Barcodes vs RFID for Work-in-Process Tracking

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Introduction

In this white paper we look at whether the use of barcode or RFID (Radio Frequency Identification) scanning is best for tracking work-in-process in manufacturing plants. We conclude that use of a combination of barcode and RFID scanning is best in most cases.

Approximately 80% of all mid-sized manufacturing plants in the USA are still using paper forms and Excel spreadsheets to track the progress of customer orders through work centers on the factory floor. They then need expediters and managers to track and schedule the customer orders to try to ensure that customer orders get made on time.

Many are reluctant to adopt barcode scanning to track the orders because of the complexity of implementing a barcode tracking system and the need to train and supervise their people in how to use these barcode tracking systems.

As one plant manager said to me “I want to see where all my customer orders are at a glance but I don’t want to have my production workers do any barcode scanning or other data entry.”

In this white paper, we examine the alternative of using RFID to automatically track work-in-process without the need for people to manually do barcode scanning.

Please note that here we are discussing the use of UHF RFID technologies, which radiate electromagnetic waves, in the frequency range 902 to 928 MHz (in the USA), illuminating a 30 degree or larger cone from each antenna and can read passive RFID tags at distances up to 20 feet or so. These are commonly used in manufacturing and warehousing applications.

UHF RFID is different from near-field RFID technology, which uses magnetic coupling, and has a scanning range of a few inches. Near-field RFID is useful for applications such as entry control and paying for your coffee in the cafeteria but has limited use in most work-in-process tracking applications.

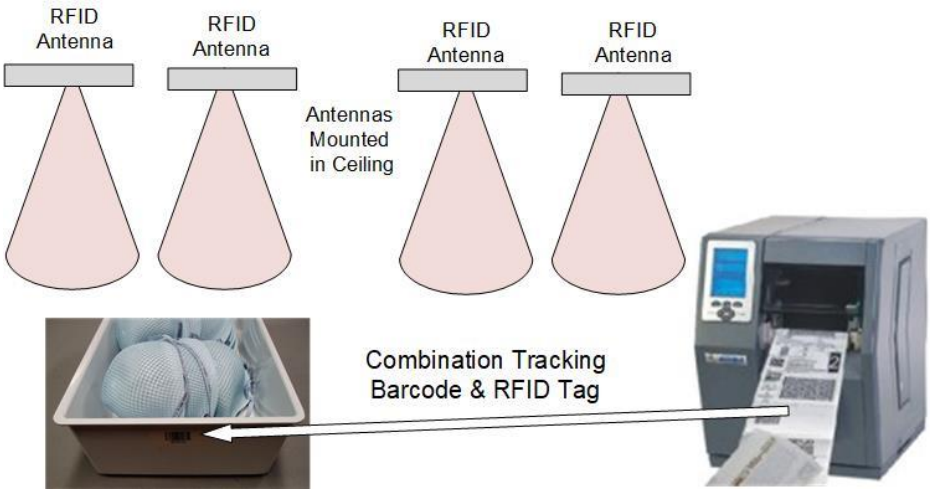
Please also note that this white paper assumes that its readers have an understanding of how barcode scanning and RFID work. For those readers who do not, I have included some useful references at the end of this white paper.

Competing Technologies

Barcode scanning, whether the barcode scanner is embedded in a ruggedized mobile computer or is linked to a PC or tablet, is very precise. This enables scanning specific barcodes on a work order traveler or on work-in-process items or totes holding work-in-process parts even when many of these are in the same proximity.

An RFID antenna on the other hand, can be mounted above each work center to record every RFID tag in the work station at any one time. These tags may be attached to each assembly, kit, or other item being made, or to totes holding sets of parts being worked on.

This enables an RFID tracking system to record when an RFID tag arrived at each work station and when it left. Also, if we attach an RFID tag to each employee's badge, the system can record who was in the work station at the same time.



We cannot, however use RFID to automatically record when an individual employee starts and stops work on a specific operation, on a specific job. Neither can we record what materials they consumed or link the materials consumed to the WIP or finished products produced by the operation. For these we need to use barcode scanning.

Example Applications

Manufacture of Electromechanical Assemblies.

This is a good use case for a combination of barcode and RFID tracking. Here barcode scanning is used to record the picking of the parts for the assembly from the stockroom. Then a combination barcode/RFID tag is printed out for each assembly. The barcodes are scanned, along with those on the containers of raw materials, to record the materials used for each assembly and then the tags are attached to the chassis for each assembly. Note that RFID tags cannot be read through metal or other conductors and so must be placed where they can be easily read by the antennas.

RFID is then used to record the movement of the assembly from one work center to the next until the end if the line when typically barcode scanning is used to record each unit being packed into a carton and then onto a pallet.

Semi-Custom Rotomolded Kayaks

When each kayak comes out of the rotomolding machine, it needs a significant number of manual steps, performed in different work centers, to remove excess plastic, drill holes, attach a variety of seats, covers, etc., and be appropriately labeled according to teach customer order. Then the kayaks need to be placed in shipping containers for each customer.

If we are doing barcode tracking, we attach a tracking barcode to each kayak and associate it with the customer work order that is specific to that kayak or a small batch of kayaks. We can then scan the tracking barcodes to record the movement of each kayak from work center to another. We can also use barcode scanning to record when each production worker starts and stops work on each operation on each canoe as well a recording who worked on it and what materials were consumed at each step.

For rotomolded canoes, this is probably overkill, as it involves a significant amount of barcode scanning. All we typically need to know is where on the factory floor each customer's order is located and to warn managers if the kayak, or whatever is being made, has not moved from one station to the next according to its schedule.

This we can do easily using RFID except for associating the RFID tag attached to each kayak with the customer order at the beginning of the line and recording which shipping container it went into at the end of the line. These first and last steps become very difficult with RFID because an RFID antenna, or even a mobile computer with an integral RFID reader, captures all RFID tags in its vicinity, making it hard to identify a specific item.

Manufacture of Vials of Biologic Pharmaceuticals

In this example, the organization was producing vials of injectable pharmaceuticals, with each vial containing a specific mix of chemicals, according to the disease being treated. But after the first few steps, the vials went though identical processing steps, in a sequence of laboratories.

The organization wanted to attach an RFID tag to each vial and then use an RFID portal to record when each vial entered and left each laboratory. Again, there was the problem of associating the RFID tag placed on each vial with the intended patient. But the bigger problem was that they wanted to record the vials as they were carried through the doorway in trays of 200 vials. Which brings us to another problem with RFID.

Basically, an antenna can only read one RFID tag at a time. If, in response to being illuminated by a radio wave sent from the antenna, all the tags responded at the same time, then they would interfere with each other and all the antenna would receive in response to its interrogating pulse would be a jumble of radio waves.

For this reason, upon being illuminated, each tag choses a random delay time at which to broadcast its unique identifying code. The antenna sends out an interrogation pulse of radio energy and then listens for responses. The maximum time for the tags to respond is set in the

interrogating beam, typically to about one second, during which time the antenna can read about 10 tags. But because the tags may choose the same random number, and other environmental factors, such as interference, typical read rates are about 6 tags per second.

The antenna then repeats the reading process every few seconds, during which time some tags may have arrived or left. As a result, attempting to record 200 tags as someone holding the tray walks through a door, which only takes a few seconds, results in many tags not being recorded. The same applies when attempting to read the tags on many boxes, stacked on a pallet, as a fork lift truck carrying the pallet is driven (never slowly) through an RFID portal in front of a dock door. For this reason, we typically do not put RFID tags on boxes that are to be stacked on pallets with an RFID tag for the whole pallet.

Please note that more complex schemes, such as frequency diversity and use of separate transmit and receive antennas, are used in some cases. But the improvements in tag read accuracy are small and don't overcome the read rate limitations imposed by the limited power and frequency spectrum imposed by FCC regulations and by Shannon's law (sort of like Einstein's theory of relativity but applied to communications theory).

Food Processing

This example is from a manufacturer of slices of American cheese which are packaged and sold to supermarkets by the pallet load. Here they are required to record all the ingredients for each batch as they are incrementally added to a large mixing vat, including each ingredient's supplier, lot number, and expiration date.

After mixing, the resultant mix is automatically poured into block molds, which are chilled by passing through a freezer on an automated conveyer, and then sliced, wrapped, packed, by an automated production machine, and stacked onto a pallet by a robot.

While barcode tracking is appropriate for recording materials added to the mix, RFID has no role to play in this application except possibly as a combined barcode and RFID tag attached to the pallet for use in recording the loading of the pallet onto a trailer for shipment to the customer's distribution center.

Conclusion from Examples

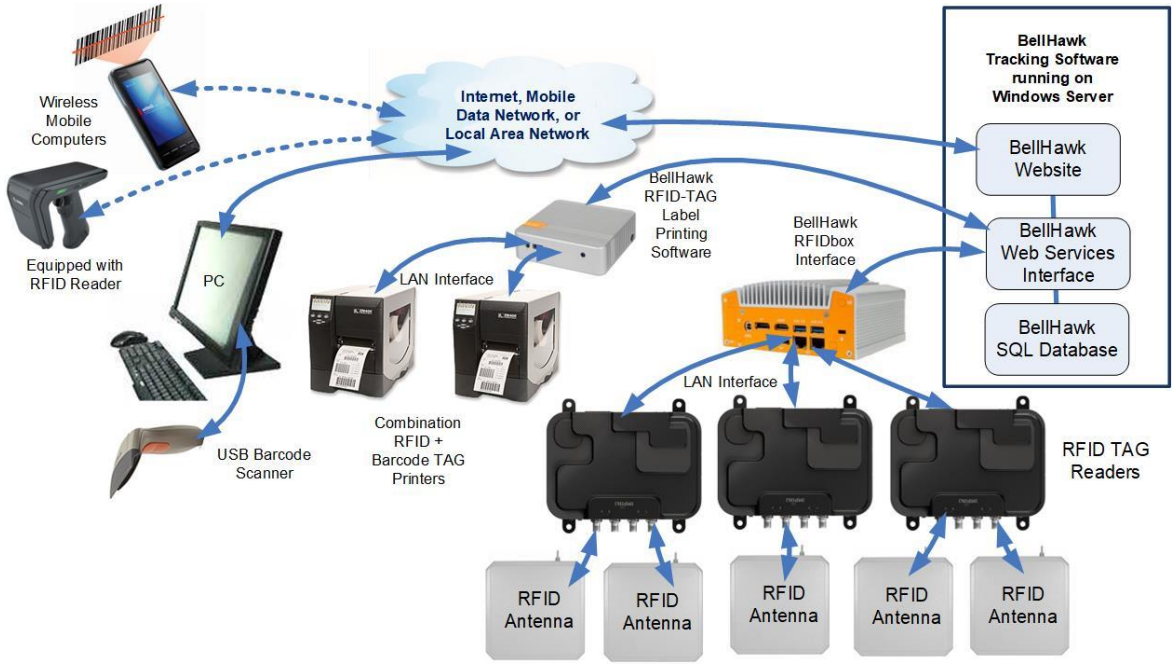
RFID technology is good for reading the identifying codes from many tags in the vicinity of the antenna providing they move slowly or are stationary for a substantial period of time. This describes exactly what happens in most work centers, where work-in-process materials arrive and spends many minutes or longer in each work center, which enables all the tags to be read with a high degree of accuracy.

RFID also works very well when there are a small number (preferably one) of tags attached to fast moving objects as they are being read. This is why RFID is used to identify cars and trucks driving through a toll gate over a highway at full speed or to record the loading of trailers using an RFID tag on each pallet but not RFID tags on its contents.

RFID is not good where operator interaction is required, as this defeats the whole purpose of using RFID, and the broadcast nature of RFID makes the whole process much more complicated than using barcode scanning or even impossible.

As a result, we conclude that RFID scanning on its own is not suitable for tracking work-in-process but, when used in combination with barcode scanning, can substantially reduce the amount of manual data entry required.

Integrating Barcode and RFID Scanning



The solution to many of the problems raised in the last section is to use an integrated barcode and RFID work-in-process tracking system, such as the BellHawk software from KnarrTek.

The BellHawk software uses the principle of License-Plate-Number (LPN) tracking to track containers of material using both barcode and RFID scanning to track containers of work-in-process materials, using an attached tracking barcode and/or RFID tag. This includes assemblies and the like with their own tracking barcodes and RFID tags.

BellHawk also extends the LPN principle to include nested containers, such as pallets containing many different items. Here we might have individually barcoded items, inside boxes with a tracking barcode on a pallet with a combination barcode/RFID tag.

BellHawk consists of a specialized website, with a web-services interface, and a SQL Server database to capture the tracking data in real-time. BellHawk can be run on a Windows Server computer at a client's own data center, or clients can use BellHawk on a server managed by KnarrTek at a secure data center in the USA.

Barcode tracking of the location of work-in-process materials is performed using PCs or tablets with external barcode scanners or mobile computers with integral scanners. All these devices perform their data capture through a web-browser interface, which eliminates the need to load or

maintain special software on the devices. It also enables data capture and viewing to securely take place on any web-browser based device anywhere there is an internet connection to the BellHawk server.

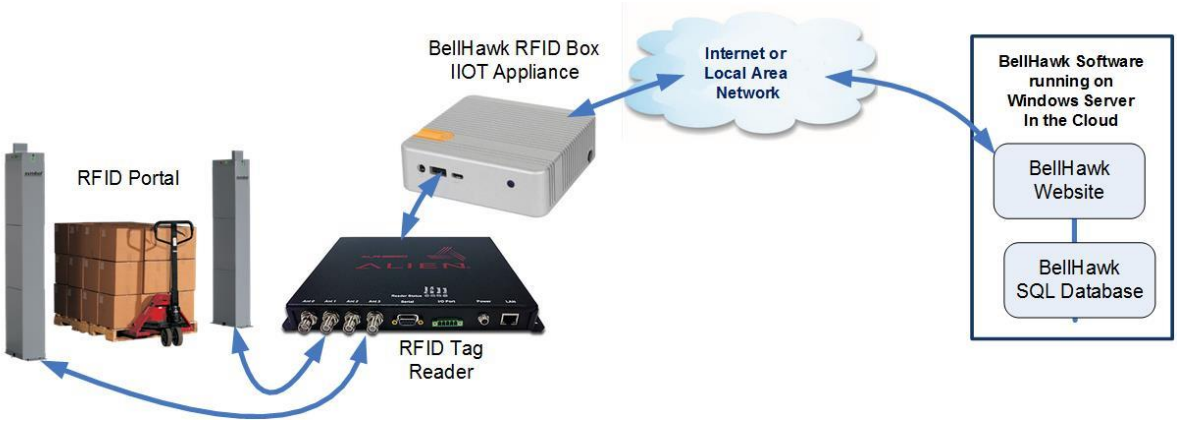
Through its barcode label printing appliance (BLPA), BellHawk can print out tracking barcodes on a wide variety of barcode label printers, in each manufacturing plant, over the Internet. This includes printing combination tracking barcode (2) and RID tags (1) on a combination barcode label printer and RFID tag encoder.

As shown above, the BellHawk RFIDBox remotely connects BellHawk to a set of RFID tag readers within a plant or warehouse, each of which can support 4 or 8 antennas, up to 100 feet from the reader.

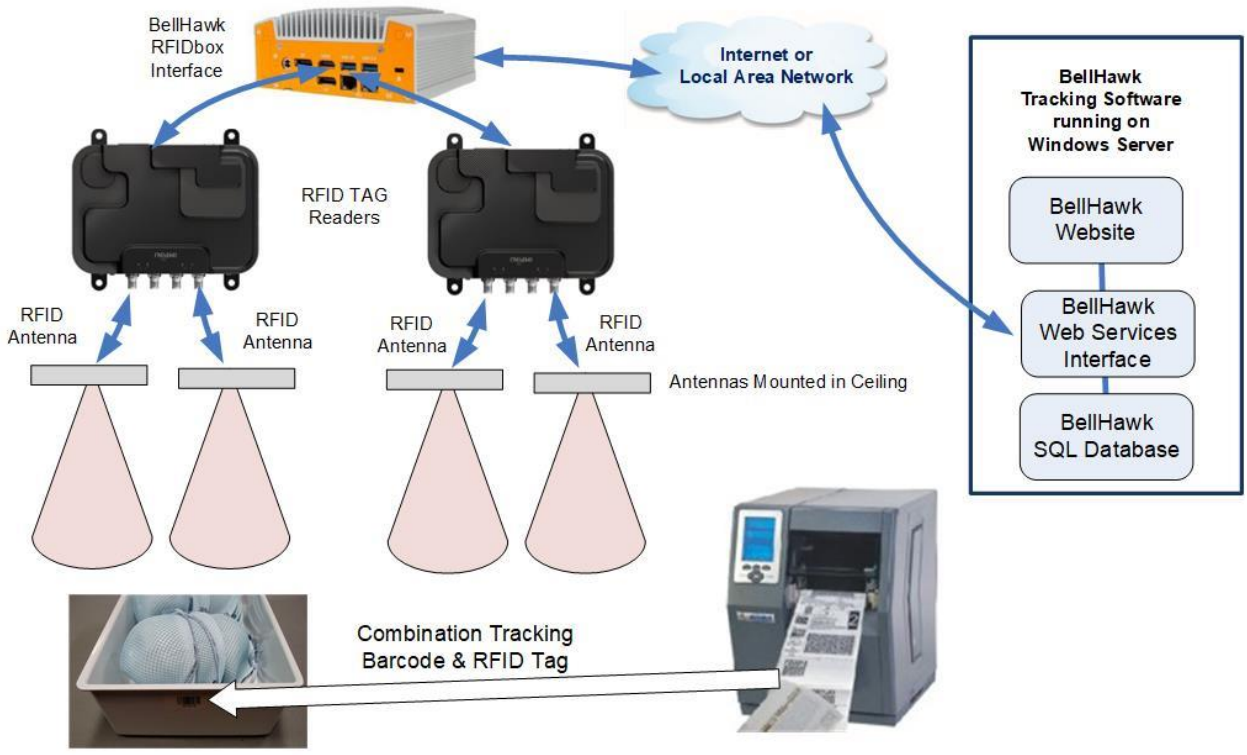
When an RFID tag comes within range of an antenna, the unique electronic product code (EPC) within the RFID tag is read automatically, and then translated by the RFIDBox into the movement of the container or item, to which the Tag is attached, to the location (such as a work-station) where the antenna is.

In this way, as an RFID tag attached to a work-in-process container or item moves through a plant or warehouse, its movement can be tracked as the Tag is "seen" by different antennas. This movement is then used to update the BellHawk tracking database so the location of materials can be tracked in real-time whether the tracking is done by barcode or RFID tag scanning or a mixture of both.

With BellHawk, antennas can be organized into a portal doorway.



But in most cases, for work-in-process tracking, it is much more convenient to place the antennas in the ceiling and track the movement of the RFID tags as they move into and out of the beams, as shown below.



Work-in-Process Materials Tracking

Barcode tracking labels and/or RFID tags can be placed on individual items or on totes in which materials are placed. In the case of totes, carts, trolleys, and vehicles, with permanent tracking barcodes and RFID tags, the RFID tags are encased in plastic and separate metal barcodes are used, sometimes with glass/ceramic covers are used to make sure they are not damaged in prolonged use.

When a batch of individually tagged work-in-process is to be tracked, the process starts out by printing out the barcode/RFID tags, one for each item to be tracked. This also results in an entry for each item being created in the containers table in the BellHawk, which is associated with the work order and/or customer order for which these items are intended.

Once the batch is released for production, the tags are activated, usually using a barcode scanner attached to a PC, as the work order is released to the floor. Thereafter the individual items are tracked as they flow from work center to work center, by the RFID antennas, which are mounted in the ceiling of each work center.

This enables individual components of a batch to be tracked individually, including through rework operations. We can also get a measure of how long each item spends in each work cell.

For smaller components, we place these parts in a reusable tote. When the process starts, we scan the barcode on the tote and associate it with the work order. Thereafter the location of the tote is tracked by RFID until the removal of the components of the tote is recorded by scanning the barcode on the tote.

Sometimes, such as in the manufacture of custom kitchen cabinets, parts are barcoded as they are cut out, and then placed on a cart for their further processing and assembly. Here we use barcode scanning to record the placing of barcoded parts on a cart but then use RFID to track the location of the cart, until we use barcode scanning to record the removal of materials from the cart.

Where the products being made go through many different forms, or it would be impossible for RFID tags or barcodes to survive the needed heat treating, chemical processing, or painting/coating operations, then a combination barcode and RFID tag is placed on the work-order jacket that contains the information for the work order being processed.

Also, typically separate ruggedized metal barcodes and RFID tags are used on totes, trolleys, carts and reusable pallets which are used to move materials. Sometimes these have the same LPN tracking number but often they do not. A system like BellHawk can use either tracking number, as needed, for barcode or RFID scanning.

Summary of Limitations

An RFID antenna will detect all RFID tags in its beam, so it is not very good at differentiating the location of each specific tag very precisely. RFID is great if all you want to do is to know which work-station the tag is in but it will not detect where in a work-station each tag is located.

Barcoding is very precise. I can scan a single item out of many in the same location, and precisely identify the item and its location down to a few inches (such as in a bin on a shelf). RFID cannot do this. But, on the other hand, people can forget to do barcode scanning.

RFID waves are blocked by metal and carbon fiber. Also, there is a limit to how many tags can be read in a specified time. Trying to read hundreds of tags in a box as it is carried at walking speed through an RFID portal will only result in about 75% of the tags being read, at best.

But for most work-in-process tracking, RFID tags stay in a work center for at least 5 minutes, resulting in a high read accuracy from an overhead antenna, even with a significant number of tags in the work center. Also, tags can be read though plastic, cardboard, leather, fabric, wood and many other materials and can be placed on the top of metal carts and the like.

Commentary

By combining barcode and RFID we can get the best of both worlds, combining the precision of barcode scanning with the automation of RFID scanning.

It is now often less expensive to use inexpensive RFID antennas rather than expensive mobile computers to do work-in-process (WIP) tracking. This also results in labor savings from manual scanning and eliminates having to train employees in how to do barcode data entry.

RFID cannot record what materials were used to make a product or the labor hours required. But, if all you want to do is to track where customer orders are on the production floor, RFID is generally a big win over barcoding for many WIP tracking applications.

The use of RFID gives near real-time visibility as to the status of each customer order, even if different parts of the order are at different stages of manufacture. We can also infer which operations have been completed, and when. Then BellHawk can use this information as input to its real-time scheduling algorithm, which advises employees which job or customer order they should be working on next, in order to make sure orders are delivered in time. Such scheduling information can be presented on a large screen display in each work center.

With BellHawk we can also use this information to send Email or text message alerts to managers, whenever an item gets "stuck" and is falling behind its planned production schedule. This is so that they can take corrective action before, and not after, it is too late.

Best of all organizations no longer need expediters to track down the status of customer orders. Customer support people can tell customers the real-time status of their order in real-time, while they are on the phone, instead of needing an expediter to "go find" the order somewhere on the shop-floor before the customer service person calls the customer back.

The other good news about RFID is that, because the data capture is largely automated, enabling organizations such as KnarrTek and its partners to implement a turnkey system with minimal time taken by managers and their staff away from their regular jobs to setup or learn the new system or to train and supervise their people in its use.

Finally, because it is automated, data capture by RFID does not require the data capture system to be adapted to accommodate the polyglot collection of languages spoken on many factory floors in the USA.

References

An Introduction to RFID on YouTube https://www.youtube.com/watch?v=bTQXzI7SRq0 by Zebra Technologies

RFID Handbook: Technology, Applications, Security and Privacy, Gordon Colbach, 2018; available from Amazon.com.

For details about how barcode scanning works, please see chapters 23, 24, and 25 of the BellHawk Software Handbook by Peter Green, 2021 which can be downloaded from www.KnarrTek.com or request a soft cover copy of this book from KnarrTek.

Author

This white paper was written by Dr. Peter Green, who serves as the Technical Director of KnarrTek Inc. Dr Green obtained his BSC (Hons) in Electrical Engineering and his Ph.D. Degrees in Electronics and Computer Science from Leeds University in England. Subsequently Dr. Green was a senior member of technical staff at Massachusetts Institute of Technology and a Professor of Computer Engineering at Worcester Polytechnic Institute.

Dr Green is a Systems Architect who is an expert in using real-time artificial intelligence methods to implement real-time Inventory Tracking and Operations Management systems for Industrial Organizations. He has led the implementation of over 100 such systems over the past decade. Dr Green also led the team which developed the BellHawk Job and Materials Tracking software and KnarrOps Operations Management Decision Support System.

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