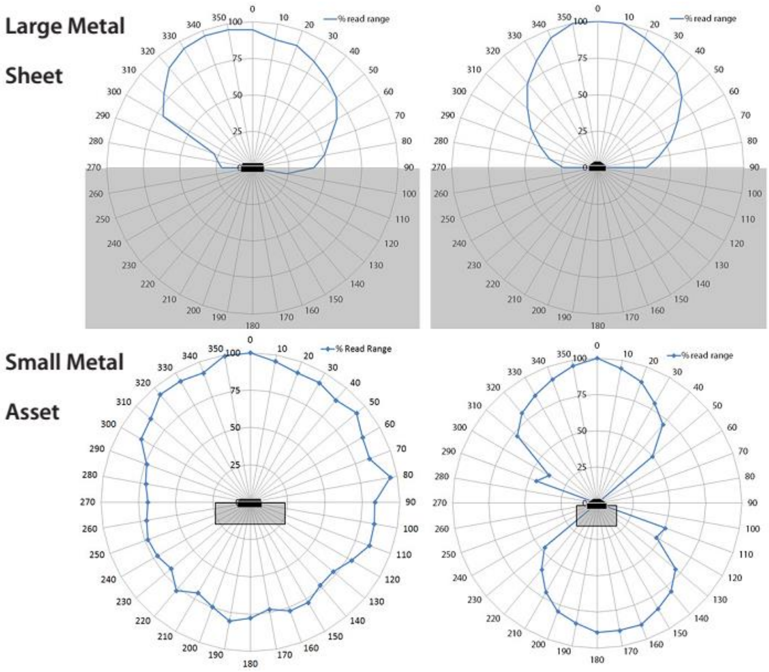

Fig. 3. The radiation patterns of fit 400 tags

We have proposed two antenna installation methods in Section II. One is mounted on the top of drawers, another is mounted on the side of drawers. In order to check the performance of these two installation ,we designed the following experiment to determine the read range in the drawer.

Experiment 1.

Antenna is mounted on 15cm above the drawer which is enclosed. Evenly place 40 tags around the drawer. Continuously narrow the range of tags until all the tags can be read stably. This range is the read range which antenna is disposed above the drawer, as it is shown in Figure.4.

Experiment 2.

Antenna is mounted on the 3cm away from the side of the drawer where the metal plate is taken out from the drawer. Evenly place 40 tags around the drawer. Continuously narrow the range of tags until all the tags can be read stably. This range is the read range which antenna is installed on the side of drawer, as it is shown in Figure. 4.

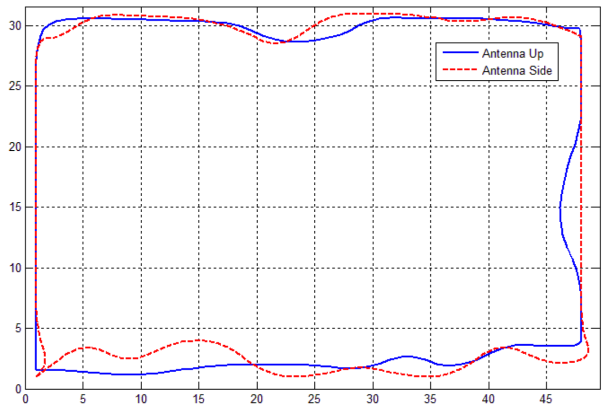

Fig. 4. The read range of two antenna installation methods(solid line is the read range of antenna up, dashed line is the read range of antenna side)

Figure.4 shows that the metal environment has influence on the read range. Not all the tags in the drawer can be read. When the antenna is installed on the top of the drawer, the read range of three edges of the drawer fluctuates, shown as the solid line in Fig.. When the antenna is installed on the side of drawer, the read range of edges of drawers which away from the antenna changes more, showed as the dashed line in Fig.. In the case of $antenna_{up}$, the strength of RF signal is relatively weak on the edge of the drawer and there are two reflection surfaces, so the fluctuation of read range produces. And in the case of $antenna_{side}$, the opposite side of antenna is metal surface. The electromagnetic wave reflection and absorption effect will be significantly stronger than other places, so the corresponding side has a greater fluctuation. Simulate the read range use matlab and then calculate the read area in the read range. From Table 1, two installation methods have similar read area, which means that the performance of the two installation methods are similar. Therefore, we can choose the right installation method according to the specific circumstance of the tool car. For example, When the intelligent tool car has a large number of drawers, we can choose the antenna mounted on the side. When with a small number of drawers, we can select the antenna installed on the top.

Table 1. The read area of two installation methods

Antennas Installation Methods	Read Area
Antenna Up	130.14 cm^2
Antenna Side	131.33 cm^2

4. Software for Intelligent Tools Management System

Software system is an important part of the intelligent tool car. The software of the system is used to configure the RFID system, query the missing tools and provide a friendly user interface for the maintenance staffs. The software uses Visual Studio 2008 and C# to program and runs on WinCE platform to real-time monitor the tools in tool car and prevent the miss of tools. Three interfaces are designed in this paper; They are tool monitor, tool management and RFID configuration. RFID configuration interface is used to connect the reader and set the RF power and the work antennas of the reader. Tool management interface is used to add and delete the original tool data. Tool monitor interface is used to real-time monitor the deletion of tools.

The software provides two detection modes in tools detection. One is real-time mode and another is fast switch mode. In real-time mode, after the program starts running, setup work *AntList* firstly according to the selected work antennas. Secondly , set antenna form *AntList* starting position. And then the reader begins to inventory and save the tag data. After the inventory, set the next work antenna. Until all the selected work antennas have worked, compare the queried tool data with the original tool data to obtain the missing tools. Finally, back to the starting position to repeat the query. The flowchart of real-time mode is shown in Figure.5. In fast switch mode, the differences with real-time mode is that do not need to select work antennas because all the antennas will work and the switching speed of antennas is faster to make the system read faster.

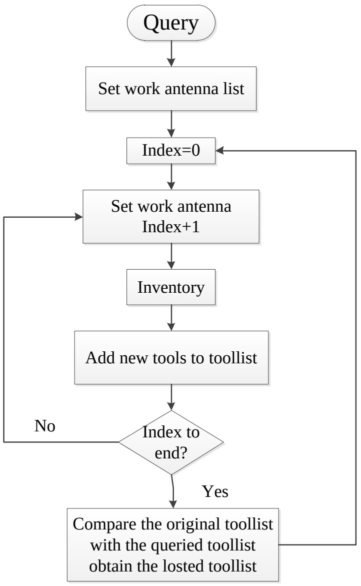

Fig. 5. The flowchart of real-time mode

5. Experimental Results

A RFID-based intelligent tools management system is designed and complemented. First, in order to check the reading performance of the system to different types tools, choose Omni-ID series four different tags affixed to tools. Test and obtain its recognition effect as shown in Table 2. In the test , in order to ignore the effects of the rotation of the tools and tags, use different rotation combinations, such as 90°tag rotation with 135°tool rotation and 180°tag

Table 2. Recognition rate of tags affixed to different tools. (Legend: Fit200, Fit210, Fite400P, Fit400 are applicable to metal, metal and non-metal, non-metal, metal surface)

Pasted Methods	Test Times	Recognize Times	Recognition rate
Fit200 pasted on metal	2160	2130	98.6%
Fit200 pasted on non-metal	2580	659	25.5%
Fit210 pasted on metal	2640	2640	100%
Fit400P pasted on non-metal	3320	3255	98.0%
Fit400 pasted on metal and Fit400P pasted on non-metal	300	295	98.3%

rotation with 180°tool rotation. Table shows that as the tags pasted to the applicable surface of items, the system recognition rate for individual items can reach more than 98%, even up to 100%. When tags pasted to non-applicable items, the recognition rate will greatly reduce.

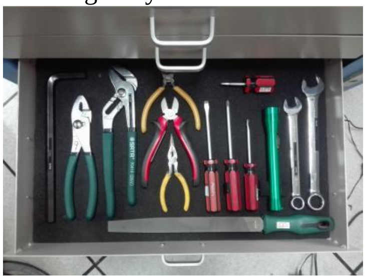

Fig. 6. The placement of tools

Then, test the system with the placement of tools shown in Figure.6 , Omni-ID Fit series tags pasted on the related tools, antennas mounted on the side of drawers. In the test, we have used 14 different tools, the reading rate is 100% in each of the drawers. When we remove the 19mm wrench, the query interface prompts the deletion of 19mm wrench and an alarm sounds, as shown in Figure.7. When freely remove the tools in the drawer, query interface prompts the deletion tool accurately and alerts, as shown in Figure.8.

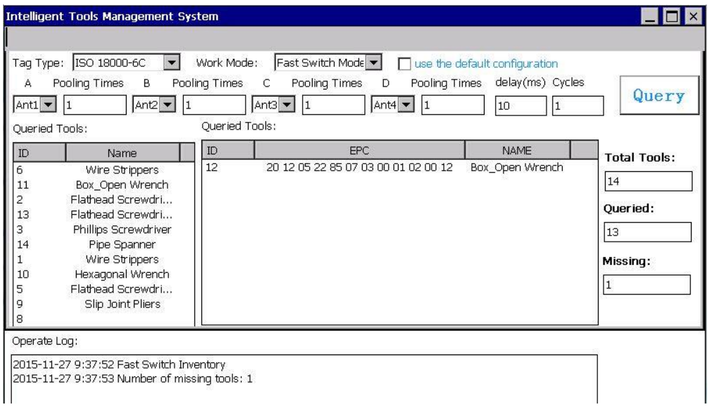

Fig. 7. Detection result of removing one tool

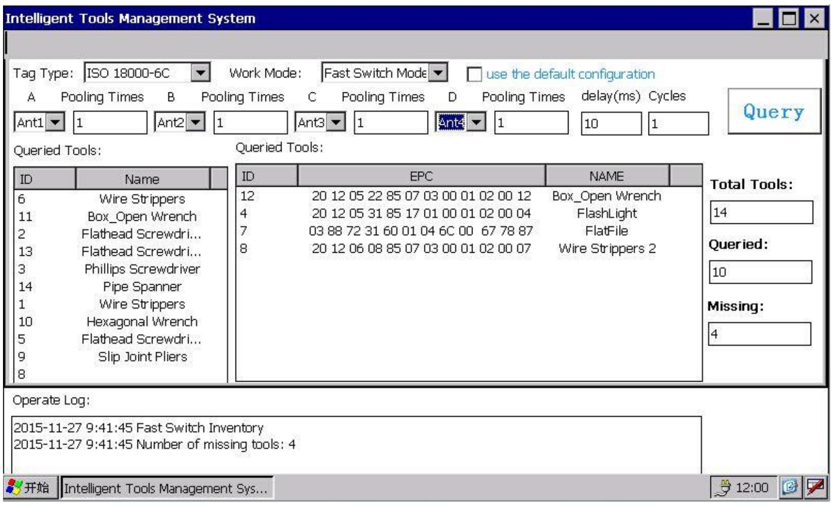

Fig. 8. Detection result of removing four tools

In the complex electromagnetic closed metal environment, placement and posture of tools will affect the test results in a certain extent. In summary, the test result demonstrate the placement of tools in Figure.6 is a reliable scheme to ensure all the tools can be reliably detected. The test result in Figure.7 and Figure. 8 further validate the reliability of the system.

6. Conclusion

Aviation security issues are getting more and more attention. Reliable management of maintenance tools is undoubtedly an important part to ensure aviation safety. In this paper, a RFID-based intelligent tools management system is designed and implemented to manage the maintenance tools effectively and reliably. Based on the feature of enclosed metallic environment, rebuild the inter structure of tool car. By using the RFID system mounted on the tool car, the status of tools can be detected real-time and the deletion tools can be get. The experimental results have confirmed the validity and the reliability of intelligent tools management system. The proposed system can be extended into the tools management of other fields in the future.

Acknowledgments

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