

Results of UHF EPC Gen2 RFID tests on DVD discs and cases

Mieloo & Alexander
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Background

- Since passive UHF RFID Gen1 and 2 technology has been available, Mieloo & Alexander has tested the readability performance of this technology for products of several of our clients for utilisation in the supply chain.
- An extremely interesting business case exists for the tagging of DVD's (and CD's and Blue Ray discs) at case and disc level, as reliable RFID readability on single items as well as on larger 'populations' e.g. boxes with 25 DVD's and promotional displays) will enable benefits for both manufacturers and retailers by:
 - Reduction of handling cost:
 - Sorting and checking of customer shipments and returns flow handling
 - Serial number tracking (to avoid 'untrue discounts')
 - Avoiding handling to apply safety protections or for repacking
 - Re-ordering, stock counting, etc.
 - Improving anti theft and anti piracy measures.
 - Increasing sales revenue by optimising stock levels, display locations and possibly influence customer buying behaviour in real time and dynamic pricing.
- The high metal density and the close proximity of tags in supply chain and retail situations have so far prohibited successful application.
- But as technical development is making rapid progress, Mieloo & Alexander has conducted a number of tests for several clients, with the objective to determine the current status of the technology for deployment on DVD's in supply chain and retail environments.

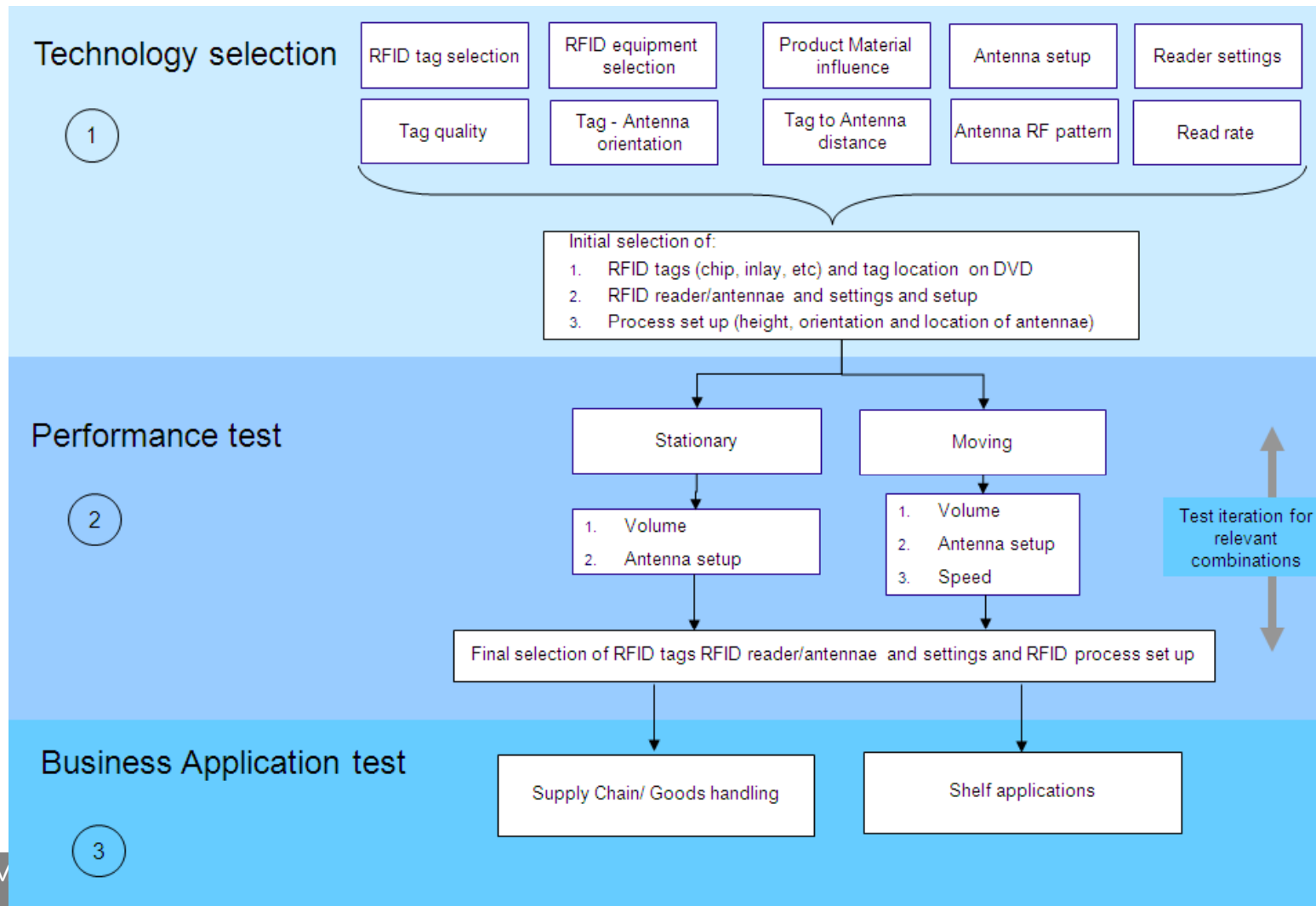
The Challenges

- Ultra High Frequency electromagnetic radio waves are reflected by metal; more than 50% of the DVD (disc and case) consists of metal. The challenge is to find a position to attach a tag to the disc or case where the tag isn't blocked by the disc itself or by other discs.
- DVD's and therefore the applied tags are typically placed very closely to each other (<1 cm) and in large numbers (>100) when DVD's are packed in a box or placed on a shelf. This has a severe negative impact on tag readability.
- When placed on a shelf, DVD's are stationary. This aspect also has a severe negative impact on tag readability.

Test Objectives

- To select the most suitable RFID EPC/UHF Gen2 technology (tags, readers, antennae) for tagging DVD's
- To validate the readability performance of the selected technology components for the application on DVD or DVD case level and utilization in supply chain and retail environments.
- To check the readiness of RFID technology for operational deployment and applications in supply chain and retail environments.

Test approach based on M&A's RFID methodology



Step 1: Technology selection (1)

Initial technology scope

- Based on experience and recent tests, Mieloo & Alexander has selected the following technology for the performance tests:
 - Tags
 - Avery Dennison AD-811 EPC class 1, Gen2 tag
 - Rafsec G2 short dipole EPC class 1, Gen2 tag
 - Impinj D EPC class 1, Gen2 tag
 - Impinj S EPC class 1, Gen2 tag
 - Reader
 - 1 Impinj Speedway reader
 - Antennea
 - 1 Poynting patch antenna
 - 1 Brickyard antennae

* See appendix for explanation Near field vs. Far field

Step 1: Technology selection (2)

Tag parameters

- Important tag parameters:
 - Size: fit in free space on DVD case or disc
 - Reading distance: minimum of 1 meter (to minimize # of antennas for 'on shelf' reads and for EAS)
 - Good performance in environment with high tag density: DVD's placed in case, storage and on shelves

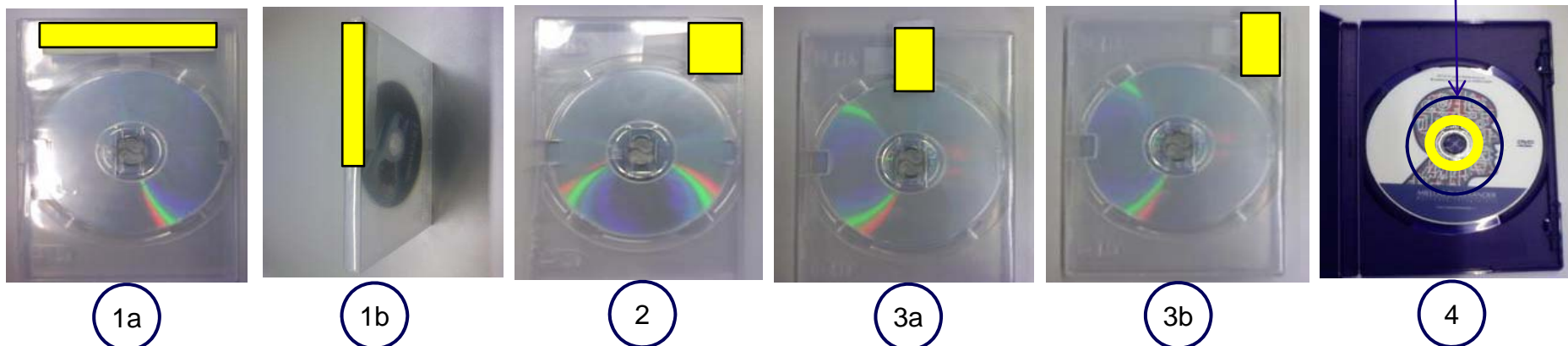
- Known performance characteristics (from previous tests)

	Tags	Communication	Protocol	Approximate Reading distance	Dimensions
1	Tag 1	Far field	EPC Class1 Gen2	up to 3 meters	92 x 10 mm
2	Tag 2	Far field	EPC Class1 Gen2	up to 2 meters	25 x 25 mm
3	Tag 3	Far field & Near Field	EPC Class1 Gen2	up to 2 meters	32 x 18 mm
4	Tag 4	Far field & Near Field	EPC Class1 Gen2	up to 1 meter	Ø 32 mm

Step 1: Technology selection (3)

Test placement

- Tag 1
 - Inside the box above the DVD
 - On the side of the box
- Tag 2 in a corner of the box, in this case the right upper corner
- Tag 3
 - In the middle overlapping the DVD and using the DVD as antenna
 - In a corner of the box, in this case the right upper corner
- Tag 4 in the center of the DVD



Step 2: Performance test (1)

Test objectives and conditions

- **Test objective:**
 - Determine which tag works best
 - Determine the best possible tag position on the DVD or case
- **Equipment used:**
 - 1 UHF reader
 - 1 circular polarized patch antenna (for tag 1 and 2)
 - 1 Near field/far field antenna (for tag 3 and 4)
- **Test conditions:**
 - 26 DVD's are placed in a carton and placed and moved before one antenna
 - **Stationary tests to simulate smart shelf process**
 - Orientation of the carton/ tags is changed in front of the antenna
 - The distance is varied between carton/ tags and antenna
 - **Dynamic tests to simulate moving boxes in distribution process**
 - Orientation of the carton/ tags is changed in front of the antenna
 - Distance between box and antenna is 30 cm



Step 2: Performance test (2)

Results



	Tag 1 a				Tag 1 b				Tag 2			
Top view of box in front of antenna	Side view	Stationairy Readability	Maximum tag - antenna distance	Dynamic Readability	Side view	Stationairy Readability	Maximum tag - antenna distance	Dynamic Readability	Side view	Stationairy Readability	Maximum tag - antenna distance	Dynamic Readability
		100%	35 cm	100%		92,3%	nvt	100%		96,2%	nvt	100%
		80,7%	nvt	100%		100,0%	53 cm	100%		38,5%	nvt	94,2%
		100%	50 cm	100%		88,5%	nvt	96,2%		38,5%	nvt	48,1%
		100%	65 cm	100%		80,8%	nvt	100%		96,2%	nvt	100%
		100%	84 cm	100%		100%	74 cm	100%		100%	30	100%
		92,3%	nvt	100%		88,5%	nvt	100%		100%	35	100%

Step 2: Performance test (3) Results



Tag 3 a					Tag 3 b				Tag 4			
Top view of box in front of antenna	Side view	Stationary Readability	Maximum tag - antenna distance	Dynamic Readability	Side view	Stationary Readability	Maximum tag - antenna distance	Dynamic Readability	Side view	Stationary Readability	Maximum tag - antenna distance	Dynamic Readability
		100%	45 cm	100%		100%	45 cm	100%		13,5%	nvt	44,2%
		86,5%	nvt	92,3%		92,3%	nvt	100%				
		40,4%	nvt	86,5%		100%	nvt	100%		0%	nvt	33%
		75%	nvt	98,1%		65,4%	nvt	100%				
		100%	40 cm	100%		100%	59 cm	100%		51,9%	0 cm	76,9%
		96,2%	nvt	100%		92,3%	59 cm	100%		40,4%	nvt	84,6%

Step 2: Performance test

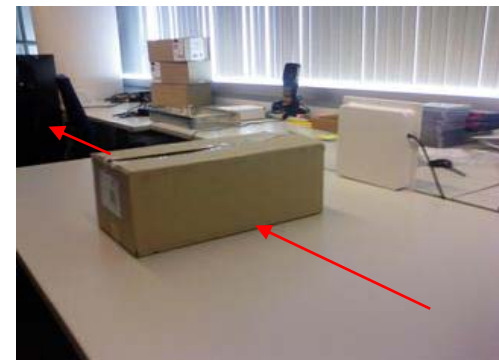
Conclusions

- Tagging the DVD with the tag designed for that purpose is not yet an option to use for shelf application or EAS solutions. The reading distance is too short (within the magnetic field of the near field antenna ~35 cm) and only small amount of tags (<15) can be read at the same time. This tag can be used however for supply chain applications (DVD's in boxes).
- Tag 1 inside the box above the disc has the best read results in stationary (4 orientations 100%) and dynamic environment (all 6 orientations 100%). The maximum reading distance in stationary environment in this test setup is up to 84 cm between tag in carton and antenna. This tag and position together with the patch antenna is therefore chosen for the business application tests of step 3.
- Best tag – antenna orientation in stationary environment is when the tag and DVD are positioned perpendicular to the antenna. This can be explained by the reflecting characteristics of the metal DVD and tag which influence the readability performance. This is also taken into account for business application tests of step 3.

Step 3: Business application tests (1)

Supply chain application – introduction

- Customer orders are picked, sorted and packed in carton boxes. Correctness is now checked manually by a second individual for all boxes leaving the warehouse which adds cycle time and cost.
- Test objective:
 - Check feasibility of automated order checking with RFID tagged DVD's.
 - Determine best antenna setup:
 - Tag - antenna distance;
 - Antenna orientation;
 - Number of antennae needed.
 - Create 100% readability for 'practical' volume of tagged DVD's and minimum amount of antennae.
- Equipment used:
 - 1 reader
 - 1 circular polarized patch antennae
 - Tag 1



Step 3: Business application tests (2)

Supply chain application – test conditions and results

- Setup:
 - Different tag to antenna orientations are tested to investigate if any packing or scanning regulations have to be taken into account when using RFID
 - Tests are repeated 5 times in every orientation
 - Box to antenna distance is 30 cm
 - Normal walking speed is used for the duration of read cycle time
 - Box volume is tested up to 52, which amounts to twice the number of DVD's than currently is being placed in a box
- Result and conclusion:
 - 100% readability performance with 100% reliability in all orientations!
 - Automatic scanning of a box with high volume DVD's is feasible with reasonable speed, exact speed regulations need to be determined.



Step 3: Bussiness application (3)

Shelf application – introduction

- When DVD's are placed on a shelf, they are placed either with the front side faced to the customer, or in worst case with their back to the customer. Both situations are simulated in the shelf application test.

- Test objective:
 - Check readability of tags on DVD's placed front or back side forward and in large quantities.
 - Determine best antenna setup;
 - Tag - antenna distance;
 - Antenna orientation;
 - Number of antennae needed.
 - Create 100% readability for maximum volume of tagged DVD's and minimum amount of antennae.

- Equipment used:
 - 1 reader
 - Circular polarized patch antennae
 - Tag 1

Step 3: Bussiness application (4)

Shelf application– test conditions and results

- The box tower setup is used for building the Smart DVD Display:
 - 4 layers
 - 6 boxes per layer
 - 5 – 10 DVD's per layer
 - 120 – 240 DVD's in total
 - 1 built-in reader
 - 4 built-in antennae*
- Results and conclusions
 - 100% readability with 100% reliability is reached with 120 DVD's.
 - When a DVD is taken out, it is directly noticed by the RFID known.
 - As has been proved by Mieloo & Alexander in further tests that can be done without NDA, these results make shelf applications with tags on DVD's possible

(*) Latest research with other antennae showed it is possible to reduce the number of antennae with 2.



Box tower setup

Summary and conclusions

- Although the metal and tag density of DVD discs and the stationary position of DVD's on shelves create severe adverse conditions for UHF EPC Gen2 RFID technology, this technology has advanced so rapidly that reliable read performance is now well within reach.
- The above is valid for case level tagging; disc (item) level tagging also shows positive results but only for limited numbers of tags and at a limited distance.
- With readability performance of case level tagging at least at 52 DVD's in a box and 120 DVD's on a shelf, supply chain and shelf applications that introduce reduced handling cost and improved stock visibility benefits are very well possible.
- As disc level tagging is not yet possible, benefits out of EAS solutions and anti theft and anti piracy applications are not yet possible, but given the rate of advance, this is a matter of limited time (max 2 years).

Appendix: Near field vs. far field UHF (1)

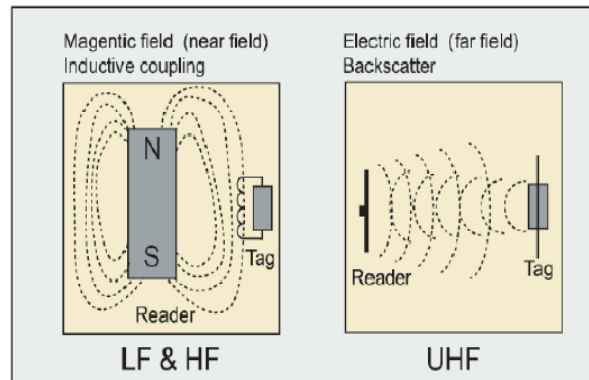
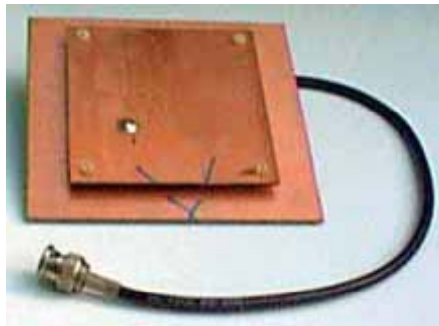
Characteristics

- **Near field UHF:**
 - Communication takes place between tag and antenna in the magnetic field within one wavelength of the frequency (up to 30 cm)
 - Stable read field
 - Well controlled and defined read field
 - No reflections by metal
 - No absorptions by fluids
- **Far field UHF:**
 - Communication takes place between tag and antenna in the electrical field of the frequency (up to 3 m)
 - Dead spots in read field
 - Less controllable and defined field caused by reflections on metal
 - Field is absorbed by fluids

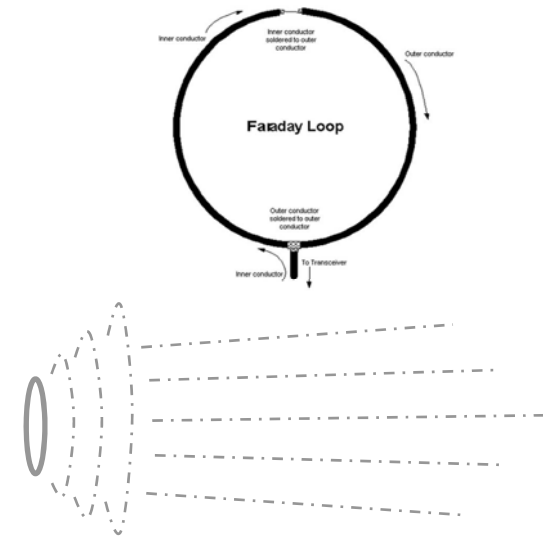
Appendix: Near field vs. far field UHF (2)

Antenna difference (868MHz)

- Far Field UHF
 - Patch antenna
 - Small magnetic field ~5 cm
 - Large electric field ~ 3 m
 - Reflected by metal
 - Absorbed by liquids
- Near Field UHF
 - Loop antenna
 - Larger magnetic field ~30 cm
 - Bends around metals
 - Through liquids
 - Large electric field ~ 2-3m



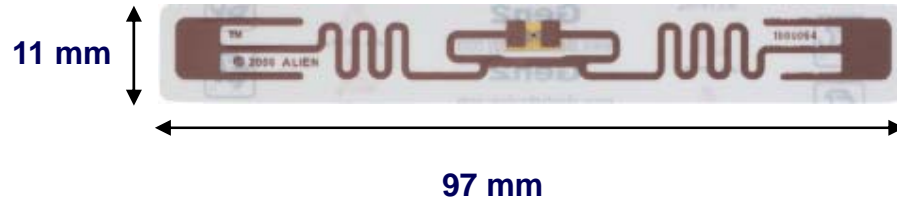
**Magnetic and Electrical
signals are always combined**



Appendix: Near field vs. far field UHF (3) Tag difference

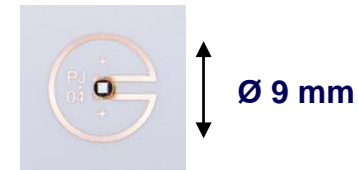
- Far field UHF

- Dipole antenna
- Designed to collect energy from electrical field



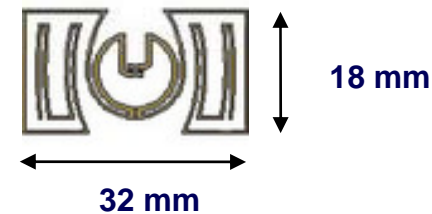
- Near Field UHF

- Closed loop antenna
- Designed to collect energy from magnetic field



- Near Field & Far field UHF

- Closed loop antenna
- Dipole antenna
- Designed to collect energy from both fields



Appendix: Near field vs. far field UHF (3)

Combining Advantages

- Advantages of UHF
 - Fast data transfer
 - More data transfer
 - Low cost technology
 - High multiple tag read rate
 - The international accepted supply chain standard

- Advantage of LF/HF
 - 'Better' performance in metal and liquid environment

- Disadvantage
 - Near field communication has a short read range of max 35 cm in free space. This range is bounded by the physics of electromagnetic waves and it depends on power settings, antenna dimensions and tag sensitivity if this range is reached or not.