Metso SmartTag – The Next Generation and Beyond
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ABSTRACT
SmartTag is a radio frequency identification (RFID) based technology designed to allow tracking of ore from its source through blasting, run-of-mine (ROM) pads, crushers, intermediate stockpiles and finally into the concentrator. This paper presents current developments and the future direction of the SmartTag™ ore tracking system, as well as presenting some case studies.

Successful applications of the SmartTag system have encouraged development to allow the system to be used in a wider variety of plants, in particular plants with finer crushing and screening stages. This presented Metso with a number of technological challenges, including RFID tag and antenna design. By reducing the traditional RFID tag diameter from 60 mm to 20 mm the RFID tags can now successfully pass through a secondary crusher. The new smaller RFID tags (referred to as mini RFID tags) have been used in some Process Integration and Optimisation projects with very promising results.

The results indicate that the miniature RFID tags have a higher survivability to blasting and through secondary crushing stages. Extending ore tracking further through the process allows more reliable linking of spatial data with time based process performance. Metso is looking at developing even smaller micro RFID tags, and is also investigating other applications for the SmartTag system, including ore tracking from the original source to the final destination (ie from the mine, through the plant and ports to the customer).

INTRODUCTION
Metso’s Process Technology and Innovations group is a world leader in mineral processing consulting. A significant amount of this consulting work involves process integration and optimisation (PIO) studies, which includes investigating the effects of drill and blast design and implementation on downstream processing. Critical to these studies is the ability to track specific ore into and through the plant. To increase the accuracy of this ore tracking, Metso Process Technology and Innovation (PTI) developed a system to track ore using radio frequency ID (RFID) transponders called SmartTag. Since its commercialisation in 2007 SmartTag (La Rosa et al, 2007) has been used in the majority of PTI’s consulting projects and several permanent systems have been installed worldwide.

The benefits of using SmartTag include:
- linking spatial mine data to time based processing data,
- increased confidence in ore blending,
- proactive process changes for known ore types, and
- accurate measurement of residence times in stockpiles and bins.

Since 2007 there have been significant advancements with RFID technology that has allowed PTI to extend the reach of SmartTag beyond secondary crushing to tertiary crushing and beyond. This has been achieved by drastically reducing the size of the SmartTags from a diameter of 60 mm to 20 mm.

The new smaller RFID tags (referred to as mini RFID tags) have been successfully used in several studies.
THE SMARTTAG SYSTEM AND RECENT CHANGES

The SmartTag system has been modified to incorporate the mini RFID tags. This section looks at the overall configuration of the system and the changes required to the system to incorporate the mini RFID tags.

The SmartTag system

A SmartTag RFID tag travels through a mine and mineral processing plant in the following steps:
1. the RFID tag and insertion location is logged using a hand-held computer or PDA;
2. the RFID tag is inserted into the ore (eg into a blasthole);
3. the RFID tag travels with the ore through digging, transport and processing;
4. the RFID tag is detected at detection locations (on conveyor belts) and the time and RFID tag recorded; and
5. the RFID tag data is loaded into a database and analysed as required.

To achieve this, the SmartTag system requires five main components, which are shown in Figure 1. The function of each component is explained below.

The first component in the SmartTag system is a PDA, which allows the initial RFID tag insertion process to become more efficient and accurate. Each RFID tag is added to the database using one of three options:
1. the RFID tag is associated with a GPS coordinate,
2. the RFID tag is associated with a predefined point (such as a blasthole), and
3. the RFID tag is associated with a new point, which can be accurately located later.

At present the system does not allow for high precision GPS but it can locate the nearest point in a series of predefined points, such as blastholes, and allow the user to associate RFID tags with these points.

The next component in the system, the antenna, is located at the conveyor belts. The antenna both induces a charge on the RFID tag and also receives a transmitted signal back from the RFID tag. The design of the antenna is decided by two parameters, which are its size and its robustness. The size of the antenna dictates the size and the strength of the field it radiates. For this application the area of field strong enough to charge the RFID tag should be as large as possible; therefore, the antenna used for the SmartTag system is the largest available for this frequency of RFID system.

An RFID reader then decodes the signal from the antenna and determines the ID of the RFID tag passing the antenna. Later versions of the readers also have auto-tuning capabilities which ensure that the maximum possible read distance is achieved at all time. In the SmartTag system the reader then transmits the ID using serial communications.
A data logging or buffer stage improves the reliability of the systems and also makes movable systems possible. The data logger receives data directly from the RFID reader, stores the IDs with the time they were detected and monitors vital system parameters, such as the tuning state of the antenna. The data logging stage also makes SmartTag less reliant on communication links (such as wireless) as the data is stored at the detection point until a link is established to the software applications. The critical communications links, like the one between the antenna and the reader, are all wired and very reliable.

The core of the SmartTag software is an SQL database. The database, located on a dedicated server, stores all the information about the detection points, detected RFID tags and original locations. There are several SmartTag software applications which either input data into the database or use the data to output information, including:

- **SmartTagServer** – reads data from the data loggers,
- **SmartTagPDA** – exchanges data with the PDAs and translates site blasthole layout diagrams, and
- **SmartTagRes** – calculates the residence time between two detection points.

The flow of information between the database, applications and physical hardware is shown in Figure 2.

Adding the mini radio frequency Identification tags

To expand the applications of SmartTag through and beyond secondary crushing a mini RFID tag was required. To incorporate the mini RFID tags into the SmartTag system, PTI faced two significant challenges; firstly, the reduced read distance, and secondly, making the mini RFID tags robust.

By reducing the size of the RFID tag, the size of the antenna in the RFID tag is also reduced. The size of the antenna in the RFID tag is directly proportional to the amount of charge that is induced, for a given field strength. Therefore, the read range of a RFID tag will be reduced as the size of the RFID tag is reduced. Through investigation, the 20 mm RFID tags were found to have an insufficient read range for the standard SmartTag installation. PTI trialled two methods for fixing this issue; one method was to use two antennas while the second method was to place the antenna closer to the RFID tags.

Both systems were tested at an iron ore mine, and Figure 3 shows how the antennas were installed. For the second approach, the antenna was placed underneath the conveyor belt (rather than above the belt) to reduce the distance between the tags and the antenna. Both approaches, dual antennas or closer antenna distance, were found to have similar detection capability. However, based purely on the ease of installation, a single antenna located under the belt, was chosen as the new standard installation method.
The second challenge faced in incorporating the mini RFID tags into the SmartTag system was how to protect them sufficiently to survive a blast. A method previously used by PTI to achieve this was to encase the RFID tags in a two part epoxy. The method works well for protecting the RFID tags, and although it is time consuming and expensive it is currently the preferred method for protecting the RFID tags. Different encasing materials, such as reinforced nylon, are still being investigated.

After encasing in epoxy, the mini-SmartTags have a diameter of 20 mm and are shown, with a standard SmartTag as reference, in Figure 4. The size of the mini RFID tags allows them to pass easily through screens with apertures down to 25 mm.

CASE STUDIES
The two case studies presented below were chosen to demonstrate applications where it is advantageous to use the mini RFID tags rather than the normal size RFID tags.

Case study 1 – secondary crushing circuit
As part of a wider PIO study a secondary crushing circuit was surveyed while being fed with a particular ore type. To determine the origin of the ore at any particular time and, most importantly, during the surveys SmartTag detection points were set up at three locations around the circuit. The three locations, as seen in Figure 5, were primary crusher product (CV1), secondary crusher feed (CV2) and secondary crusher product (CV3).

A total of 384 mini RFID tags were placed on eight polygons (a polygon is defined as different ore zones within the mine block model) after the blast, the ROM pad and trucks as they tipped ore into the primary crusher. Table 1 shows the original location of the RFID tags and the number of RFID tags placed in each location.

Results
Of the 384 RFID tags placed onto either the muck pile or on the ROM pad, 45 per cent were detected. However, if this is compared with the percentage of each polygon that had been excavated (Figure 6) by the end of the trial it is a fair conclusion that many of the RFID tags that weren’t detected were also not excavated during the trial. Note, that in some cases, a higher percentage of RFID tags were recovered compared to the percentage of polygon excavated, which could have been caused by the RFID tags not being distributed evenly across the polygon.
To determine the survival rate of the RFID tags during secondary crushing the number of RFID tags detected before and after the secondary crusher were compared. Of the 128 RFID tags detected before the secondary crusher, 97 were also detected after secondary crushing. However, as there were 52 RFID tags that were detected after the secondary crusher but weren’t detected before the secondary crusher the real survival rate is difficult to determine. By just comparing RFID tags detected at both detection points, it can be concluded that at least 76 per cent of the mini RFID tags survived secondary crushing although this number is likely to be much higher.

The screen immediately following the secondary crusher uses panels with 55 mm apertures, and as expected, none of the SmartTags were recycled back through the secondary crusher.

The primary application for SmartTag was to determine the origin of the ore being processed during the plant surveys. To this end, Figure 7 shows the origin of the RFID tags leading up to and immediately after the surveys were carried out.
From Figure 7 it is clear that the material in the plant at the time of the first survey was a mix of ores from ROM, POLY1 and POLY2. If the RFID tags had been evenly distributed across the polygons then a more accurate indication of blending would have been possible. The ore in the plant during second and third surveys was predominantly POLY4 with a small amount of POLY3. POLY4 and POLY3 are located adjacent to each other so some mixing would be expected.

In this application, where the plant feed included ore from ROM mixing and stockpiles, SmartTag was essential for determining which materials were processed in the plant at the time of the surveys. Mini SmartTags were required to enable the ore source to be tracked all the way through secondary crushing, and proved to be robust enough to survive both blasting and secondary crushing.

**Case study 2 – high pressure grinding circuit**

PTI was contracted to assess the performance of a circuit at a mine located in South America. The flow sheet for the operation including the locations of the SmartTag detection points is shown in Figure 8. The SmartTag system was used in this application to allow the PTI engineers to know exactly when a surveyed blast was being processed. For this reason, detection points were located on conveyor belts carrying the product of the primary crusher, the output of the stockpile and the high pressure grinding roll (HPGR) feed.

### TABLE 1

SmartTag placement details.

<table>
<thead>
<tr>
<th>Original location</th>
<th># Tags</th>
<th>Original location</th>
<th># Tags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks</td>
<td>30</td>
<td>POLY4</td>
<td>40</td>
</tr>
<tr>
<td>ROM</td>
<td>40</td>
<td>POLY5</td>
<td>20</td>
</tr>
<tr>
<td>POLY1</td>
<td>40</td>
<td>POLY6</td>
<td>40</td>
</tr>
<tr>
<td>POLY2</td>
<td>40</td>
<td>POLY7</td>
<td>34</td>
</tr>
<tr>
<td>POLY3</td>
<td>40</td>
<td>POLY8</td>
<td>60</td>
</tr>
</tbody>
</table>

![FIG 6 - Comparison of percentage of radio frequency identification tags detected and percentage of polygon excavated.](image-url)
As the blast was being audited RFID tags were deposited into 68 blastholes, using an even split of 34 normal RFID tags and 34 mini RFID tags. A further 50 RFID tags were later added into the trays of 25 trucks at the primary crusher, using one of each of the two different types of RFID tags in each truck. Figure 9 shows the layout of the holes in the blast and the type of RFID tag that each hole received.
Results

A total of 68 tags were identified at the primary crusher product detection point, 23 at the stockpile output detection point and 41 at the HPGR feed detection point. Figure 10 shows the cumulative number of RFID tags detected over time at each detection point.
The stockpile antenna was installed above the belt rather than under the belt and was decommissioned by an oversized rock on 16 March. This explains why there was no detection of RFID tags after this date.

The blast occurred on 22 January and the excavation of the muck pile between 15 - 17 March (two months later). The SmartTag system monitored the material passing through the process over a period of 30 hours. During this period, a total of 67 different RFID tags were detected; 33 were of normal size and 34 were mini RFID tags. Table 2 shows the number of RFID tags detected for each detection point, the RFID tag type and the origin (mine or truck).

As stated earlier the stockpile antenna was damaged and this truncated the results in Table 2.

### TABLE 2
Detected radio frequency identification tags at each detection point.

<table>
<thead>
<tr>
<th>Tags</th>
<th>Primary crusher product</th>
<th>Stockpile</th>
<th>HPGR feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 mm, truck</td>
<td>22 of 25</td>
<td>14 of 22</td>
<td>11 of 22</td>
</tr>
<tr>
<td>20 mm, truck</td>
<td>21 of 25</td>
<td>3 of 21</td>
<td>15 of 21</td>
</tr>
<tr>
<td>60 mm, mine</td>
<td>11 of 34</td>
<td>2 of 11</td>
<td>3 of 11</td>
</tr>
<tr>
<td>20 mm, mine</td>
<td>10 of 34</td>
<td>1 of 10</td>
<td>8 of 10</td>
</tr>
<tr>
<td>Total 60 mm</td>
<td>33</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Total 20 mm</td>
<td>31</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>20</td>
<td>37</td>
</tr>
<tr>
<td>Recovery 60 mm total</td>
<td>55.9%</td>
<td>48.5%</td>
<td>42.4%</td>
</tr>
<tr>
<td>Recovery 20 mm total</td>
<td>52.5%</td>
<td>12.9%</td>
<td>67.6%</td>
</tr>
</tbody>
</table>

For the stockpile and HPGR feed detection points, the recovery was calculated with reference to the 64 distinct RFID tags detected at the primary crusher. Of the normal RFID tags detected at the primary crusher detection point, 42.4 per cent were then detected at the HPGR feed detection point; whereas for the mini RFID tags 67.6 per cent of tags detected at the primary crusher were also detected at the HPGR feed. This shows that the survival of the mini RFID tags in the circuit is higher than the normal RFID tags. In a hypothetical situation, where the secondary screening mesh is smaller than 50 × 50 mm, normal RFID tags certainly would not reach the HPGR.

The detection of RFID tags at the primary crusher was also affected by the removal of the SmartTag system before the entire blast was processed (for logistical reasons).

The RFID tags were used to track the material during an optimisation campaign at the plant. The blast map in Figure 11 shows that during the plant survey the material that fed the plant originated from the central portion of the blast.

An unexpected result was that three of the mini RFID tags were twice detected at the HPGR feed detection point. An explanation for this is that they survived the HPGRs and returned with the circulating ore (screened to +5 mm). The transit times of these three RFID tags are shown in Table 3. The differences in the transit times in the circuit are probably due to different levels in the HPGR feed bins.

This case study was originally presented, in more detail, by Nozawa et al (2009).

### TABLE 3
Transit time through the high pressure grinding roll circuit.

<table>
<thead>
<tr>
<th>ID tag</th>
<th>Transit time</th>
</tr>
</thead>
<tbody>
<tr>
<td>335</td>
<td>86 min</td>
</tr>
<tr>
<td>224</td>
<td>23 min</td>
</tr>
<tr>
<td>251</td>
<td>2 min</td>
</tr>
</tbody>
</table>
CONCLUSIONS

PTI has successfully incorporated a smaller or mini RFID tag into their SmartTag system. The changes to the system installation are minor and increase the reliability of the system as a whole. In several examples the mini RFID tags have proven to be, on average, more robust than normal sized RFID tags. PTI envisage that with the successful incorporation of the mini RFID tags into the SmartTag system it will allow applications for the system to be expanded. These new applications could include a wider use in the iron ore industry where size is the critical material quality. PTI is now working on proving the reliability of the next size of RFID tags, the even smaller micro RFID tag, which can pass through a 10 mm mesh screen. Figure 12 shows the new micro RFID tag in a 6 mm screen.

FIG 11 - Detected radio frequency identification tags during the period of sampling.

FIG 12 - Micro radio frequency identification tag in 6 mm mesh.
With the decreasing size of RFID tags and the development of SmartTag into a truly distributed system SmartTag can be extended past the mine to cover the whole minerals supply chain. Detection points can now be located in the plant, the port and even at the location of the customer, such as a blast furnace.

REFERENCES


Nozawa, E, Corsini, J, La Rosa, D, Valery, W and Allport, A, 2009. SmartTag system improvements for increase of ore tracking performance from mine to mill and other applications, in Proceedings Tenth Brazilian Symposium on Iron Ore, Ouro Preto (Brazilian Association of Metalurgy, Materials and Mining).