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Development of Steel Production and Logistics Automation System

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In steel coil packing lines, errors in coil IDs will have severe consequences for the manufacturer and its customers. To avoid this situation, a technology to track continuously moving Radio-Frequency IDentification (RFID) tags was developed to prevent packing-line coils from being falsely identified. The additional transaction information in the RFID tags also enhances the cranes' positioning capability while transporting the coils in the stock house. An RFID multi-gate shipping portal technology was also developed that can simultaneously check the coils' IDs on different trailers, and therefore increase the coil shipping efficiency. This paper presents the accomplishment of the production and logistics automation by applying the RFID technologies to the coil packing and shipping processes.

Keywords: RFID, Tag Tracking, Logistics

1. INTRODUCTION

Cold rolling coils are the highest value-added steel products and their production depends on the market demand. Coil IDs in the packing lines have to be guaranteed to be correct, or they will result in severe consequences for the manufacturer and its customers. RFID technology has played a crucial role in correctly tagging coils and has been applied on the internet of things. RFID can be used to automatically read the coil IDs, and thus speed up the product logistics. The faster product logistics can help workers avoid attaching the wrong tags to coils in the case of the electronic message chaos resulting from the manufacturing equipment malfunctions. However, commercial metal tags are normally too expensive to be accepted by users. On the other hand, when RFID tags continuously pass through the RFID portals, the tag identification signal interferes with the multi-path and backscatter properties of radio in free-space. To solve the foregoing, we developed a customized RFID tag with a much lower cost than the commercially available tag, and with RFID tracking and positioning technologies that enabled the radio interference problems to be resolved. The integrated information flow from packing to shipping further improves the coil logistics management.

2. TRACKING THE CONTINUOUSLY MOVING RFID TAGS

2.1 The RFID Tag Applied on Metal

RFID is a rapidly developing technology. Figure 1 illustrates the operation of a passive RFID system. A typical RFID tag consists of an antenna and an integrated circuit (chip), both with complex impedances. The chip obtains power from the radio frequency (RF) signal transmitted by the base station (called the "RFID reader"). The tag sends the information back by varying its input impedance and thus modulating the back-scattered signal.

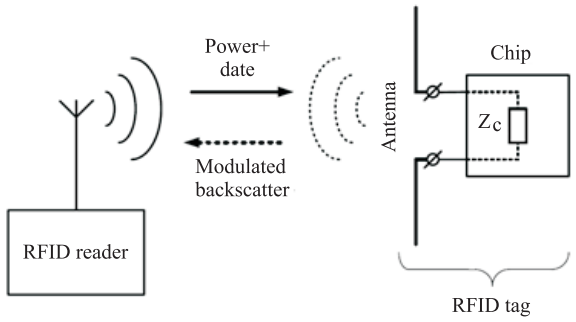

Fig.1. Passive RFID system.

The developed RFID mono-polar antenna is presented as Fig.2. With a much higher performance, lower cost, and a longer access range in free-space than

the other tags, the RFID tag is designed to be solid standing and is attached directly on the inside of the coil to avoid collision damage, as presented in Fig.3. The coil's product information recorded in the chip memory is automatically accessed while the coil passes through the RFID reader.

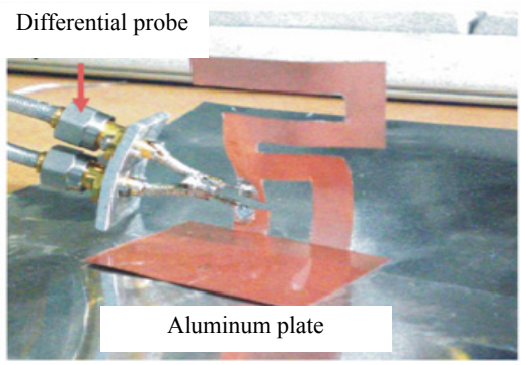

Fig.2. The mono-polar antenna of RFID tag.

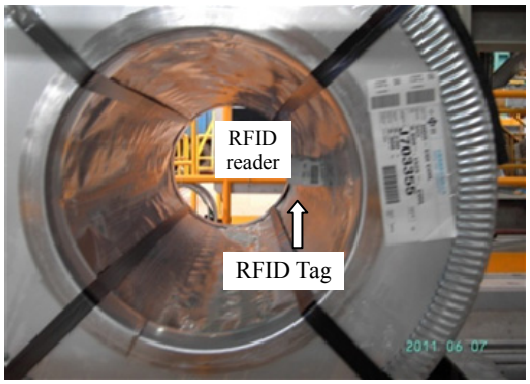

Fig.3. The customized RFID tag on the coil inside.

2.2 Predicament of Radio Interference

RF signal multi-path is an inevitable phenomenon, common to virtually all types of radio communications and navigation systems. The multi-path propagation, referred to Fig.4, resulting from the variety of signal paths that may exist between the transmitter and receiver can give rise to interference in a variety of ways including distortion of the signal, loss of data and multipath fading [1].

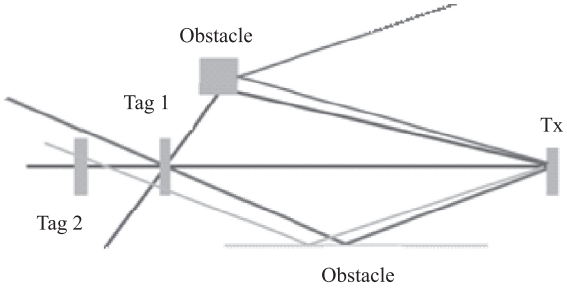

Fig.4. Radio multipath propagation scenario.

It is important to analyze the multi-path influences especially since tag tracking and positioning are critical issues applied in practical logistics. Nowadays, even though there have been multi-path literature studies made with the measured data in laboratories, these studied technologies are hardly applied to the practical production lines, because it is impracticable to measure RF by using the same instruments as research laboratories.

2.3 Moving Tag Detection

Sequential lobing is one of radar methods used in tracking processes[2]. It is often referred to as lobe switching or sequential switching since radar moves its beam from one position to another position by closing and opening switches, and gets the different return signal strength, referred to Fig.6. However, the switching lobes still incur the predicament of multi-path interference caused by obstacles like the production equipments.

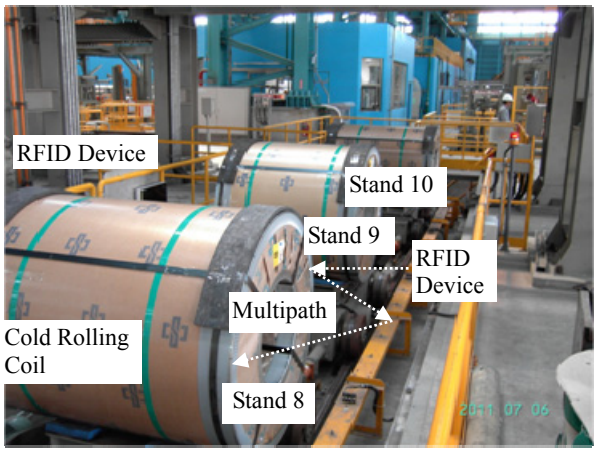

Fig.5. Tracking the continuously moving RFID tags.

In practical tag tracking and positioning detection, we only use the essential RFID devices, as presented in Fig.5, to transmit and receive RF signals, but not utilize the additional instruments. Coils are transported by the pallet conveyers. The RFID devices are symmetrically mounted on bilateral rails, and read the coil information in the attached RFID tags while passing by the devices. The coil information is transacted into the mechanical and electrical equipments for further coil ID validation. The algorithm of tracking and positioning the continuously moving RFID tags includes following rules:

1. Calculate the received signal strength indicator (RSSI) variations over a period.
2. Count the access frequencies of the RFID chips.
3. Set the threshold to filter the deviated performances of tags.

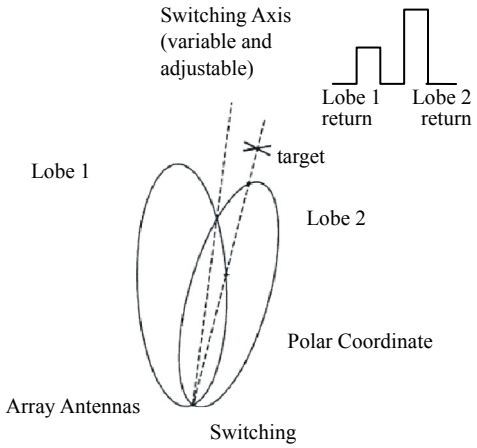

Fig.6. Sequential lobing tracks moving target in free-space.

By the judgement rules, the system can accurately track and position the moving RFID tags. The on-line system monitoring Graphical User Interface (GUI) is presented as Fig.8.

3.RFID MULTI-GATE SHIPPING PORTAL

3.1 State of RFID shipping portals

Commercial RFID shipping portals are normally designed as a single shipping portal. A shipping portal is basically composed of RFID readers, antennas and frames. The most important issue for an RFID multi-gate shipping portal system, as shown in Fig.7, is that it has to correctly identify which RFID tags are read from the specified gate. Some of the ways to approaching the issue are proposed as:

1.Isolating the background radiations by the back-enveloped antennas.
2.Enlarging the portal intervals.
3.Radio shielding by using inductive filters.
4.Clustering tags by their RSSI measurements.

Item 1 only precludes the radiations from the antenna rear. While the RFID tags pass through one portal, the antennas of the other portals can still reach the tags. Item 2 needs large portal setup spaces in order to fall outside other portal RF access ranges[3]. The smaller the mesh of the iron net the better the effect of an inductive filter. To offer an effective RF shield, the implementation of Item 3 needs inductive filters to be widely constructed. Item 4 is based on the argument that in free space, the magnitude of RSSIs should have a positive correlation to distance. However, in a physical situation, RSSIs are influenced by radio multi-path propagation effects, and the directionality and gain of the antenna etc.; the circumstances influence in correctly clustering the tags.

3.2 Automatic multi-gate shipping portal operation

While the tags are passing through the multi-gate

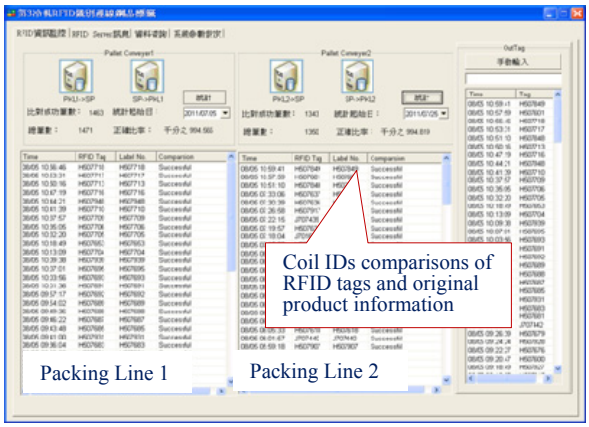

Fig.8. Moving RFID tags tracking GUI.

Fig.7. Panoramic view of the RFID multi-gate shipping portal.

shipping portals, it is essential to cluster the tags correctly. The current commercial RFID shipping portal and foregoing hardly provide a reliable clustering sequence. For this reason, we propose a clustering mechanism developed in accordance with the relative location and direction of the antennas to process the radio multi-path effects. Figure 9 presents the GUI settings matched to the practical configuration of antennas. Generally speaking, if the tags are nearer the antennas, they have correspondingly higher RSSIs. This phenomenon is used as the minor clustering mechanism. By these mechanisms, each single shipping portal can correctly identify the nearest tags. The implementation of the developed RFID system at the multi-gate shipping portals improves the shipping procedure, effectively prevents truck overload, enhances personnel safety, and increases the efficiency of logistics and information flows.

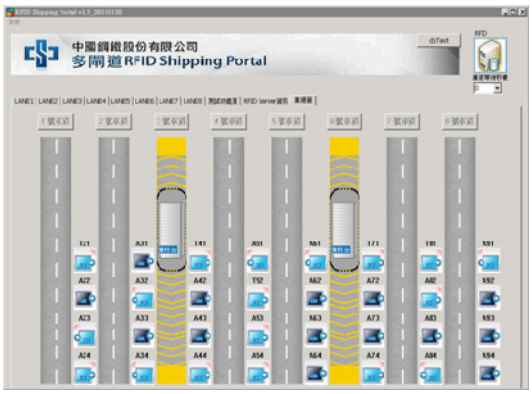

Fig.9. Antenna arrangement GUI.

4.RFID APPLICATION SYNERGY

In the coil packing-line, the read rate of the RFID labels reached 995‰ which apparently gave the staff enough confidence to accept the consequences of identifying coil classifications. The automated RFID information, feasible to be integrated in the information transaction mechanism, streamlines the transportation and stock process. The multi-gate shipping system saves tremendous labour effort, and raises the shipping efficiency more than 40%. The RFID technology applied in production and logistics management of the coil products has an active impact on increasing the enterprise profit and its competitiveness.

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