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Assessment of RFID Read Accuracy for ISS Water Kit

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1 Introduction

The Space Life Sciences Directorate/Medical Informatics and Health Care Systems Branch (SD4) is assessing the benefits Radio Frequency Identification (RFID) technology for tracking items flown onboard the International Space Station (ISS). As an initial study, the Avionic Systems Division Electromagnetic Systems Branch (EV4) is collaborating with SD4 to affix RFID tags to a water kit supplied by SD4 and studying the read success rate of the tagged items. The tagged water kit inside a Cargo Transfer Bag (CTB) was inventoried using three different RFID technologies, including the Johnson Space Center Building 14 Wireless Habitat Test Bed RFID portal, an RFID handheld reader being targeted for use on board the ISS, and an RFID enclosure designed and prototyped by EV4.

2 RFID Tagged Water Kit

The pilot test is performed on a RFID-tagged water kit. In this test configuration, the water kit is the middle one of three large Ziplock bags inside a half-size CTB (see Figure 1). This middle Ziplock bag contains two other Ziplock bags labeled as the Microbial Analysis Packet Assembly (MAP) and the Water Sample Collection Packet (WSCP). The MAP and WSCP contain additional Ziplock bags and/or supplies. Figure 2 shows the RFID-tagged water kit.

Figure 1. The tagged water kit (slightly raised) is located between two other bags inside a CTB.

Figure 2. The RFID-tagged water kit.

The passive RFID technology used for this study conforms to the Electronic Product Code (EPC) Global Class 1 Generation 2 (C1G2) standard. These tags operate in the Ultra High Frequency (UHF) band. All tags used are the Alien Technology “Squiggle Tags” (mixture of Higgs 2 and Higgs 3 integrated circuits), with the exception of a single Alien Technology Higgs 3 “2x2 Tag” for better tag placement on the item. A total of fifty-eight tags are applied to the water kit, including the middle Ziplock bag itself. A tag is applied to most items, including the Ziplock bags. Items not tagged are the packaged wipes (BZK antiseptic towelette and benzalkonium chloride antiseptic towelette). Most tags are taped onto the item so that they can be easily removed; however, a few tags are tied onto items, such as a small syringe. Appendix A lists the items inside the water kit and shows the tag identification (ID) naming convention.

3 Testing Concept

With the items of the water kit tagged with RFID tags and the water kit stowed inside the CTB, the CTB was tested at the Wireless Habitat Test Bed portal, tested with a RFID handheld reader, and tested inside an RFID enclosure. After the tests, the items of the water kit were removed from the Ziplock bag and then the items were randomly repacked back into the Ziplock bag. The CTB with water kit was again tested using the three RFID methods. This random repacking and subsequent RFID testing was performed three more times for a total of five different packing configurations and test set results.

Because results can vary for the portal and handheld reader tests based upon the attributes of the testers, five testers took part in the testing (Chau Phan, Haley Waterman, and Andrew Chu of Engineering Directorate and Diane Byerly and Stephanie Gunn of Space Life Sciences Directorate). Three testers taken from the five person tester pool were used to perform each test to preclude biased results based on the performance of any one person. These five testers were of different heights,walked at different speeds, and scanned the CTB in different ways to produce averaged test results less dependent on the actual tester.

4 Testing with the Wireless Habitat Test Bed Portal

4.1 Habitat and Portal Description

The Wireless Habitat Test Bed resides in the high bay of the Johnson Space Center, Building 14. The habitat structure is a horizontal cylinder constructed of ¼ inch aluminum skin. The cylinder measures 10 feet in diameter and 20 feet in length. The aluminum end caps of the cylinder each contains an aluminum door. The habitat is fitted with a raised floor of 27 tiles with metal plate backing. Mounting channels at three depths on both cylindrical walls provide a method to build out walls, cabinets, and supports for mounted equipment. The closeout walls are made of 1/8" thick Kydex supported by vertical unistruts. Cabinets and soft shelves have been outfitted on one side of the habitat. The other wall has been fitted with monitors and data entry stations. Outside of both doors are a landing and stairwell made of aluminum. Figures 3 and 4 show the test bed.

Figure 3. External view of the habitat structure.

Figure 4. Interior arrangement of the habitat.

An RFID portal resides at one entrance of the test bed. The portal utilizes an Impinj Speedway reader and four Cushcraft circular polarized antennas (two each of S9028PCL and S9028PCR). Two antennas can be seen mounted above and to the right side of the doorway in Figure 3. Two antennas are also mounted behind the walls in the interior of the habitat.

4.2 Portal Test Description

For each CTB packing, a set of portal tests is performed. A portal test set consists of three different people carrying the CTB into and out of the habitat. Each person carries the CTB through the portal holding the CTB, using three different methods: 1) holding the CTB in front with both hands, 2) carrying the CTB by a handle in the right hand, and 3) carrying the CTB by a handle in the left hand. In addition, tests are performed with the RFID reader in both Sessions 1 and 2. Therefore, a portal test set consists of 3 people, 2 directions, 3 carrying methods and 2 reader sessions for a total of 36 tests.

When a person carries the CTB into the habitat, the RFID reader is manually triggered to read as the person steps onto the first step of the stairs. Reading is commanded to stop when the person reaches the middle of the habitat. Conversely, when a person carries the CTB out of the habitat, the reader starts reading when the person is at the middle of the habitat and stops when the person steps onto the ground from the stairs.

The rate that a person passes through the portal has an effect on the success of capturing the RFID tags. The time used for each tester to pass through the portal is measured. The average time for the slowest and fastest person to pass through the portal are 7.0 sec and 4.5 sec, respectively.

The MultiReader software provided by the vendor was used to perform the inventory tests. The reader output power for all four antenna ports was set at 30 dBm. The reader was configured to dense reader M = 4 high speed mode, dual target search, and a tags-in-view estimate of 50.

5 Testing with a Handheld Reader

Previous testing has identified the AT570U purchased from ACC Systems Inc. as the best compromise between size and performance (barcode and RFID) for use on the ISS[1]. This reader has the capability to read both one-dimensional and two-dimensional barcodes and C1G2 UHF RFID tags. Figure 5 shows the AT570U. The demo software provided by the vendor is used to perform the inventory. The reader output power is set to 28 dBm, which is the maximum output supported by the reader. The application features a "scan time" parameter which establishes the time during which the reader waits for a tag response.

Figure 5. The AT570U proposed for ISS use.

The read success test was performed by setting the CTB on a nonconductive table and scanning the top and sides of the CTB with the reader antenna within two inches of the CTB for 20 seconds. Three operators performed the test, each scanning the CTB in Sessions 1 and 2. For each Session, both 0 and 60 scan time settings are tested. Therefore, for each CTB packing configuration, a total of 12 measurements were made.

6 Testing with EV4 Enclosure

EV4 has designed and prototyped several RFID enclosures[2]. Advantages for the enclosures include improved tag read reliability and prevention of reading unintended RFID tags located in

[1] "Performance Evaluation of Four Handheld Barcode and RFID Readers", JSC-64866.
[2] JSC technical innovation disclosure MSC-24758-1.

the surrounding environment. A deployable enclosure is used for this RFID tag read test. The CTB is placed inside the enclosure about 3 inches above the base of the enclosure.

An Impinj Speedway Revolution reader was used to query the tags inside the CTB. The reader was configured for an output power of 23 dBm. A test was performed to read the CTB in Sessions 1 and 2 and in each of three modes (dense reader M = 4 high speed, autoset dense reader, and autoset single reader modes). Two reads were performed for each setting and with the different sessions and modes, a total of twelve reads were performed for each packing configuration.

7 Results

7.1 Results for Portal Testing

The average read success rate of all portal tests for the five randomly packed CTBs is 91%. The difference in success rate for Sessions 1 and 2 is minor (see Figure 6). The difference in success rate for the carrying method and direction is low, with a maximum absolute difference of 4.6% (see Figure 7). Figure 8 appears to support the logic that a CTB passing through the portal more slowly results in a higher read success rate.

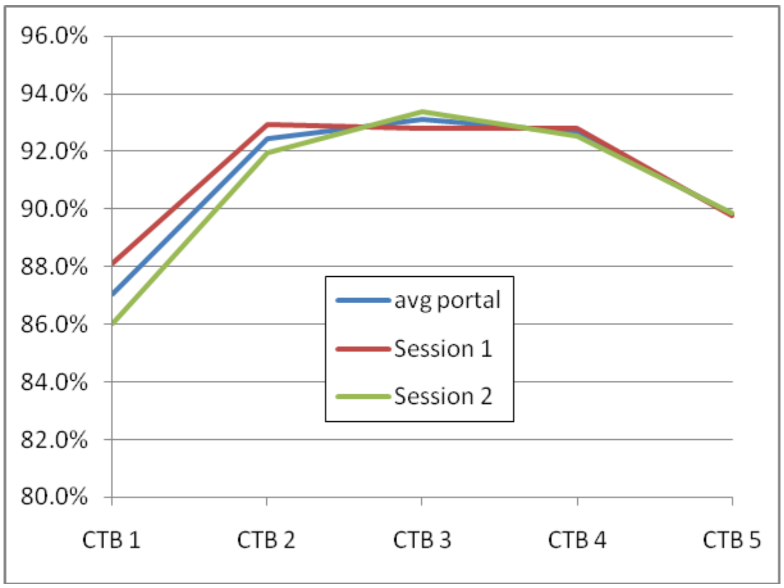

Figure 6. Portal read success rate for the five CTB packing. The read rate for Sessions 1 and 2 are also shown.

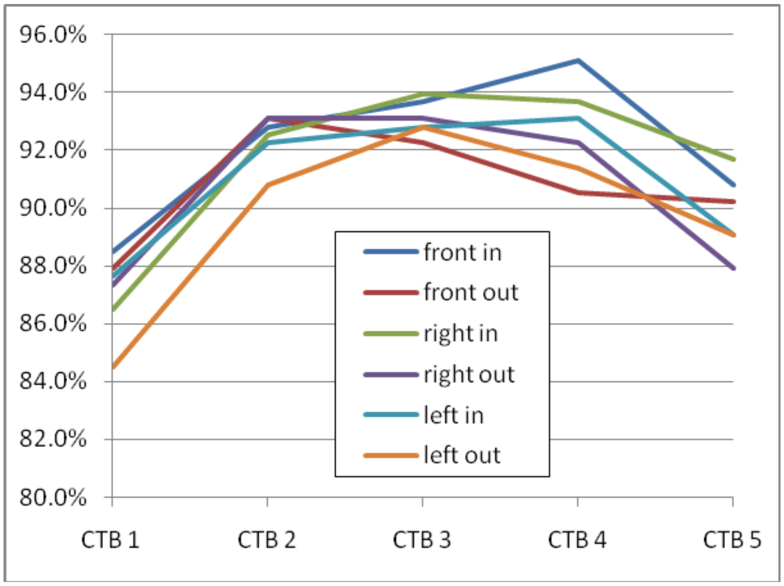

Figure 7. Portal read success rate based on carry method and direction for the five CTB packing.

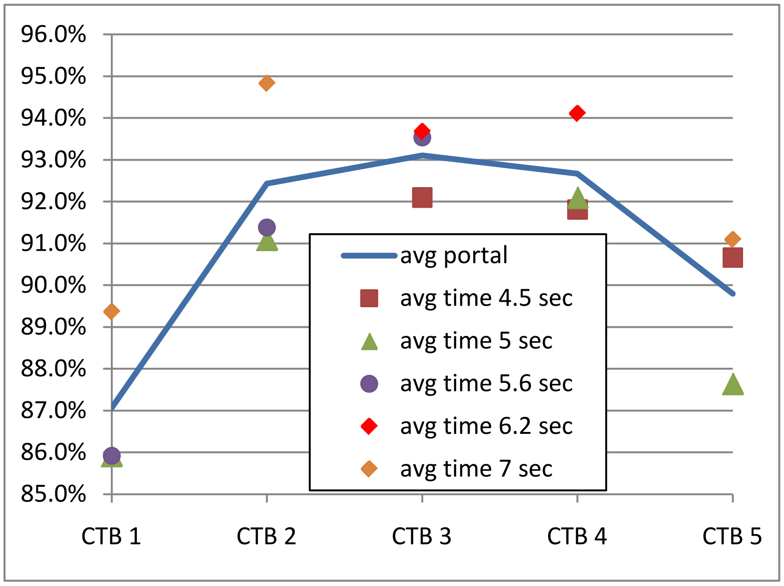

Figure 8. Portal read success rate compared to the speed that the CTB passes through the portal. In general, the slower the speed, the higher the read rate.

7.2 Results for Handheld Reader Testing

The average read success rate over all handheld reader testing, including the five randomly packed CTBs, is 98.4%. The difference in success rate for Sessions 1 and 2 is minor (see Figure 9). Also, the software's scan time parameter has little affects on read rate.

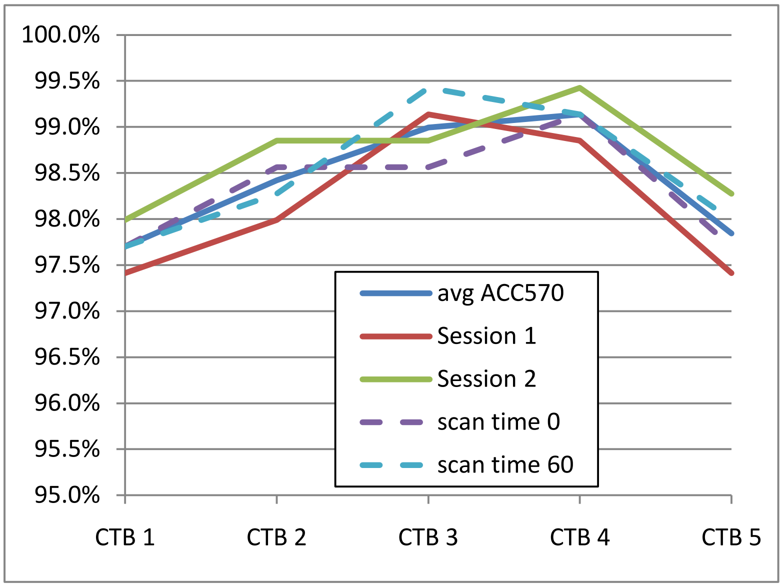

Figure 9. Handheld read success rate based on session and the software's scan time parameter for the five CTB packing.

7.3 Results for RFID Enclosure Testing

Every test performed in this series of tests using the portable RFID enclosure was characterized by a 100% read success. Often all tags are read within 3 seconds. The 100% read rate is independent of the session and reader density mode used. Also, no external tags are read from outside the enclosure, although the room where the enclosure measurements are made contains many tags.

8 Conclusion

A water kit on loan from SD4 was tagged with RFID tags and placed between two other Ziplock bags of supplies inside a half-size CTB. The CTB was interrogated using a portal, handheld reader, and RFID enclosure. The items inside the water kit were randomly packed five times. The average read success rate for the RFID portal, handheld reader, and RFID enclosure are 91.0%, 98.4%, and 100%, respectively.

Limitations with respect to read success for the portal and handheld readers are presumably due to signal blockage from nearby items. In addition, the increased space loss from the portal, relative to that associated with the handheld reader, and the increased blockage from the person carrying the CTB through the portal, likely account for the reduced accuracy of the portal compared to the other readers. In comparison, the prototype enclosure exhibited a success rate of 100% on each of five trials.

Appendix A. Listing of items inside the water kit.

The third of twenty-four bytes of the Tag ID is used to signify the packaging level. For this test, the water kit is the highest level and its third byte value is a "0". The next level of Ziplock is the MAP and WSCP and their third byte is a "1". The next level of Ziplock has a "2" in the third byte. The item level supplies are characterized with a "3" in the third byte. Available part numbers and expiration dates are coded into the Tag ID. The last four digits provide a unique identifier for each item in the CTB. The packaged wipes highlighted in yellow are not tagged.

Tag	Description	PN	Expiration	Tag ID					
1	Middle Ziplock			F2	00	10000000	100	00000	0001
2	Microbial Analysis Packet Assy (MAP)	SEG46121615-301		F2	10	46121615	301	00000	0002
3	small waste water bag	SEG46119988-612		F2	30	46119988	612	00000	0003
4	MCD storage bag			F2	30	10000000	100	00000	0004
5	coliform detection packet	SEG46119991-303		F2	20	46119991	303	00000	0005
6	coliform detection bag	SEG46119991-602	12/14/06	F2	30	46119991	602	39065	0006
7	70cc syringe			F2	30	10000000	100	00000	0007
8	10cc syringe	309604		F2	30	10000000	100	00000	0008
	BZK antiseptic towelette								
	BZK antiseptic towelette								
9	minisart single use filter unit	LOT16555 080319	4/30/11	F2	30	10000000	100	40663	0011
10	Fisherbrand cat # 09-719A	LOTR8JN00386	7/30/11	F2	30	10000000	100	40754	0012
11	microbial capture device (MCD)	KLSK270349-302		F2	30	00270349	302	00000	0013
12	syringe	KLSK270173-302		F2	30	00270173	302	00000	0014
13	Water Sample Collection Packet (WSCP)	SEG46121614-602		F2	10	46121614	602	00000	0015
14	potable water collection packet SRV-K	SEG46119988-311		F2	20	46119988	311	00000	0016
15	small waste water bag	SEG46119988-609		F2	30	46119988	609	00000	0017
	benzalkonium chloride antiseptic towelette								
	benzalkonium chloride antiseptic towelette								
16	valve			F2	30	10000000	100	00000	0020
17	potable water collection packet SRV-K	SEG46119988-311		F2	20	46119988	311	00000	0021
18	small waste water bag	SEG46119988-609		F2	30	46119988	609	00000	0022
	benzalkonium chloride antiseptic towelette								
	benzalkonium chloride antiseptic towelette								
19	portable water sampler	SEM46110793-306		F2	30	46110793	306	00000	0025
20	potable water collection packet SVO-ZV	SEG46119988-310		F2	20	46119988	310	00000	0026
21	small waste water bag	SEG46119988-609		F2	30	46119988	609	00000	0027
	benzalkonium chloride antiseptic towelette								
	benzalkonium chloride antiseptic towelette								
22	valve			F2	30	10000000	100	00000	0030
23	PWD collection packet	SEG46119988-316		F2	20	46119988	316	00000	0031
24	water microbiology kit micro sample in-flight analysis	KLSK270288-307		F2	30	00270288	307	00000	0032
	BZK antiseptic towelette								
	BZK antiseptic towelette								
25	valve			F2	30	10000000	100	00000	0035
26	micro sample in-flight analysis packet	SEG46119988-307		F2	20	46119988	307	00000	0036

27	micro sample in-flight analysis bag	SEG46119988-606	1/25/07	F2	30	46119988	606	39107	0037
28	micro sample in-flight analysis packet	SEG46119988-307		F2	20	46119988	307	00000	0038
29	micro sample in-flight analysis bag	SEG46119988-606	1/25/07	F2	30	46119988	606	39107	0039
30	micro sample in-flight analysis packet	SEG46119988-301		F2	20	46119988	301	00000	0040
31	micro sample in-flight analysis bag	SEG46119988-601	11/12/04	F2	30	46119988	601	38303	0041
32	micro sample in-flight analysis packet	SEG46119988-307		F2	20	46119988	307	00000	0042
33	micro sample in-flight analysis bag	SEG46119988-606	1/25/07	F2	30	46119988	606	39107	0043
34	TOCA analysis packet	SEG46121617-301		F2	20	46121617	301	00000	0044
35	Ziplock			F2	30	10000000	100	00000	0045
36	TOCA clip			F2	30	10000000	100	00000	0046
37	Iodine sample analysis packet	SEG46119988-317		F2	20	46119988	317	00000	0047
38	Ziplock			F2	30	10000000	100	00000	0048
39	TOCA analysis packet	SEG46121617-301		F2	20	46121617	301	00000	0049
40	Ziplock			F2	30	10000000	100	00000	0050
41	TOCA clip			F2	30	10000000	100	00000	0051
42	TOCA analysis packet	SEG46121617-301		F2	20	46121617	301	00000	0052
43	Ziplock			F2	30	10000000	100	00000	0053
44	TOCA clip			F2	30	10000000	100	00000	0054
45	chemical sample post-flight analysis packet	SEG46119988-309		F2	20	46119988	309	00000	0055
46	chemical sample post-flight analysis bag	SEG46119988-608		F2	30	46119988	608	00000	0056
47	micro sample post-flight analysis packet	SEG46119988-302		F2	20	46119988	302	00000	0057
48	micro sample post-flight analysis bag	SEG46119988-602		F2	30	46119988	602	00000	0058
49	micro sample post-flight analysis packet	SEG46119988-302		F2	20	46119988	302	00000	0059
50	micro sample post-flight analysis bag	SEG46119988-602		F2	30	46119988	602	00000	0060
51	micro sample post-flight analysis packet	SEG46119988-302		F2	20	46119988	302	00000	0061
52	micro sample post-flight analysis bag	SEG46119988-602		F2	30	46119988	602	00000	0062
53	chemical sample post-flight analysis packet	SEG46119988-304		F2	20	46119988	304	00000	0063
54	chemical sample post-flight analysis bag	SEG46119988-604		F2	30	46119988	604	00000	0064
55	chemical sample post-flight analysis packet	SEG46119988-304		F2	20	46119988	304	00000	0065
56	chemical sample post-flight analysis bag	SEG46119988-604		F2	30	46119988	604	00000	0066
57	chemical sample post-flight analysis packet	SEG46119988-304		F2	20	46119988	304	00000	0067
58	chemical sample post-flight analysis bag	SEG46119988-604		F2	30	46119988	604	00000	0068