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# COMPARATIVE STUDY OF RFID TAGS FOR METALLIC PRODUCTS IN INVENTORY TRACKING SYSTEM

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**ABSTRACT:**

**It has always been challenging and critical to implement Radio Frequency Identification tags and technologies for inventory tracking for metallic product because of interference of metal on RFID signals, rough environment especially in presence of extreme moisture and high temperature in manufacturing units. A very extensive research and experiments are needed, to choose Radio Frequency Identification tags for metallic products in manufacturing. Therefore by comparing various RFID technologies, its features and performance we will try to find out availability and feasibility of Radio Frequency Identification Tags which are most suitable, cost effective and efficient for Metallic Products especially in harsh manufacturing environment.**

**This paper presents a comparative study where we will assess and compare various features and performance parameters of Radio Frequency Identification tags available in the world and review their technology, implementation, working efficiency and cost effectiveness in depth so as to get a clear understanding about tag's performance and feasibility on Metallic product. It will help in taking better decision in the selection of Radio Frequency Identification Tags for Metallic products for inventory tracking system.**

**Keywords: RFID; tags; inventory; tracking; metallic; traceability.**

## I. INTRODUCTION:

Recently, radio frequency identification technology has grown from complicated technology into mainstream applications which are used for faster handling of manufactured goods and various materials. Radio Frequency Identification Technology empowers identification from a distance, and unlike popular bar-code technology, it does so without keeping the product in a line of sight. RFID tags can contain large amount of product data than bar codes like unique IDs , manufacturer, type of product, batch no and even measure environmental factors like temperature, moister etc. Furthermore, Radio Frequency Identification systems can identify many different tags located in the same common area or premises without human assistance [1].

Radio Frequency Identification tags are mainly categorized into two types 1) Active Tag and 2) Passive Tag though there is also another type called Semi-Active Tag but it is scarcely referred. Active tag works on integrated battery energy source. It has its own power source which is usually integrated battery or sometime external power source. Therefore it is comparatively costlier than passive tag. On other hand passive tag receives its power from RFID reader. Hence cost wise it is cheaper than active tags. But it work in smaller range whereas active tag can work for larger area.

## II. RFID TECHNOLOGY:

A Radio Frequency Identification system includes of tags (transponder) with an antenna, a reader (transceiver) with an antenna, and a host terminal. Figure 2 shows these components. The Radio Frequency Identification reader behaves as a receiver and transmitter and transmits an electromagnetic field that ''wakes-up'' the tag and supplies the power needed for the tag to operate [2].


A Radio Frequency Identification tag is a memory device that is portable and located on a chip that is covered by a protective shell and can be embedded in any other product or object which stores multiple information about the product. Tags has a small integrated circuit chip, along with an antenna, to enable it to receive and respond to radio frequency information from a Radio Frequency Identification reader. Radio Frequency Identification Tags can be categorized as Read-Only or RO, Write Once Read Many or WORM, and Read–Write or RW in which the storage capacity of their inbuilt memories differing from a couple of bits to thousands of bits. Radio Frequency Identification tags can be bifurcated into active tags

(battery powered) and passive tags, which are powered only by the magnetic field emitted from the reader, and, therefore, have an unlimited lifetime. There are also ultra-low-cost tags, known as chip less tags, although they have a short read range. The ranges for Reading and writing depend on frequency which they operate on (low, high, ultra high, and microwave). Low frequency systems normally operate at 124 kHz, 125 kHz or 135 kHz. The systems operate with High frequency at 13.56 MHz and ultra high frequency (UHF), and use a band ranging from 400 MHz to 960 MHz [3]. Tags which work Ultra High Frequency (UHF), do, have longer reading ranges than tags which are operating at other frequencies. Similarly, active tags usually have longer reading ranges than passive tags. Tags also differs in the amount of information they can hold, life expectancy, ability to recycle itself, method of attachment, usability, and the cost. The distance of communication between RFID tags and RFID readers may suffer a substantial decrease due to disturbances by any metal objects and/or moisture in the locality that is on the shop floor or manufacturing plant. Because Active tags have internal battery sources, it has a shorter lifespan of approximately two to ten years [4].

## III. ACTIVE RFID TAG VS PASSIVE RFID TAG:

### A. Active RFID Tag:

Active RFID systems consist of three main parts: a reader or interrogator, antenna, and a tag. Active RFID tags have its own power source that is usually an internal battery that makes them capable of reading from extremely long distance and large memory capacity.


Example of an extremely rugged Active RFID tag

Usually, active RFID tags are supplied by a battery that provides power to it around 2 – 5 years. But when the battery gets exhausted, the active tag will needed to be replaced. May be in future the fixed battery may be replaced with replaceable batteries which will be a cost effective and convenient. The overall functionality of the system may mainly depend on the type of tag chosen for particular application. Basically, two types of active RFID tags are available – transponders and beacons.

Transponders – this system consist of an active transponder tag, and the RFID reader sends a signal first, this active transponder then sends a signal back to RFID reader with the concern information. Because these transponder tags uses very less battery power and saves battery life when the tag is out of range of RFID reader, they are very efficient, and power saving. Transponders are prominently used under their secure access control environment and in in-house inventory systems.

Beacons – on other hand is a system that utilizes an active beacon tag, where the RFID tag will not wait to receive the reader's signal. Rather as its name suggest, the tag will 'beacon' or send out its specific information periodically for say every 3 to 5 seconds. These types of tags are extensively used by the oil, gas industries, or mining and cargo industries for tracing their products. Though the capacity of Active tag's beacons is to be readable from hundreds of meters away, but, usually it is recommended to save battery life, we should set it to a convenient lower transmit range which typically may cover around 100 meters as a readable range [5].

### B. Passive RFID Tag:

On contrary to active RFID tags, the passive RFID tags consist of two main parts: the tag's antenna and the microchip or integrated circuit. Because it is passive instead of sending signal, the passive tags wait for RFID reader to send a signal to it. Then the RFID reader sends energy to RFID tags' antenna which it converts the energy into an RF wave and sent it into the red zone. And once the tag is read within the red zone area, the internal antenna of RFID tag then draws in the energy from the RF waves. The energy flows from the tag's antenna to the chip and gives power to the chip which in turn generates a signal back to the RF system. This complete process is called backscatter. The change in the electromagnetic or RF wave or backscatter, is detected by the RFID reader (though the antenna), which is responsible for interpreting the information.

Example of a roll of Passive RFID inlays

As mention above the Passive RFID tags do not have its own internal power source, and it only consist of an IC Chip and internal antenna; this basic structure of passive RFID tag is commonly called as an RFID inlay. Though many other types of passive RFID tags do exist in the industry, but all most all tags can be mainly categorized into two main categories that is an inlays tags or hard tags. The Hard RFID tags are made up of plastic, metal, ceramic or rubber material they last for a long time. Passive RFID tags are manufacture is variety of shapes and sizes. It can also be designed to suit or to fit into the specific design of

product on a specific material, or it may be design according to specific function and application.

The passive hard tags have been divided into different groups. Where, some tags may falls into two or more groups.

**High Temperature** – Healthcare industries, usually track the number of cycles that instruments going through in arduous sterilizers. There for this kind of application a specific passive RFID tags are to be designed that can withstand very high temperatures and can be used for those types of applications.

**Rugged** – Also in a situation like outdoor environments or very tough warehouses and other setups that have to face snow and ice, dust and debris, continuous vibrations or the crushing forces felt beneath the tractor wheel needs a tag that can sustain all these condition and withstand the environment. Therefore, a highly rugged passive tag is required to be made to it can work with these applications.

**Size** – Depend on the product size and type we also need different size constraints for different application when tracking these small or large items. As size is one of the most important aspect when selecting an RFID tag, because there are tremendous variety of different sizes available.

**Materials** – Specially when we consider of using Tags on metal products or asset for tracking it, we have to be depend on only UHF metal-mount tags. Because these tags are designed in a way to mitigate the issues UHF RFID encounter around metal.

**Embeddable** – If due to wear and tear issues a tagging of an products becomes a real problem for particular applications, the best option is an embeddable tags that can be fit into small clefts and be covered by strong adhesives and coatings and laminates to keep it safe [5].

All passive RFID tags necessarily do not operate using same frequency. There are three prominant frequencies within which they usually can operate. To determines the read range, an attachment materials, and application

Table 1: Comparison of Tag Types

| | Low Frequency (LF) | High Frequency (HF) | Ultra High Frequency (UHF) |
|---|---|---|---|
| **Frequency Range:** | 125kHz, 134.2kHz | 13.56 MHz (Global) | 865 – 928 MHz (Regionally dependent) |
| **Typical Read Range of TSL products:** | Up to 8cm for Texas Instruments 32mm glass, up to 7cm for EM4102 50mm disc (transponder and antenna dependant) | Between 5cm and 8cm (transponder and antenna dependant) | Between 1.5m and 2.0m (transponder and antenna dependant) |
| **ISO Standards:** | ISO 11784, ISO 11785, ISO 18000-2 | ISO 15693, ISO 14443 | ISO 18000-6C |
| **Data transmission rate:** | Slow data transmission rate | Higher data read rate than LF tags | Fast data transmission rate |
| **Multiple reads capability:** | Usually only single reads | Good | Excellent multiple reads capability |
| **Supported Tags:** | A wide variety of manufacturer specific transponders including NXP (Philips) HITAG, EM Microelectronic and Texas Instruments | A wide variety of transponders at 13.56 MHz including ISO 15693, ICODE (I & II) and the complete Mifare family of ISO14443 (A & B) | EPC Class 1 Gen 2 Transponders |
| **Tag Suppliers:** | NXP, Sokymat, EM Microelectronics, Texas Instruments | ACG, HID, Toshiba, iDTRONIC, Invengo, Tagsys, UPM Raflatac, X-ident and many more | Alien, Avery Dennison, Avonwood Eureka , Caen, Confidex, iDTRONIC, Intermec, Invengo, Omni-ID, Toshiba, TI, UPM Raflatac, X-ident and many more |
| **Tag Cost:** | Relatively expensive | Varies depending on type of tag | UHF tags can be very low cost (at high volumes) due to the simpler manufacturing process . |
| **Reader Cost:** | Lower (more established technology) | Lower (more established technology) | Higher (newer and more complex technology) |
| **Reader Antenna size:** | Short range mobile LF readers require only a small antenna | Short range mobile HF readers require only a small antenna | Mobile UHF reader antennas are relatively large, reduced antenna sizes can be used if compromising on read range |
| **Read field:** | Small Read Field, but easier to define – ideal for reading unique items at close range | Small Read Field, but easier to define – ideal for reading unique items at close range | Read field is much larger than LF or HF, but the radio waves can bounce off objects farther away. Excellent performance in environments with high tag density |
| **Tag memory capacity:** | Smaller memory sizes in comparison to passive HF RFID tags | Capable of relatively high memory capacity, typically 256 bits to 8 Kbytes | Smaller memory sizes in comparison to passive HF RFID tags, typically 96 bits to 1 Kbits |
| **Performance in close proximity to liquids and metals:** | Performance unaffected by surrounding water or metals | Proven track record of reliable and accurate performance of HF tags on liquids and metals | Unless properly engineered, UHF tags can be detuned by proximity to metals, liquids and human tissue. However, mount on metal UHF tags exist and in some cases outperform their HF counterparts |
| **Security:** | Low encryption capabilities | Multiple encryption/security features | Read/write protection and anti-cloning, low encryption capabilities |

options we need to consider the frequency range, along with other factors, precisely.

- 125–134 KHz – Low Frequency (LF) – Though is an very long wavelength but is has usually a short read range, about 1–10 centimeters. This frequency is normally used for tracking animal at it is not affected by water or metal.
- 13.56 MHz – High Frequency (HF) & Near-Field Communication (NFC) – It is a medium wavelength having a typical read range of about 1 centimeter up to 1 meter. This type of frequency is normally used with applications that do not need a long read range like data transmissions, access control applications, DVD kiosks, and in passport security.
- 865–960 MHz – Ultra High Frequency (UHF) – It is a short, with high-energy wavelength of about 1 meter which provides a long read range. Passive UHF tags is capable to read from an average distance of about 5-6 meters, but larger UHF tags normally achieves read range up to 30+ meters with an ideal conditions. This frequency is usually used with race timing, tracking IT asset, file tracking, and managing laundry as all these applications normally need more than a meter of read range.

As a common rule we derive, a higher frequencies will have shorter, higher energy wavelengths and, therefore, it has longer read ranges. However, generally speaking, the higher the frequencies, the more issues an RFID system will have around non-RFID-friendly materials like water and metal [5]. Please refer to Table 1 for comparative properties of LF, HF, and UHF types of tags.

## IV. ANALYSIS OF RFID TAG PRODUCTS BY MANUFACTURER:

Selecting right RFID tag for a metallic product is very complex procedure and a big challenge. Firstly, there are not, comparatively, many manufacturers who manufacture RFID Metallic Tags which can stand under harsh, metallic and humid environments. Secondly, selecting a right RFID for a metallic product from available manufacture requires great deal of understanding of applying product along with technical feasibility with the costing aspect of RFID tag product. From almost more than 30 manufactures of RFID tag product we have selected these 5 manufacturers and 2 online stores to analyze their RFID tag products to be used for our metallic product from automobile industry. We have analyzed their product on the basis of their features, performance and cost, illustrated here in the form of tables ( i.e. Table 2,3,4,5 and 6) indicating their features cost , specifications and performance.

Following Table 2 illustrates the price and features of RFID Tags available on two major online stores atlas RFID store and Ali express [6],[7].

Table 2: RFID tags compared from online stores[6],[7]

| ACTIVE TAGS UF | RELATIVE HUMIDITY | HIGH TEMPERATURE | ELECTRO. EFFECT | DURABILITY | COST |
|---|---|---|---|---|---|
| 1-XTREME TAG FLEX | 40%-80% | -40 TO 160C | NO | 241 BAR PRESSURE, 3500 PSI WATER | $19 PER TAG |
| 2-XTREME TAG DUO | 40%-80% | -40 TO 160C | NO | 241 BAR PRESSURE, 3500 PSI WATER | $19 FOR TWO |
| 3-UHF LAUNDARY TAG-04 | 100% | -25 TO 120C | NO | DUARABLE WITH WATER BUT NOT WITH TEMP. | $0.6 PER TAG |
| 4-OMNI-ID DURA 3000 | - | -40 TO 165C | NO | DURABLE WITH RESPECT TO MIL STD 810-G | $49 PER TAG |
| 5-CC-71 EMBEDDED TAG | 100% | -50 TO 200C | NO | 2500 PSI MINIMUM | $39 FOR 10 |
| 6-CONFIDEX SILVERLINE CLASSIC | 50% | -35 TO 85C | AVOID ACETONE | TESTED FOR 65 HOURS IN 1 METER DEEP WATER | $49 PER TAG |

We have analyzed RFID tag products from Shenzhen Jietong Technology Co. Ltd. from China who are professional UHF RFID manufacturer. Their tags details are given in table 3, compiled from www.jtspdeedwork.com [10].

Table 3:www.jtspeedwork.com [10].

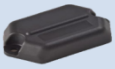
| NAME | UHF Mini Metal Tag JT-P1002 | UHF Mini Tool Tag 10*3MM | RFID UHF Metal Tag JT-2208 | UHF Metal Tag Gun Management 36*13 |
|---|---|---|---|---|
| PHOTO |  |  |  |  |
| WORKING FREQUENCY | 860-960MHZ | 860-960MHZ | 860-960MHZ | 860-960MHZ |
| DIMENSION | 10x02*1.5m | 10x03*1.5m | 22x8x2m | 36x13x3 mm |
| PROTOCOL | ISO 18000-6C | ISO 18000-6C | ISO 18000-6C | ISO 18000-6C |
| CHIP | Impinj M4QT/Alien Higgs3 | Impinj M4QT/Alien Higgs3 | Impinj M4QT/Alien Higgs3 | Impinj M4QT/Alien Higgs3 |
| STORAGE CAPACITY | EPC 96 bits, User memory 512bits | EPC 96 bits, User memory 512bit | EPC 96 bits, User memory 512bit | EPC 96 bits, User memory 512bit |
| WORKING TEMPERATURE | -40℃- 140℃ | -40℃- 140℃ | -40℃- 140℃ | -40℃- 140℃ |
| MATERIAL | PCB | PCB | PCB | PCB |
| INSTALLATION | 3M adhesive | 3M adhesive | 3M adhesive | 3M adhesive |
| LIFE | 100,000 times, 10 years | 100,000 times, 10 years | 100,000 times, 10 years | 100,000 times, 10 years |
| NET WEIGHT | 4g/pcs | 4g/pcs | 4g/pcs | 4g/pcs |

A North American Company called GAO RFID Inc. is a leading company providing more than 1000 types of RFID tags and more than 300 RFID products since more than 20 years. Their RFID tag products with specification and features are illustrated in table 4 and 5 [8].

Table 4:www.gaorfid.com [8].

| NAME | UHF RFID Anti-Metal Tag JT-8020 | Flexible Anti-Metal Tag 112*24 | UHF RFID Anti-Metal Tag 95*25 | UHF 860-960 MHz Harsh Environment RFID Tag |
|---|---|---|---|---|
| PHOTO |  |  |  |  |
| WORKING FREQUENCY | 860-960MHZ | 860-960MHZ | 860-960MHZ | 860-960MHZ |
| DIMENSION | 80x20x3mm | 112*24*1.5mm | 22x8x2m | 210× 110× 20.8 mm |
| PROTOCOL | ISO 18000-6C(GEN 2) | ISO 18000-6C | ISO 18000-6C | MIL STD 810-F |
| CHIP | Impinj M4QT/Alien Higgs3 | Impinj M4QT/Alien Higgs3 | Impinj M4QT/Alien Higgs3 | Impinj M4QT/Alien Higgs3 |
| STORAGE CAPACITY | EPC 96 bits, User memory 512bits | EPC 96 bits, User memory 512bit | EPC 96 bits, User memory 512bit | EPC 96 bits, User memory 512bit |
| WORKING TEMPERATURE | -25℃- 140℃ | -20℃- 100℃ | -40℃- 140℃ | -40 ℃ to 85 ℃ |
| MATERIAL | PCB | PCB | PCB | PCB |
| INSTALLATION | 3M adhesive | 3M adhesive | 3M adhesive | 3M adhesive |
| LIFE | 100,000 times, 10 years | 100,000 times, >10 years | 100,000 times, 10 years | 100,000 times, 10 years |
| NET WEIGHT | 4g/pcs | 4g/pcs | 4g/pcs | 300g/pcs |

Table 5:www.gaorfid.com [8].

| Name | UHF 860-960 MHz RFID Rugged RoHS Lock Tag | UHF 860-928 MHz RFID Bolt Tag | UHF 433 MHz Active Industrial Asset RFID Tag | UHF 900 MHz Prox RFID Tag |
|---|---|---|---|---|
| Photo |  |  |  |  |
| Operating Mode | Passive | Passive | Active | Passive |
| Frequency Range | 865 MHz to 928 MHz | 866-925 MHz | 866-925 MHz | 902 MHz to 928 MHz |
| Read Range | 3 m | Up to 1.5 m | 1 to 100+ meters | Up to 3.0 m |
| Protocol | ISO18000-6C, EPC Class 1 Gen2 | EPC Global Class 1 Gen2ISO18000-6C | ---------- --- | ---------- - |
| Protection Rate | IP67 | ---------- ---- | ---------- ---- | ---------- ----- |
| EPC memory | up to 240 bit | 96bit | 96bit | 512 bits |
| Extended memory | 512 bit | 512 bit | 512 bit | 512 bits |
| EPC memory content | Unique EPC number encoded by default | Unique EPC number encoded by default | Unique EPC number encoded by default | Unique EPC number encoded by default |
| Operating Temperature | -30 °C to 70 °C | -30°C to +85°C | -30 °C to 60 °C | -20 °C to 55 °C |
| Dimension | 73x 15 x 17 mm | 10X16 mm | 68 x 36 x 16 mm | 54.5 × 16 × 7.8 mm |

Finally, we analyzed RFID Tags manufactured by AXEM Technology, France who are specialized in RFID, NFC And Mobile Technologies. Their product analysis is presented in table no. 6 [9].

Table 6:www.axemtec.com [9]

| Name | Rivet | Retro | Cart | TROI Armored 300c |
|---|---|---|---|---|
| Photo |  |  |  |  |
| Operating Mode | Active | Active | Active | Active |
| Frequency Range | 860 - 960 MHz | 860 - 960 MHz | 860 - 960 MHz | 865-869 MHz |
| Read Range | 7.6 Meters | 4.3 Meters | 4.3 Meters | 1 – 2 meters |
| Protocol | UHF, EPC Class 1 Gen 2, ISO 18000-6C | UHF, EPC Class 1 Gen 2, ISO 18000-6C | UHF, EPC Class 1 Gen 2, ISO 18000-6C | EPC Class 1 Gen 2, ISO 18000-6C |
| Protection Rate | IP69K | IP69K | IP69K | IP69K |
| EPC memory | 128 bit | 128 bit | 128 bit | 128 bit |
| Extended memory | ---------- | ---------- | ---------- | 240 bit |
| EPC memory content | Unique EPC number encoded by default | Unique EPC number encoded by default | Unique EPC number encoded by default | Unique EPC number encoded by default |
| Operating Temperature | -40C to 85C | -40C to 85C | -40C to 85C | -50ºC to +300ºC |
| Dimension | 155 L x 37 W x 6 H (mm) | 86 L x 25 W x 4 H (mm) | 162 L x 25 W x6 H (mm) | 54.2 L X 44.6 W X 14.6 H(mm) |

Above details, illustrated in the table, have also been comparatively tested under the guidance of information received from various other resources like www.rfidjournal.com, www.omni-id.com etc. The product from OMNI-ID, Japan also has durable range for metallic product like Omni-iD™ ultra. The Ultra is the first passive UHF RFID tag with a read range of 100 feet on metal. It has comparatively lower cost and longer lifetime [11].

Finally we can say, while selecting an RFID tag for metallic product or any other product, in general, we must check the following points considered for our research:

1- We must check the material whether it is a metal or not.
2- The interference of water, high temperature, humidity and harsh surface impact.
3- Approximate reading distance from the product.
4- The frequency range of tag, because cost is also based on its reading frequency.
5- Whether Active or Passive?
6- Memory type it holds and capacity.
7- Read/Write and Programmability.
8- Last, but not least, its security feature.

The above table 7 illustrates the best general criteria while choosing RFID tags, for any types of product. But penetration of materials and data transfer rate is crucial factor in decision making so far, as metallic product is a concern. Success and failure of RFID is mainly dependent on these two factors if RFID is being implemented on metallic product.

## V. CONCLUSION:

After the detail study and analysis on RFID Tags, its technology and manufactured product, we have come to the conclusion that considering harsh environment of metallic product manufacturing unit, presence of metal, humidity and high temperature, RFID metal tags with capability of withstanding high temperature, high and varying humidity and presence of metal which disturbs the signals can only be used. On other hand, the RFID Tags made with plastics, fiber must be discouraged, though some fiber may withstand higher temperature. There is no question of using any paper-based RFID tag on metallic product. RFID Tags with frequency range of 860 and above, which can sustain humidity above 50$^{o}$ and temperature above 100$^{o}$C could perform well and are suggested for implementation on metallic products. But, on the contrary, lower frequency range below 134 kHz performs well with metal and water and their only disadvantage is that they can read only within 1m distance.

Table 7: RFID Tag selection criteria [12]

| Frequency | LF<br>120 ~ 134 kHz | HF<br>13.56 MHz | UHF<br>850 ~ 960 MHz |
|---|---|---|---|
| Read Range | 0.5 ~ 1 m | < 1 m | > 3 m |
| Cost | Relatively expensive | Less expensive | Least expensive |
| Penetration of Materials | Excellent ← → Poor | | |
| Affected by Water? | No | To some extent | Yes |
| Antenna | Coil | Coil | Dipole, Slot |
| Data Rate | Slower ← → Faster | | |
| Reading Multiple Tags | Poor | Good | Very Good |
| Applications | Immobilisers, industrial-identification | "Pharma", libraries brand protection, tickets, payments, passports | Pallet/case tracking, tolls bag-gage tracking, **PCB tracking** |

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