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Washington, D. C. 20590

Qualification Test of a Prototype Radio Frequency Identification (RFID) System for Baggage Identification and Tracking Applications

Quick Look Test Report

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U.S. Department of Transportation
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Draft Report

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Federal Aviation Administration

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16. Abstract

The following is a quick look test report for the Newark Qualification Test of a prototype RFID system.

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EXECUTIVE SUMMARY

This report describes the qualification test conducted at Newark International Airport on a prototype RF identification system for use in passenger baggage identification and tracking applications. The system tested was one made by Avante, which operates at 13.56 MHz. It consisted of a freestanding conveyor belt, an HF antenna array, a long-range reader and baggage tags that incorporate an antenna and an integrated circuit.

The test demonstrated that the system was able to achieve a 98.54% read rate ({number of successful tag reads}/{number of read attempts}) for over 1000 read attempts on the set of 22 bag tags used in the test. However, several issues would have to be addressed before this prototype system could be used in a live operational environment: a) bag tag durability, b) compatibility of the tags with bag tag printing equipment, c) ruggedness and reliability of the exposed, unshielded antenna array, and d) feasibility of implementing a conveyor belt which uses non-conductive material under the belt for the purpose of reading tags close to the belt.

ACRONYMS

HF	High Frequency
IATA	International Air Transport Association
RF	Radio Frequency
RFID	Radio Frequency Identification
RFDCTS	RF Data Collection Test Set
TSA	Transportation Security Administration

1. INTRODUCTION/BACKGROUND

This RFID qualification test is part of a series of tests begun by the FAA Aviation Security Research and Development Division to determine the feasibility of using RF technology to accomplish identification and tracking of passenger baggage on foreign and domestic commercial airlines for security purposes. Now as part of the Transportation Security Administration (TSA), the Transportation Security Laboratory is continuing to explore the viability of various systems that may be used to achieve this objective. This test was conducted on a prototype RFID system made by Avante International Technology, Inc. The test was conducted at Newark International Airport.

This Quick Look Report discusses the following:

- Test site and conditions
- Test participants
- Test procedures
- Test equipment
- System under test
- Test problems/anomalies
- Test results and conclusions

2. TEST DESCRIPTION

The test of the Avante RFID System took place at the Newark International Airport on July 10-11, 2002. It was conducted to demonstrate that the Avante RFID System could accurately read and identify RFID baggage tags attached to test bags moving along a conveyor belt in a representative operational airport environment. Participants in the test included representatives of the TSA, contractor personnel working for the TSA, and Avante personnel. TSA personnel oversaw the conduct of the test. Contractor personnel from Veridian Engineering working for the TSA were responsible for the overall planning and coordination of all test activities, monitoring of vendor test equipment installation/checkout, monitoring of the operation of the test equipment and data collection.

The test was performed by setting up a freestanding test belt in the baggage handling area of the airport. This was done so that the testing could be accomplished without impacting the normal airport baggage processing operations. The test belt was self-powered, and moved at a rate comparable to standard airport baggage belts (approximately 3 feet / second), but was smaller in width than normal baggage-handling belts. The test belt, configured as it was used in the test, is shown in Figure 1.

The unshielded antenna array consisted of a series of HF U-shaped antennas intertwined through mesh panels on both sides and underneath the belt (Figures 1, 3 and 4). The running surface

underneath the belt was made of a non-conductive material to allow for tag reading beneath the belt.

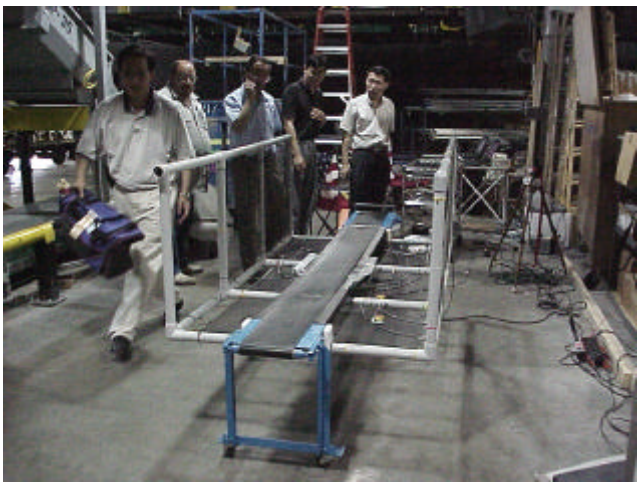

Figure 1. Test Belt Used in Newark Test, Set Up in Baggage Handling Area

The antenna array was connected to a long-range reader (not visible in figures) that performs the reading of the data encoded in the baggage tags. The system's operating frequency is 13.56 MHz. The specifications for the antenna and reader are shown in Appendix A. The dimensions of the belt system are shown in Figure 2.

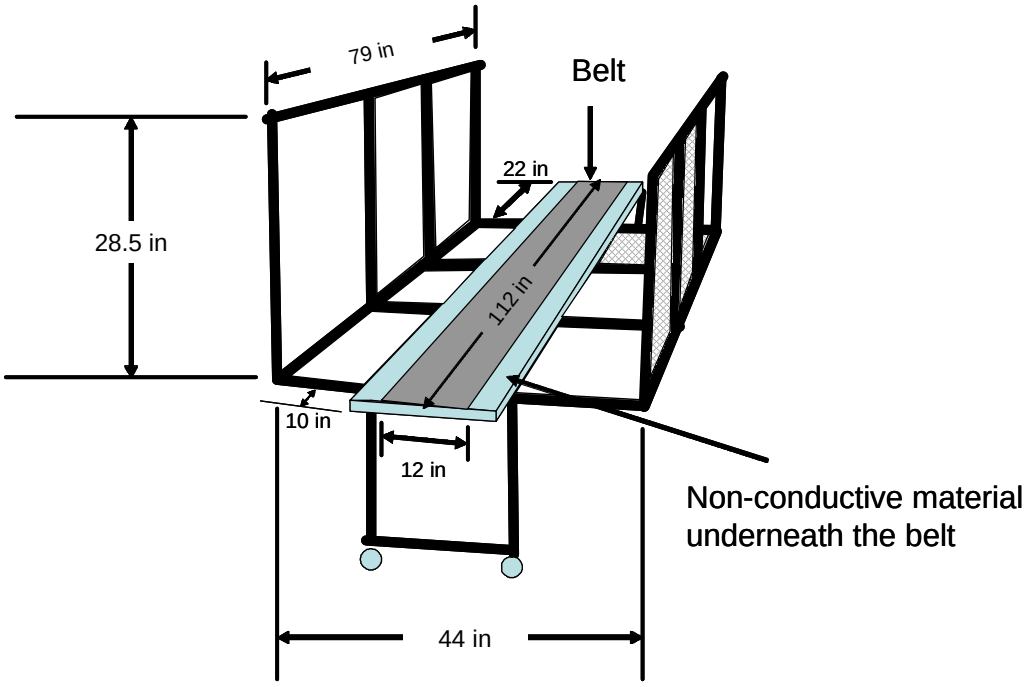

Figure 2. Dimensions of Avante RFID Belt System

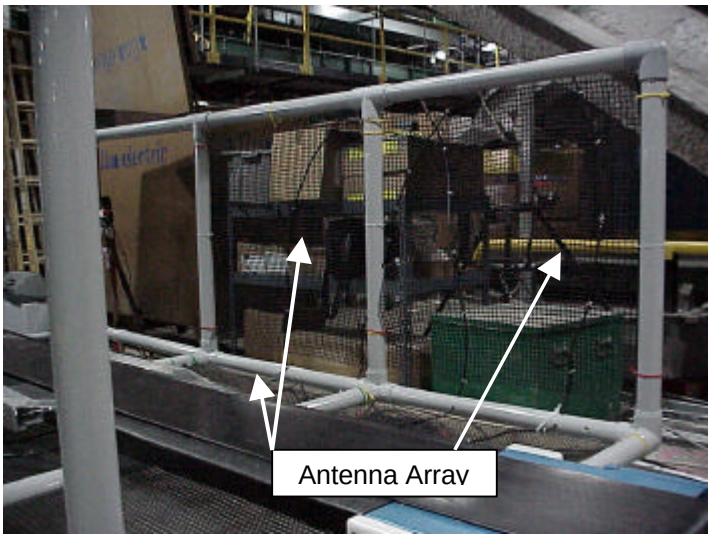

Figure 3. Antenna Array Used in Newark Test

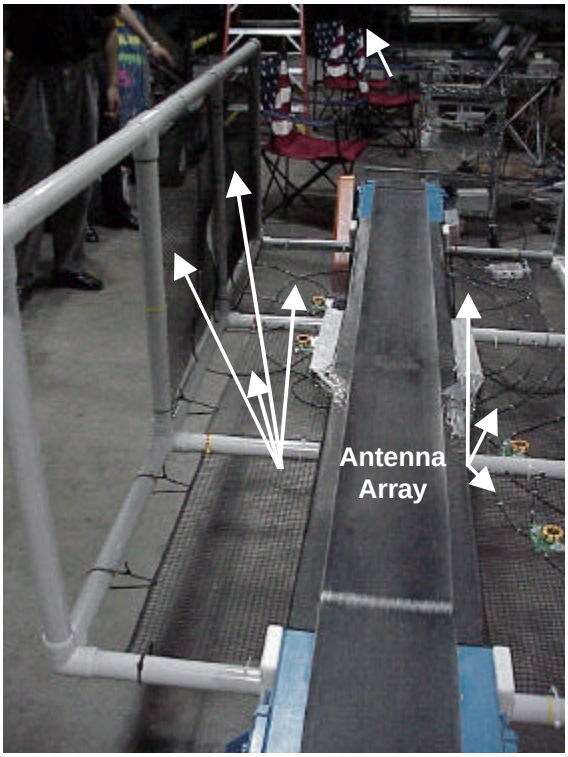

Figure 4. Close-Up View of the Test System Belt

The RFID baggage tags that were used in this test consisted of an antenna and an integrated circuit inlaid on a paper tag, as shown in Figure 5. The integrated circuit used in the tag design is

the Philips I-Code chip. Specifications for the I-code chip are included in Appendix A. One tag was attached to each of the test bags. A 10-digit number representative of the standard IATA barcode number was pre-programmed into each tag.

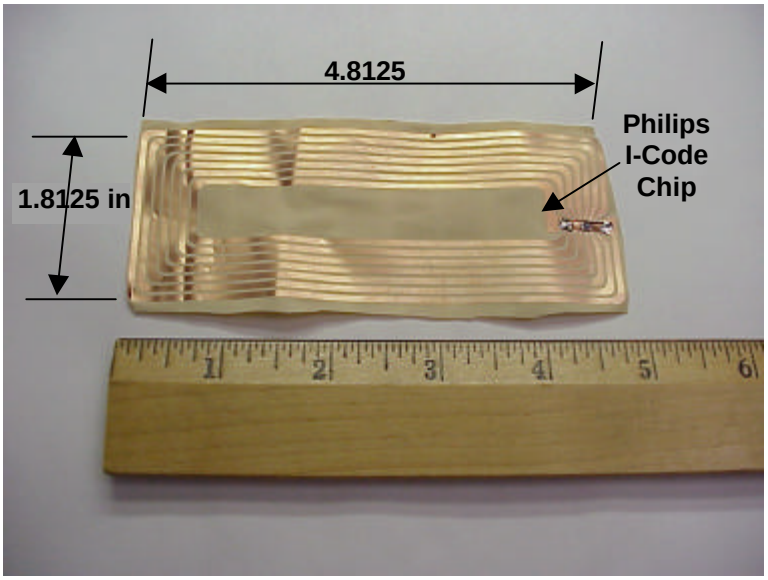

Figure 5. Avante RFID Baggage Tag Used in Newark Test

Contractor personnel used an RF Data Collection Test Set (RFDCTS), pictured in Figure 6, to monitor any electronic interference that might be produced by the Avante RFID system. The RFDCTS consists of a spectrum analyzer, computer and a set of interchangeable antennas that cover the frequency range from 0 to 3 GHz. Calibration factors for each antenna are stored in the RFDCTS computer to convert the recorded RF signal power levels to RF field strength in dBμvolt/meter. The RFDCTS can be seen in position at the test site at the left in Figure 7, next to the Avante RFID system. The position of the RFDCTS antenna is shown in Figure 8.

Figure 6. RF Data Collection Test Set (RFDCTS)

Figure 7. Newark Test in Progress

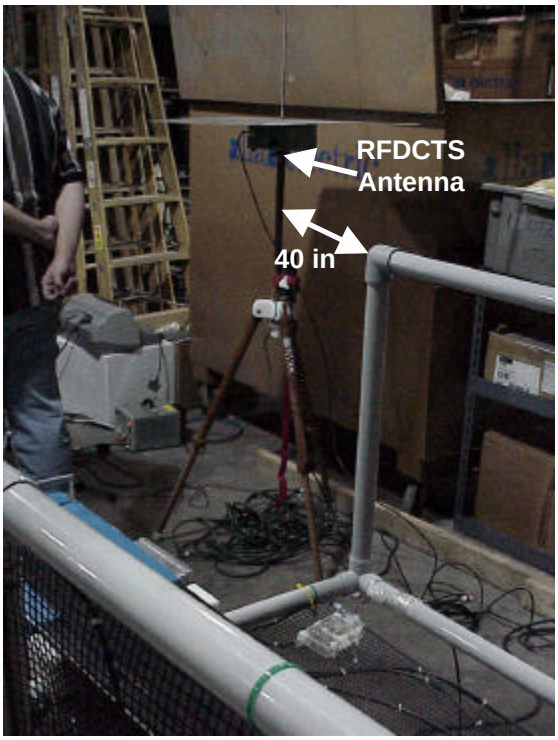

Figure 8. RFDCTS Antenna Used in Newark Test

2.1 Test Procedures

The RFDCTS equipment and Avante RFID system were set up in the designated baggage handling area at Newark International Airport on the first day of the test. All equipment was tested to ensure that it was operational. When the RFID system was started, the Avante team had problems getting the system to read the tags (See Test Problems and Anomalies section).

There were 18 test items of baggage that were used in the test. One RFID tag was attached to each of the test bags using methods which included manual insertion in standard barcode tags and mounting the tag to the bag using adhesive tape. Each tag had a unique ten-digit number pre-encoded onto the tag so that it could be tracked throughout the test. An RFID tag attached to one of the test bags is shown in Figure 9 below. The tagged bags as they were used in the test can be seen in Figure 10.

Figure 9. RFID Tag Attached to Test Bag

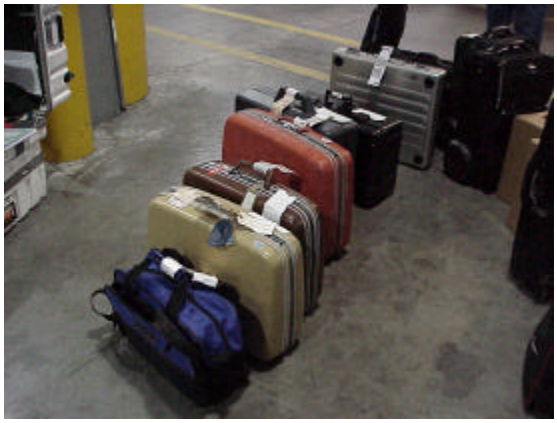

Figure 10. Test Bags with RFID Tags Attached

After checking the equipment, the conveyor belt was started up. The belt speed was set to approximately 3 feet/second. One "run" consisted of moving the 18 tagged bags past the RFID antenna array on the belt. At one end of the belt, one of the test personnel placed a tagged bag. As the bag moved along the belt, another tagged bag was placed on the belt behind it, representing typical airline handling of checked baggage. The bags passed by the antenna array, and were removed from the belt when they reached the other end. After all 18 bags had passed by the reader, one run was completed. This process can be seen taking place in Figure 7. During the testing, the positioning and spacing of the bags, and the orientation of the tags with respect to the system antenna array were randomly varied to be representative of actual baggage handling operations. There were 57 runs that were completed during the test. This was done to ensure that a minimum of 1000 read attempts would be performed.

As the test bags passed by the antenna arrays on the sides of the tunnel reader, the identification data transmitted by the tag was recorded by the reader and logged by the software running on a laptop computer attached to the reader. If a tag did not read during a run it was checked to determine whether it was defective. A tag was determined to be defective if: a) it was found to have been damaged, or b) it was impossible to achieve a successful read by manually placing the tag next to the RFID antenna. Whenever a tag was determined to be defective, it was replaced with another tag for the remainder of the test. After all 57 runs had been completed, the recorded tag data from the reader was downloaded for offline analysis.

3. TEST PROBLEMS AND ANOMALIES

During the initial setup and test of the Avante RFID equipment, it was found that the performance of the system was not as expected. According to Avante, previous laboratory tests had resulted in a 100% read rate. The first day of the test (July 10th) was spent making adjustments to the system. Originally it was planned to use a smaller RFID tag than the one used in the actual test. In order to attempt to improve the system performance, the larger tag had been substituted. By the end of the first day, the system was still not correctly reading the RFID tags. Testing was postponed until the following day while personnel from Avante returned to the laboratory to make adjustments to the system. By the next test day, July 11th, the team had isolated and corrected the problem with the system. Software had been written by Avante specifically for this test. The team found that the reader sampling rate had been set incorrectly in the software, which caused the initial poor performance.

4. RESULTS AND CONCLUSIONS

No pass/fail criteria were set for this Qualification Test. This section presents the results and conclusions, and it is left to the reader to determine whether the results are acceptable for a particular application.

The test results are presented in Table 1. The results of each run are shown in the column below the Run Number. The “ones” indicate a successful reading of the tag number in the intersecting row. The “zeros” indicate instances in which the tag was not successfully read. Blocks marked with “F” represent a tag failure, followed by replacement with another tag.

The test consisted of 18 RFID tags continuously cycled through the reader. As described in the Test Procedures section, if a tag was not read during a run it was checked to determine whether it was defective. Whenever a tag was determined to be defective, it was replaced with another tag for the remainder of the test. The test consisted of 57 runs. This allowed for a total of 1026 read attempts. The read rate ({number of successful reads}/{number of attempted reads}) of the Avante RFID system for this test was 98.54%.

During the test a total of 4 tags failed (thus a total of 22 tags were used in this test). Examination of these tags did not immediately reveal a cause for the tag failure. The tags used consisted of the antenna traces and the I-code chip laminated to paper material. However, the tags used during this test were not coated, exposing the traces and the chip to possible damage during handling. Avante stated that they had the capability and experience to properly coat the tags for future tests. During this test no consideration was given to the compatibility of the tag (size, thickness, ruggedness, etc.) with bag tag printing equipment. These issues would need to be examined prior to any live operational installation and test of this equipment. The reader antenna array consisted of a series of exposed cables interleaved through mesh panels mounted on the side of a belt system (See Figures 3 and 4). Testing and installation of this equipment in a live operational environment would require evaluation of the ruggedness and reliability of such an exposed and unshielded system.

The belt used during this test was only 12 inches wide. This is not representative of a standard baggage handling belt. Also, the test belt system consisted of a non-conductive material underneath the belt, allowing for reading of tags close to the belt. Testing and installation of this equipment in a live operational environment would necessitate addressing the issue of how such a system would be implemented on existing belt systems that are surrounded by metal sides and metal underneath the belt.

Table 1. Results of Avante RFID System Testing

	Run Number																											
Tag Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
8000000058	1	1	F	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
8000000061	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000062	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000063	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000064	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000065	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
8000000066	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000067	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000069	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000070	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000071	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000072	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	0	1
8000000075	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000076	1	1	1	0	0	F	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
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8000000079	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
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8000000081	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000082	X	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000084	X	X	X	X	X	1	1	1	0	1	1	0	1	0	F	----	----	----	----	----	----	----	----	----	----	----	----	----
8000000085	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000087	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Run Total	18	18	18	17	17	18	18	17	16	18	18	17	18	17	17	18	16	18	16	18	18	18	18	18	18	18	17	18

	Run Number																											
Tag Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
8000000058	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
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8000000062	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000063	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000064	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000065	1	1	1	1	1	1	1	1	1	1	1	1	0	F	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
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8000000067	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000069	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000070	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000071	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000072	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000075	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000076	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
8000000078	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000079	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000080	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000081	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000082	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000084	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
8000000085	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8000000087	X	X	X	X	X	X	X	X	X	X	X	X	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Run Total	18	18	18	18	18	17	18	18	18	18	18	18	17	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

Total Reads	1011
Total Read Attempts	1026
Read Rate (%)	98.54

LEGEND	
0 = Tag not read	X = Tag not used
1 = Tag read	F = Tag failed/damaged and replaced prior to run

Figures 11 and 12 are plots of the RF environment data generated by the RFDCTS. Figure 11 displays the RF environment prior to activation of the Avante RFID system. The plot in Figure 11 indicates that there is no significant interference from surrounding airport systems at the frequency of operation of the Avante

RFID system (13.56 MHz). Figure 12 shows the environment during the actual test of the Avante RFID system.

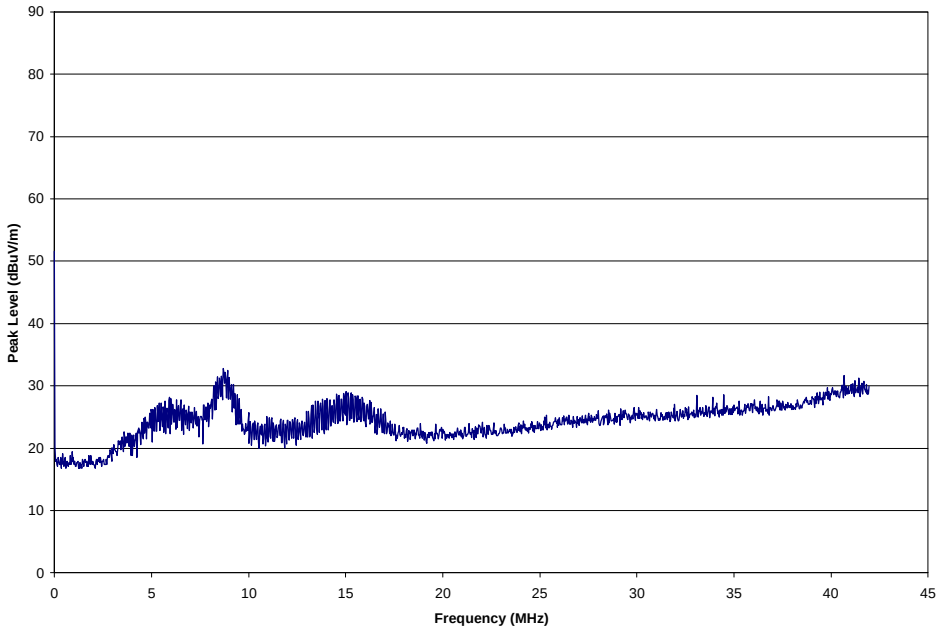

Figure 11. Test RF Environment Without Activation of Avante RFID System

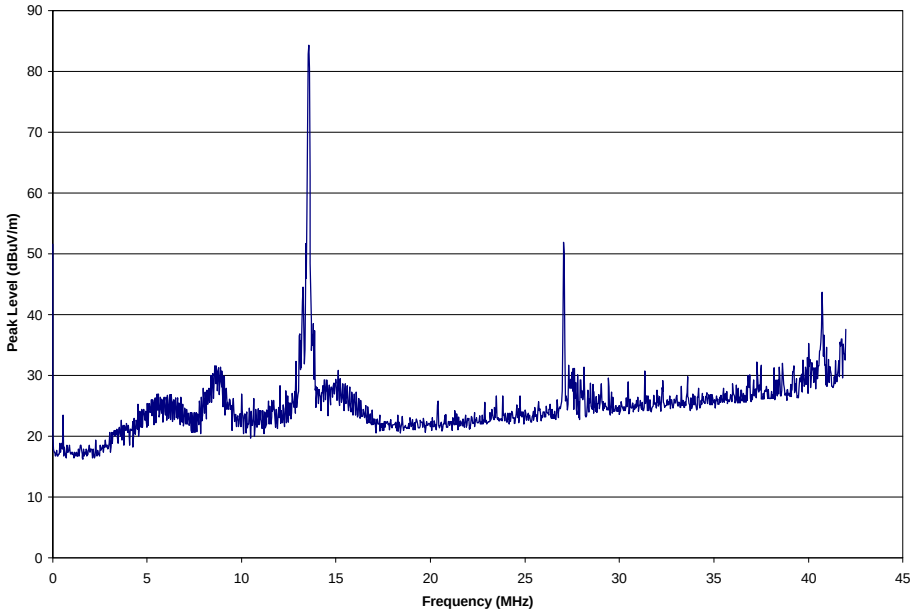

Figure 12. Test RF Environment During Activation of Avante RFID System

APPENDIX A – AVANTE RFID SYSTEM SPECIFICATIONS

Avante International Technology, Inc.
70 Washington Road, Princeton Junction NJ 08550
Tel: (609) 799-8896 Fax (609) 799-9308
www.avantetech.com

Technical Data for I-Code Chip

Manufacturer: **Philips Semiconductors**
Product Code: **SL2 ICS 20**
Storage: **Total of 512 BITs**
512 Bit read/write memory is divided into:
384 Bit user memory
64 Bit unique serial number
64Bit system memory (configuration etc…)
52 Characters can be written to the tag
Data retention: 10 years
Operating Temperature: –25 TO +70°C
Operating Range: Up to 1.5m EAS detection, up to 1.2m memory read and write.
Anti-collision: Simultaneous operation of several tags
Reliable EAS Detection: Avoids false alarms
High Speed: 30 tags per second (Anti-collision)
13.56 MHz Universal Standard
Compliance: FCC 15 Part 3, RTSI 300 330 & ETSI 300 683

Open Communication Protocol
Application identifier saves time, only the labels of the **"right"** application are responding to a selective request from the reader.

Benefits:
Highest automation for item scanning process
Passive RFID – No Battery required
No line of sight necessary
No item singulation required
Maintenance free, suitable for harsh environments
Functionality of bar code, EAS label and RF –Transponder in one label
Accurate inventory through automated control
Information directly attached to the product
Enables proof of genuineness

Fully ISO compliant, this I•CODE IC allows cost efficient, flexible and upgradeable system solutions and can be identified by any ISO 15693 reader.
I-Code is a major step towards standards and open systems for radio frequency identification technology.

Avante International Technology, Inc.
70 Washington Road, Princeton Junction NJ 08550
Tel: (609) 799-8896 Fax (609) 799-9308
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Technical Data for Avante HF U-Shaped Antenna

Specifications:

Operating Frequency:	**13.56MHz.**
Impedance	**50Ω**
Maximum RF Power:	**4 W**
Operating Temperature:	**-25°C to +55°**
Storage Temperature:	**-25°C to 60°**
Case Material	**Plastic**
Dimensions (L X W X H)	**200mm X 110mm X 74mm**
Weight:	**8000g**
Connector	**SMA male (50Ω)**
Cable:	**Type: RG58; Length: 3.9m**

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Technical Data for Avante Long Range Reader

Basic Features:

24 VDC power supply input
13.56 MHz carrier frequency
RS232 serial interface, 115.2 or 57.6 Kbaud data rate
Regulated RF-Output Power, software adjustable from 2 W up to 10W @ 50Ω
Software adjustable modulation index from 10% to 20%
Firmware-upgrade via RS232
Programmable I/O ports (optional)
EAS stand-alone mode (EAS output signal optional)
Anti-collision capability
Support of Standard and Fast Mode
BAPT and FCC approval
CE compliant

Power Supply:

To work with the Avante I-Code Long Range Reader, a power supply which meets the following basic specification has been used.

Output Voltage: +24VDC
Current: 2 A

The reader contains some filtering circuits for the power supply. Some requirements are fulfilled by the power supply. The maximum ripple of the supply voltages (+24 V) must not exceed the following values:

Frequency of ripple f	**Maximum amplitude of ripple u [mVpp]**
50Hz ≤ 10Hz	100
10MHz ≤ f < 20MHz	50
20 MHz ≤ f	100

SYMBOL	PARAMETER	TEST CONDITIONS	RATING	UNIT
T_{stg}	**Storage Temperature Range**		-25 to + 85	°C
V_{dd}	Maximum Supply Peak Voltage		+27 / -0.6	V

Notes:
Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any conditions other than those described in the Operating conditions and Electrical Characteristics section of this specification is not implied.

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Technical Data for Avante Long Range Reader (Con't)

Operation Conditions:

Symbol	Parameter	Test Conditions	MIN	TYP[1]	MAX	UNIT
T_{amb}	Operation Ambient Temperature		0		+ 70	°C
T_i	Operating Incase Temperature		0		+85	°C
V_{dd}	Supply voltage		+23	+24	+25	VDC

Notes:

1. Typical ratings are not guaranteed. These values listed are at room temperature**.**

Electrical Characteristics

T_{amb} = 0 +70 °C, 50 Ω Antenna Load

Symbol	Parameter	Test Conditions	MIN	TYP[1]	MAX	UNIT
I_{dd4W}	Current Consumption [3]	RF Output Power = 4 W		0.975	1.100	A
P_{min}	Minimum RF Output Power [2]				3	W
P_{max}	Maximum RF Output Power [2]			Adj	4	W

Notes:

1. Typical ratings are not guaranteed. These values listed are at room temperature**.**

2. Calculated from measured RF-output voltage on 50 Ω load. RF output voltage measured with Tektronix TDS520B oscilloscope.

3. Values listed above are continuous currents; peak value can be up to 650 mA higher by switching or modulating the RF-carrier.

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Technical Data for Avante Long Range Reader (Con't)

EMC/EMI

The Avante Long Range Reader is designed in such a way, that it is possible to build systems with it, which are in conformance with EMC / EMI standards.
The conformance to EMC and EMI standards can only be guaranteed for systems – not for components.
Electromagnetic emissions comply with guidelines in BAPT 222 ZV 122 and EN 300 330.
The following configuration is in compliance with the Telecommunication Standards:
Avante I-Code Long Range Reader
Output power 4W at 50Ω; modulation index-15%; Standard Mode
Linear power supply according to the recommendations when connected via the delivered power supply cable
Avante HF U-Shaped Antenna
Size 200mm X 110mm X 74mm, impedance 50Ω, connector SMA male (50Ω**),** Max power 4W, cable connection type RG58; length 3.9m

The following measurements have been passed:
EMI: EN 300 330, BAPT 222ZV 122, FCC 47 part 15

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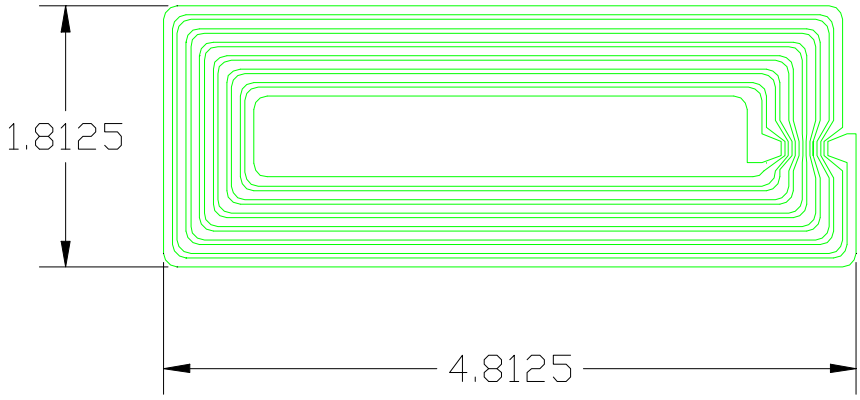
Avante Tag layout as used during test at Newark Airport



7 TURNS
LINES 1/16″
SPACES 1/32″