RFID TRIALS
FOR BAGGAGE TAGGING

1.1 RFID Trial Results

Summary: *During the last years, a number of trials have been conducted between airports, airlines and manufacturers and additional ones should start in a near future with other airports. The main results are summarized in the following table.*

RFID Trial	Date	Read –Rate (Average)	Read-Rate Range (daily range)
Kuala Lumpur Airport	2005 - 2006	- With Gen 2: 100% - With Class 0 Gen 1: > 98%	
Kansai Airport – Hong Kong Airport	2005	95.54% 98.78%	94.25%~100%
Asiana - Korean Airport Corporation	2004 - 2005	97.00%	-
TSA World-wide Trial	2004 - 2005	~99%	96% - 100%
Narita Airport (HF)	2004	-	92% - 95%
British Airways at Heathrow T1	1999	96.40%	95.4% - 99.4%

Table 1: Overview of RFID trail read rates

The map provides an overview of the trials and their actual status:

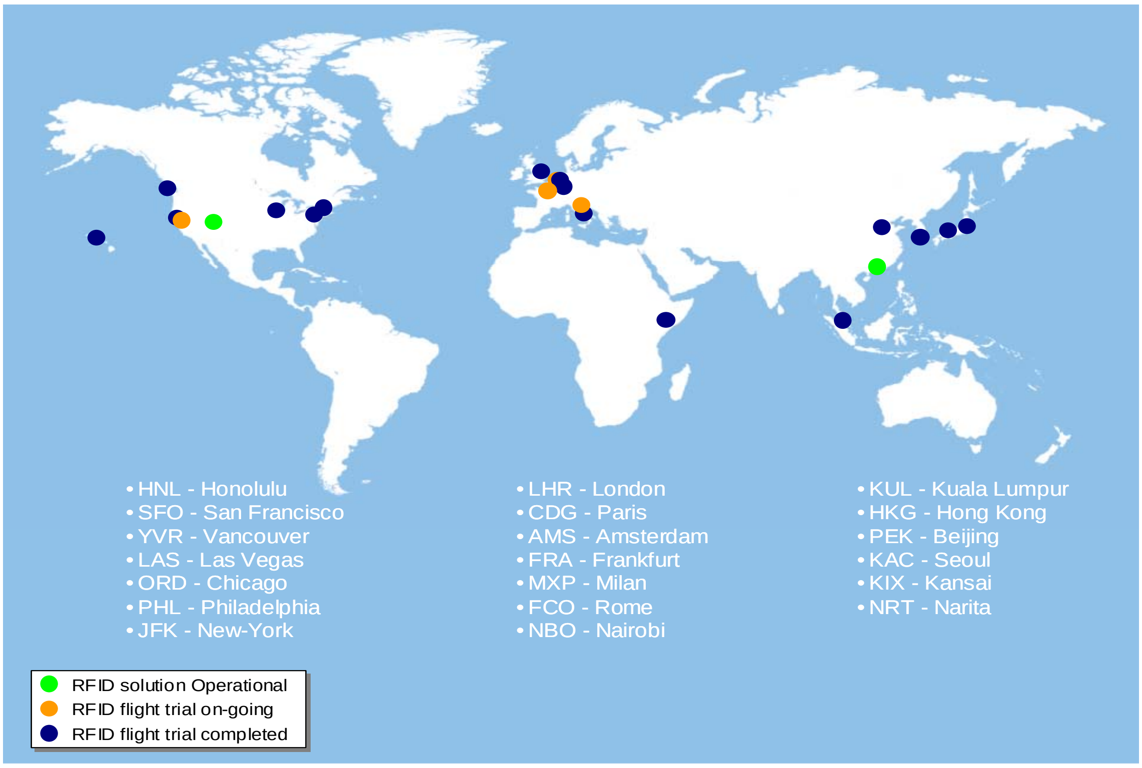


Figure 1 : Worldwide trial distribution

1.1.1 Kuala Lumpur International Airport Trial

1.1.1.1 Introduction

This trial of UHF band involved the FEC Group, the Malaysia Airports Group, the Malaysia Airlines System BHD, and the Toppan Forms Co., Ltd. and the CBS Technology BHD.

This trial had two main objectives:

- To study the characteristics of UHF tags placed on the test baggage in various situations to identify when reading would become difficult
- To study the recognition rate by placing the UHF tags on passenger's baggage in the actual airport environment and:
    - To verify the effectiveness of the baggage tags during operations between airports
    - Effects on UHF band by the airport facility materials

In this trial, a large amount of RFID materials has been tested and performances analyzed in details. The process starts with the tag preparation (pre-encoding), the tag issuing and tag reading along the baggage chain.

1.1.1.2 Description of the trial equipment

Type	Equipment	Manufacturer
Reader	Sensormatic Agile 2	Tyco
	AR400	Symbol
Antenna	Sensomatic Omniwave	Tyco
	High Performance Area RFID Antenna	Symbol
Baggage Printer	BT 201e	Genicom / IER
	PF2i	Intermec
RFID Handy Terminal	IP4 Portable (UHF)	Intermec
	MC 9060 (UHF)	Symbol
Inlet	Meander line	Toppan Forms
	EPC Class 0+, Dual Dipole Antenna	Symbol
	EPC C1 Gen2, Dual Dipole Antenna	Symbol

Table 2: RFID Trial equipment

1.1.1.3 Trials Results

In this flight trial, recognition rate in using EPC Class 0+ Gen 1 inlet was 98.38%. In the latest protocol of the next generation, EPC Class 1 Gen 2, inlets with chip were tested with different readers and antennas yielded a 100% recognition rate.

1.1.2 Kansai International Airport – Hong Kong International Airport Trial

1.1.2.1 Introduction

This Trial of UHF Band Wireless IC Tag (e-Tag) for airline checked baggage was conducted by ASTREC and executed between Kansai International Airport (KIX) and Hong Kong International Airport (HKG) with the cooperation of Japan Airlines.
The trial was conducted on both directions. E-tag was affixed to the airline bag of the Kansai International Airport and read at the arrival process at Hong Kong International Airport. The same was conducted at the reverse direction.

The trial consisted of:

- Reading of IC tags which were affixed to checked baggage on a JAL701, KIX to HKG and conducted between November 28 through December 16, 2005
- Reading of IC tags affixed to checked baggage, already a standard operating procedure at HKG, on JAL 702, HKG to KIX and conducted during the same period
- Individual experiments conducted over 3 days during the end of February 2006

The main purpose of this trial was to accomplish a basic performance validation in an operational environment and different from Narita Airport and:

- to verify the international interoperability of Japan's UHF-band airline baggage tag
- to confirm the data recognition of the airport baggage tag affixed at Hong Kong and read it at Kansai International Airport
- to verify characteristics of UHF band radio frequency
- to verify electric intensity measurement inside the airport
    - E-tag recognition area measurement in the positioning of the antenna

ASTREC undertook trials using both 13.56 MHz and UHF band RFID devices. The primary reason for this is that the only globally interoperable frequency that can be used at sufficient power for baggage handling is the UHF band. The adoption of UHF band RFID in Japan has only begun following changes to the radio laws in April 2005.

1.1.2.2 Description of the trial equipment

Two different types of inlay were used (different antenna shape). The inlays were embedded in the back of the trial tags.

Five fixed antennas were used:

- Antenna 1 at the F Counter Belt in KSI
- Antenna 2 at the Baggage Make-up area at KSI
- Antenna 3 & 4 at HKG arrival
- Antenna 5 at the arrival baggage process of KSI

Inlays	Antennas
↗ Manufactured by Symbol Technologies	↗ Symbol Technology Model AR-400J
↗ Range: 902 Mhz – 928 Mhz	↗ KIX: compliant with new Japan Radio Code
↗ RF Air Protocol: EPC global class 0, Version 1 (Class 0+)	↗ HKG: compliant with Hong Kong Radio Code
↗ Memory: 96 bits + 16 bit CRC	↗ Output 1W
↗ Electronic Product Code (EPC) compliant	↗ Frequency KIX: 952 MHz – 954 MHz
↗ Read/write	↗ HKG: 920 MHz –925 MHz
	↗ RF Air Protocol: EPCglobal Class 0, Version 1 (Class 0+)

Table 3: Inlay and antenna manufacturers for trials

1.1.2.3 Trials Results

From Kansai International Airport to Hong Kong International Airport

1388 items of baggage were tagged. The following tables compare read rate results between antennas. Antenna 1 was used to read the tags located at the F counter, just after check-in. The bags were then conveyed to the make up area where antenna 2 was installed.

Read rate Antenna 2 vs Antenna 1	Total
Number of trial tag Antenna 1 read at KIX Departure	336
Number of trial tag Antenna 2 read at KIX Departure	321
Number of No Read	15
Read Rate	95.54%

Table 4: Read rate improvements between antennas at KIX

Evaluation of Read Rate Antenna 2:
The averaged daily fluctuation of Read Rate was between 94.25% to nearly 100%.
The main causes of No-Read were due to:

- Tag wrapping around the handle of the baggage
- The tag was placed under metal baggage.
- Affixed tag to online transfer baggage beyond HKG (miss handling), taking a non-antenna installed route
- The baggage travels on a particular side of the side guard at the junction point of sorter in the BHS (where the tag contacts the side antenna).

From Hong Kong International Airport to Kansai International Airport:

The baggage loaded into the JAL flight from KSI to HKG were then unloaded to the conveyor belt at KHG and read by Antenna 3.

Read rate Antenna 3 vs Antenna 2	Total
Number of trial tag Antenna 2 read at KIX Departure	1067
Number of trial tag Antenna 3 read at HKG Arrival	1054
Number of No Read	13
Read Rate	98.78%

Table 5: Read rate improvements between antennas at KIX

Evaluation of Read Rate Antenna 3:
The averaged daily fluctuation of Read Rate was also between 94.25% to nearly 100%.
The main causes of No-Read were due to:

- Tag wrapping around the handle of the baggage
- The tag was placed under metal baggage.
- Affixed tag to online transfer baggage beyond HKG (miss handling), taking a non-antenna installed route.

Additional tests were conducted during 3 days from February 27, 28 and March 1, to investigate the tags not previously read.
Twenty-one pieces of test baggage covering various e-tag affixing configuration and characteristics of the conveyor line were prepared to verify the recognition based on e-tag affixing method and material differences.

- The test of bag material revealed that the tag affixed to the metal baggage need a distance of 10 mm or more between the tag and the baggage itself to be recognized by the antenna. It was also not possible to read tags on baggage that contained items wrapped in evaporated metal packaging, such as instant noodles.
- The recognition based on various e-tag affixing configuration were tested. As a result insufficient recognition was verified when the e-tag was folded or coiled around the handled of the bag.

1.1.3 Asiana - RFID Airline Baggage Tracking and Control System

This trial was performed in Korea between the Korean Airport Corporation, NCA and Asiana IDT. The trial ran from October 2004 to April 2005, with a pilot phase running from June 2005 to December 2005.
The trial used many Korean airports, as shown below:

Baggage tags for the trial were issued at check-in and then read at a number of points throughout the baggage process. RFID was used to track baggage through security, reconciliation and finally to verify arrival. When the bag had been placed on the reclaim belt it was possible to contact the passenger by SMS to tell them where their bag was. This information could also be displayed on FIDS.

The trial had some issues with the encoding of tags, and work had to be undertaken to develop the encoding software by Asiana IDT.

The trial also enabled a number of new processes. There was a link between the security screening station and the airline security database allowing baggage belonging to passengers listed in the database to be notified to the security staff. This baggage could then be manually searched after x-ray.

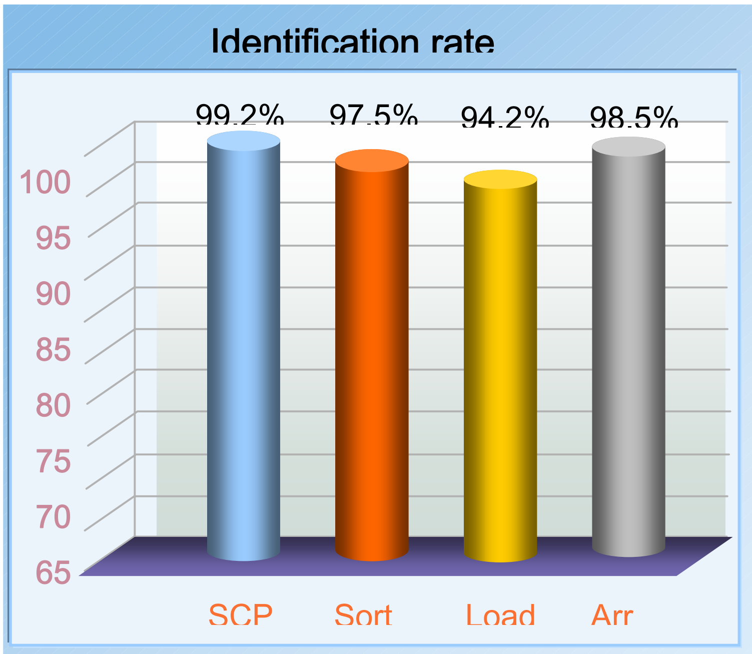
RFID was also used for sortation, and the trial was the first use of RFID to enhance a manual sortation process. Baggage loaders were informed that the bag on the carousel was for their flight by the RFID reader. The functionality was also extended to reconciliation through the use of lights for loading, and recording the licence plate of the loaded bag.

The display of information to the passenger was a particular challenge, although the issue was one of law. It was not possible to display the passenger names on the arrival FID, so instead the passengers’ seat number was shown.

The trial was a success, achieving a 97% read rate. The trial also provided insight into that way in which RFID can be used to enhance processes and improve customer service.

The trial also showed that RFID had improved the baggage handling operation by 40 seconds per bag. This was estimated to return a benefit of $1 million per annum. The accuracy of sortation was also improved, although the manual process had very few errors in the first place. The expectation was that RIFD would lead to a reduction in baggage mishandling saving the airline $570,000 per annum.

The read rates at each process step are shown below:



The reasons for read rate failure were examined and found to be:

- Tag attaching error 30%
- Network problem 25%
- Baggage type 15%
- Environment 40%

These errors accounted for the 3% read rate loss.

Asiana IDT remain involved in the use of RFID for baggage and other airline operations, having founded an RFID development centre in Seoul. Despite a very successful trial and a great amount of knowledge acquisition, there are no plans to implement RFID at this stage.

1.1.4 UHF RFID BAGGAGE TAG World-wide TRIALS by TSA

1.1.4.1 Introduction

This aim of this world-wide trial was to demonstrate interoperability of UHF RFID Baggage Tag systems between worldwide geographic regions having different UHF transmission regulations (low, middle, high of band):

- U.S. and Japan that have different UHF transmission regulations (2004)
- U.S. and Europe that have different UHF transmission regulations (2004)
- Worldwide 2005 UHF Interoperability Trial

1.1.4.2 UHF RFID Worldwide Interoperability – Background

- By design, a UHF RFID tag's performance will be "optimal" within a subset of the entire UHF band.
- The tag, however, generally is designed to operate over the entire band with minimal degradation in performance.
- This leads to frequency interoperability of the UHF RFID system since each country can operate its RFID reader equipment at the designated frequency for that country while the tag, which moves from one country to another, can operate at multiple frequencies within the UHF band.

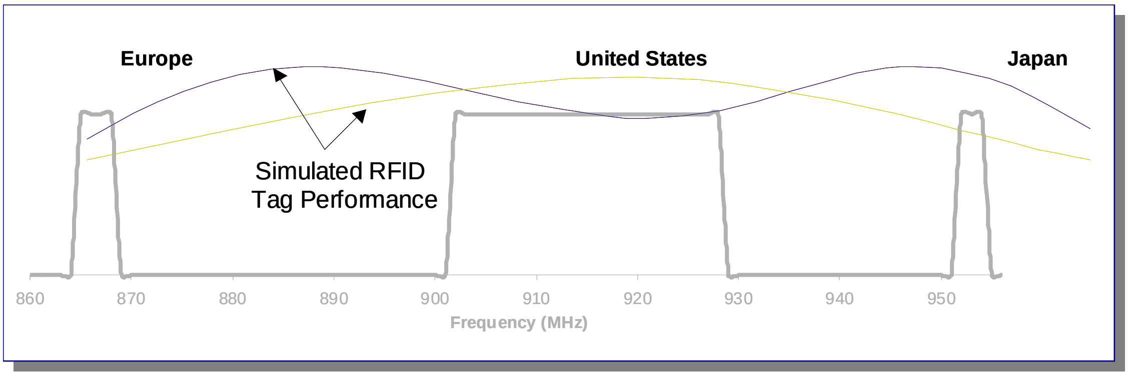


Figure 2: Ideal antenna characteristics

1.1.4.3 Description of the trial equipment

- The trial tested UHF RFID systems provided by Symbol Technologies (formerly Matrics, Inc.) and included writable tags containing RFID inlays.
- The frequency/power of operation of the reader equipment used at each location is as follows:

Location	Frequency	Power
Chicago, Beijing and Nairobi	902 - 928 Mhz	4 watts ERP (1 Watt (30 dBm) at connector, 6 dBi antenna gain maximum)
Narita	952 - 954 Mhz	4 watts ERP (1 Watt (30 dBm) at connector, 6 dBi antenna gain maximum)
Amsterdam	865 - 868 Mhz	2 Watts ERP

Table 6 : TSA Interoperability trial frequencies

The trial included:

a) pre-encoding of RFID baggage tags using RFID equipment operating in the frequency range specified for the location where the tags are issued,
b) reading of RFID baggage tags via belt readers as the baggage was transported through the baggage handling system, and
c) reading of the RFID baggage tags via belt readers as the baggage was placed on the arrival belts.

All RFID tags were pre-encoded with data. All pre-encoding was done using RFID equipment operating in the frequency range specified for the location where the tags were issued.

Example: Tags issued in Narita, Japan (NRT) were pre-encoded using RFID equipment operating in the 952-954 MHz range.

Encoding at one frequency and reading at another verifies the frequency interoperability of the RFID tags across the UHF band of 860 to 956 MHz.

RFID UHF Tag Inlays	Readers
↗ Provided by Symbol Technologies	↗ ORD Arrival: Read at 902-928 MHz, 4 Watts EIRP
↗ RF Air Protocol: EPCglobal Class 0, Version 1 (Class 0+)	↗ NRT Departure: Encode/Read at 952-954 MHz, 4 Watts EIRP
↗ Memory: 96 bits + 16 bit CRC	↗ AMS Departure: Encode/Read at 865-868 MHz, 2 Watts ERP
↗ Size: 1 in. x 4 in. (2.5 cm x 10.2 cm)	↗ PEK Departure: Encode/Read at 902-928 MHz, 4 Watts EIRP
↗ Electronic Product Code (EPC)™ compliant	↗ NRT Arrival: Read at 952-954 MHz, 4 Watts EIRP
↗ Read/Write Single Dipole	↗ NBO Departure: Encode/Read at 902-928 MHz, 4 Watts EIRP

Table 7: TSA Interoperability trial inlays and readers

1.1.4.4 U.S. and Japan Interoperability results

Key result indicating success of the Interoperability trial is the read rate of the arrival readers

- Average read rate for HNL arrival reader à 98.46%
- Average read rate for NRT arrival reader à 98.01%

It proves that a UHF RFID tag can successfully operate at both the U.S. band of 902-928 MHz and the Japanese band of 950-956 MHz.

The Read rates averaged in excess of 98%. Although to some observers they may be considered slightly less than desired, these rates can be attributed both to less-than-optimized installations and to first-generation RFID tags.

1.1.4.5 U.S. and Europe Interoperability results

Key result indicating success of the Interoperability trial is the read rate of the arrival readers

- Average read rate for PHL arrival reader à 98.82%
- Average read rate for FCO arrival reader à 96.26%

The lower observed read rate on the arrival reader in Rome was almost exclusively due to the less than optimum single antenna configuration of the arrival reader.

It also proves that a UHF RFID tag can successfully operate at both the U.S. band of 902-928 MHz and the European band of 865-868 MHz.

1.1.4.6 Worldwide 2005 UHF RFID Baggage Tag Interoperability Trial results

The aim of this trial was:

- To demonstrate the interoperability of UHF RFID systems between worldwide geographic regions having different UHF transmission regulations (low, middle, high of band) and
- To prove the theory that UHF RFID tags can operate outside of the designed frequency range with little degradation in performance. This in turn would support the global adoption of UHF RFID technology for baggage

The main Routes were:

- Amsterdam (AMS) to/from Chicago (ORD),
- Narita (NRT) to/from Chicago (ORD), and
- Beijing (PEK) to Chicago (ORD) with United Airlines.

The Feeder Routes were:

- Beijing (PEK) to Narita (NRT) with Air China, and
- Nairobi (NBO) to Amsterdam (AMS) with Kenya Airways.

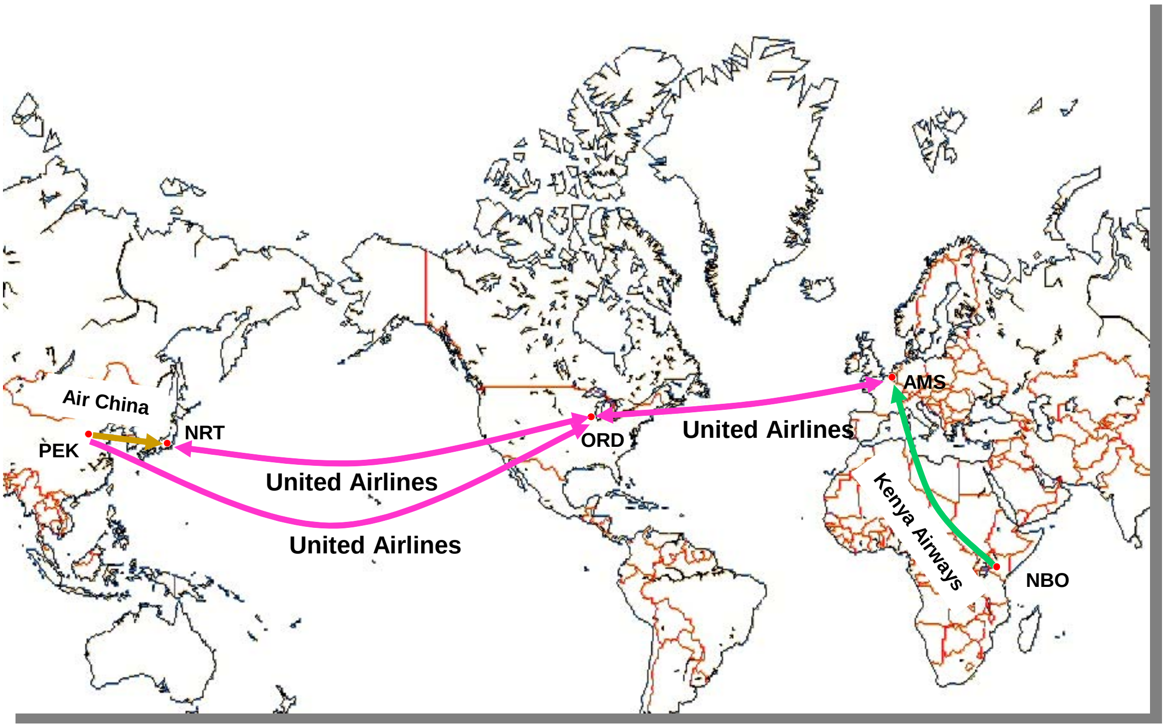


Figure 3 : TSA interoperability Trial locations

- A limited number of empty test bags were used that traveled from NRT to ORD to AMS and back during the trial.
- The provided data allow to evaluate the interoperability across the entire UHF spectrum (European, U.S., and Japanese)
- The results (99.2% to 100%) clearly indicate that, as predicted, the UHF RFID tag is interoperable across the entire UHF spectrum.

Amsterdam (AMS) through Chicago (ORD) to Narita (NRT)		
865-868 MHZ AMS Departure	902-928 MHz ORD Transfer	952-954 MHZ NRT Arrival
99.4%	100.0%	99.2%
Narita (NRT) through Chicago (ORD) to Amsterdam (AMS)		
952-954 MHZ NRT Departure	902-928 MHZ ORD Transfer	865-868 MHZ AMS Arrival
100.0%	100.0%	99.2%

Narita (NRT) to Chicago (ORD)	
ORD Arrival Read Rate	ORD Arrival – Total Tags Read
98.8%	4586
Amsterdam (AMS) to Chicago (ORD)	
ORD Arrival Read Rate	ORD Arrival – Total Tags Read
99.6%	1199
Beijing (PEK) to Chicago (ORD)	
ORD Arrival Read Rate	ORD Arrival – Total Tags Read
99.2%	4628
Beijing (PEK) to Narita (NRT)	
NRT Arrival Read Rate	NRT Arrival – Total Tags Read
99.3%	7540
Nairobi (NBO) to Amsterdam (AMS)	
AMS Arrival Read Rate	AMS Arrival – Total Tags Read
98.2%	2593

Table 8: TSA Trial Interoperability Read Rates

1.1.4.7 Conclusions

- The Worldwide UHF RFID Trial was the culmination of a decade of work by the FAA/TSA as related to RFID baggage tracking and security.
- UHF EPCglobal compliant RFID systems also have been viewed as the future for supporting baggage/cargo and many other assets identification requirements for security and operational tracking applications.
- This trial was intended to demonstrate operation of UHF RFID baggage tags at multiple UHF frequency assignments (860 MHz to 956 MHz) to ensure around-the-world baggage tag read interoperability, and to determine/prove the basic interoperability between UHF RFID baggage tags programmed at one frequency and read at a different frequency.
- The demonstrated read rates averaged in excess of 98.2% for the operational portion of the trial, and in excess of 99.2% for the test bag portion of the trial therefore successfully achieving the desired goal of demonstrating interoperability.

1.1.5 Narita International Airport Trial - 2004

1.1.5.1 Introduction

The Advanced Airport Systems Technology research Consortium (ASTREC) was founded in August 2003 to promote the use of RFID technology in an airport environment and establish the basis for technology for advanced airport systems such as baggage handling, in a more diverse and advanced information-based society. More than 60 corporations are members of the consortia (NAA, JAL, ANA, Delivery companies, Vendors, etc.)

The trial consisted of evaluating the RFID performances on the 13.56 MHz frequency band at Narita Airport with the participating:

- Airlines: Japan Airlines and All Nippon Airways
- Airports: JFK, Vancouver, Amsterdam Schipol, Frankfurt

At the time of the trial, Japan’s Radio Law did not allow the UHF band. Read rates of 92 to 95% were achieved. The main issue with reading the baggage was that the tags were in contact with the metallic sides of the reader. There are materials useable in the region of the reader to provide the strength of the metal framework with RFID transparency. Metallic bags and wet bags read successfully, although issues were found if bags were loaded exclusively with pots of instant noodles as the evaporated metal packaging cause reflective RFID read errors.