RFID Portal System Design – Guidance

Guidance on a system design using the Times-7 portal focused on stray-read elimination for reading at ingress and egress dock-door installations in warehouse environments.

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1. Overview

This document provides a system design overview for an RFID portal reading pallets of assets at three levels: pallet level, carton level, and item level, at ingress and egress points within a busy warehouse environment. Two adjacent dock-doors with installed Times-7 portals are used as the example system.

The central challenge addressed by this system is the elimination of stray reads, tag reads that occur between antenna gates or reads captured by an adjacent gate that do not belong to the current portal crossing event. The two back-to-back gates are placed across adjacent dock-door openings and must operate simultaneously without cross-contaminating each other's read sessions. ETSI lower-band and reader-tag communication technique is used in the example, as fixing the frequency band is supported and adoption is widespread.

Core design goals: assign every EPC / UII read to the correct gate; correlate reads across pallet, carton, and item hierarchy into a unified event; and auto-commit clean manifests to the Warehouse Management System (WMS) while routing discrepancies to an exception queue for error management (often a secondary scan).

Important Note: If using FHSS, typical for **FCC** band readers, then ignore point 2. With FHSS, interference will occur very infrequently for a single cycle when clock synchronisation occurs between adjacent readers and these readers power antennas facing the same direction, so we are not considering it an addressable issue in this document.

2. Physical Gate Topology

The two portals share neighbouring dock-door openings but are isolated through frequency separation. When scaling, this can be implemented across all docks, with each adjacent reader working on separate bands. Each gate is assigned dedicated reader channels to prevent interference between adjacent antennas, powered simultaneously by different readers. ETSI channel bands can be found in [1, pp. 14-15].

2.1 Antenna Configuration

- **Gate Coverage (portal width):** Between 2.0m to 3.8m measured distance face-to-face. The Portal can go further, with our recommended max width set to maintain a low impact keep-out zone of 1.2m from antenna edge.
- **Gate A:** Four antennas, one reader, channel 4 (865.7 MHz) and channel 7 (866.3 MHz)
    - If using upper ETSI bands – use channel 3 (916.3 MHz) and channel 6 (917.5 MHz)
- **Gate B:** Four antennas, one reader, channel 10 (866.9 MHz) and channel 13 (867.5 MHz)

    - If using upper ETSI bands – use channel 9 (918.7 MHz) and channel 12 (919.9 MHz)
- **Reader:** One antenna per port, preventing unintended combined radiating patterns
- **Antenna placement:** Four per gate making up one Times-7 Portal System (top-left, top-right, bottom-left, bottom-right), creating overlapping read fields within the portal, and energising to the full portal height (2.2m, see Figure 1 illustration)

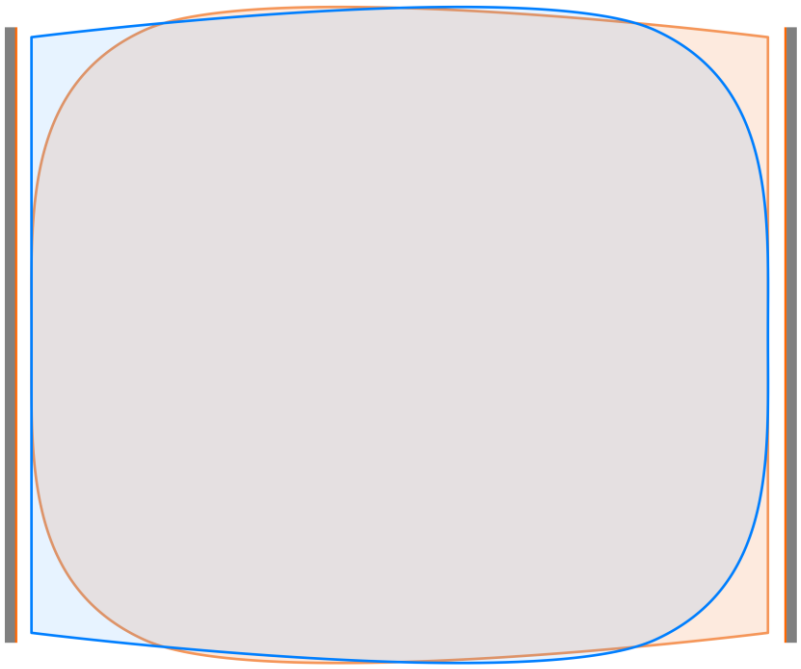


Figure 1. *Front-on view. Evenly distributed vertical radiation pattern provides total and consistent height coverage without dead zones or missed reads.*

3. Read Ingestion

Every bank 01 memory read event captured by the reader carries four mandatory fields that are used by all downstream filtering and classification stages.

3.1 Raw Read Event Fields

- **EPC / UII:** The Electronic Product Code (GS1) / Unique Item Identifier (ISO) of the tag
- **RSSI:** Received Signal Strength Indicator in dBm – used for zone gating
- **Antenna ID:** Identifier of the antenna that produced the read
- **Timestamp:** High-resolution timestamp (microsecond resolution) – used for temporal clustering and direction classification

4. Stray-Read Elimination Pipeline

The below three points cover measures to implement across different techniques to ensure stray reads are not present within the genuine read databank.

4.1 Physical Trigger

Accessory attached to the portal for the purpose of providing a physical trigger. This is the most steadfast and reliable filter. Example used for this system is an IR (infra-red) laser gate, covering both the ingress and egress sides of the portal allowing for direction of movement tracking.

- Use 2 IR triggers to infer directionality of pallet movement. When first trigger is tripped, begin corresponding ingress/egress session (discussed in point 5).

4.2 RSSI Limit Gate

An empirically calibrated RSSI floor is configured per antenna during site commissioning. Tag responses can be compared as a backup layer to a physical trigger for determining gate location of the pallet. This is the fastest and most computationally inexpensive filter to either remove or suspect tag responses.

- RSSI readings are compared against the per-antenna threshold
- Reads below the floor are discarded immediately
- Thresholds are calibrated at commissioning and stored per antenna ID

4.3 Temporal Cluster Filter

A single opportunistic read at the edge of a zone is insufficient evidence of a genuine portal crossing. The temporal cluster filter requires a tag to appear at least N times within a sliding Temporal Window (T_w) on antennas belonging to the same gate.

- Configurable parameters: minimum read count N and window duration T_w
- Reads are tracked per EPC / UII per gate – cross-gate reads do not contribute to either gate's cluster count
- If the cluster threshold is not met within T_w, the reads are discarded

5. Direction Classification

Once a read cluster has passed all three implemented stray-read measures, the direction classifier determines whether the tag movement represents an ingress or egress event. This determines which session manager receives the validated cluster.

5.1 Classification Method

The classifier orders the antenna activations within the validated cluster chronologically. The positions within the portal of each antenna are established during commissioning.

- **Ingress:** Front-facing IR laser gate is tripped before rear-facing IR laser gate & genuine tags are read within a set time window
- **Egress:** Rear-facing IR laser gate activates before front-facing IR laser gate & genuine tags are read within a set time window
- RSSI slope is used as a secondary confirmation signal and to handle slow-moving or temporarily stationary pallets

6. Session Management

Definition: Session, referred to in sections 6-8, is used in relation to the software data system for a period, akin to an inventory cycle and not a reader session.

On the first confirmed and direction-classified tag read, a session is opened by the appropriate session manager (ingress or egress). The session accumulates all subsequent reads associated with the same pallet movement event.

6.1 Ingress Session Manager

- Opens a session on the first validated tag read classified as ingress
- Starts a 500-millisecond inactivity timer – each subsequent read from the same pallet refreshes the timer
- Locks the session to the pallet-level EPC / UII (SSCC) as the session anchor
- Session closes when the timer expires with no further reads – signalling the pallet has cleared the gate

6.2 Egress Session Manager

- Operates identically to the ingress session manager, for egress-classified reads
- Maintains an independent session store – a simultaneous ingress and egress event (two pallets passing simultaneously) produces two independent sessions

6.3 Concurrent Pallet Handling

If two pallet EPC / UIIs appear simultaneously – for example, back-to-back pallet movements – each gets its own session keyed to its unique pallet tag. Carton and item tags are distributed to the correct session using EPC / UII prefix matching against each session's anchor EPC / UII.

7. EXAMPLE Software Architecture - Hierarchical Tag Correlation

Each session accumulates reads across all three tag levels and builds a live tree structure. The session is not committed until a confident pallet-level anchor has been established.

7.1 Hierarchy Structure

- **Pallet tag (root):** SSCC (GS1) or ISO equivalent encoding scheme pallet-level EPC / UII – required as the session anchor before a commit, largest tag with best response
- **Carton tags (children):** SGTIN (GS1) or ISO equivalent encoding scheme case-level EPC / UIIs, joined to the pallet by EPC / UII company prefix match or pre-loaded ASN manifest
- **Item tags (grandchildren):** SGTIN (GS1) or ISO equivalent encoding scheme item-level EPC / UIIs, joined to the parent carton by EPC / UII prefix or ASN pre-load lookup

7.2 Manifest Pre-Load

Where available, an Advanced Shipping Notice (ASN) is pre-loaded into the session engine before the expected pallet arrival. This enables deterministic parent-child resolution even when tag reads arrive out of expected order and significantly reduces the ambiguity of EPC / UII prefix-only matching in mixed-SKU pallets.

8. Session Reconciliation

On session close, the accumulated read set is compared against the expected manifest from the WMS or ASN. Discrepancies are flagged and a read confidence score is computed.

8.1 Logic Set

- The read set is compared against the expected manifest EPC / UII for the read EPC / UII
- Missing EPC / UIIs (expected but not read) are flagged as potential read failures or missing items
- Unexpected EPC / UIIs (read but not in manifest) are flagged as potential mis-reads or unknown origin tags
- Count mismatches at each level (pallet, carton, item) are reported independently

8.2 Read Confidence Score

A read confidence score is computed for each session:

Confidence = (confirmed_reads ÷ expected_reads) × 100

- Sessions scoring above the configurable threshold (typically 95–99% expectation for apparel using the Times-7 portal) are auto-committed to the WMS
- Sessions scoring below the threshold are routed to the exception queue for manual intervention

8.3 Routing Outcomes

- **Clean session:** Manifest written to WMS, inventory updated, session closed and archived
- **Discrepancy session:** Alert raised in WMS, pallet held at dock door, re-scan prompt issued to operator

9. System Tuning Parameters

The following parameters are configurable per installation and should be tuned during site commissioning. Starting values below are appropriate for most standard dock-door deployments but will require adjustment for high-density, high-speed, difficult item or otherwise unusual RF environments.

Note: *Pallet and carton-level tags should achieve near 100% read reliability in a calibrated Times-7 portal regardless of item type. Item-level reads on dense pallets may run 92–97% due to RF shadowing between tags, item detuning or reflections, so the confidence threshold is typically set lower for item-level reconciliation and supplemented by a re-scan rule at the exception station.*

Parameter	Typical starting value	Effect
RSSI floor	−65 dBm	Raise to tighten zone; lower for sparse tags
Temporal window T_w	300–800 ms	Too short = misses slow pallets; too long = session bleed
Minimum read count N	3–5 reads	Filters one-shot stray reads
Session dwell timeout	400–600 ms	Close session after pallet fully clears gate
Confidence threshold	95–99%	Depends on read-rate expectations per tag level (pallet, carton, item)

10. Implementation Notes

10.1 Commissioning Sequence

The following sequence is recommended when commissioning a new portal installation:

1. Install and align antennas per the Times-7 portal installation guide
2. Assign frequency channels to Gate A and Gate B. This will be based on frequency selection technique (FCC / ETSI). Ideally make use of full band for separation
3. Calibrate per-antenna RSSI floors using known tag positions at the zone boundary under both ideal and worst-case testing
4. Tune T_w and N using live pallet movements at expected operational speed
5. Configure ASN pre-load integration with WMS if available
6. Set confidence thresholds and run acceptance testing with representative pallet loads

10.2 Known Limitations

- Item-level RF shadowing on dense pallets is inherent. The confidence threshold should be adjusted rather than attempting to read every tag on a dense pallet at forklift/line speed
- Direction inference becomes unreliable when pallets stop and reverse direction partially through the gate. A configurable reverse detection timeout is recommended for installations with frequent partial entries
- Simultaneous pallet movement through Gate A (ingress & egress) on the same dock door requires the session engine to correctly isolate sessions by EPC / UII prefix, relying on consistent pallet-level EPC / UII encoding across all suppliers

11. References

[1] *Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W and in the band 915 MHz to 921 MHz with power levels up to 4 W; Harmonised Standard for access to radio spectrum,* ETSI EN 302 208 V3.4.1, 2023-12. Available: https://www.etsi.org/deliver/etsi_en/302200_302299/302208/03.04.01_60/en_302208v030401p.pdf