ETSI TR 102 644-1 V1.1.1 (2008-12)

Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); RFID Plugtests to investigate the interoperability of tags manufactured by different vendors; Part 1: RFID Plugtests report

Reference

DTR/ERM-TG34-006-1

Keywords

radio, testing, SRD

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

The present document is part 1 of a multi-part deliverable covering RFID Plugtests to investigate the interoperability of tags manufactured by different vendors, as identified below:

Part 1: "RFID Plugtests report";

Part 2: "Test plan and preliminary tests".

Introduction

The present document describes an RFID Plugtest that was performed at the MGI centre in Neuss and at the VanDerLande premises in Veghel during the period 11^{th} - 15^{th} June 2008. The purpose of the tests was to investigate if there were any problems of interoperability when multiple tags manufactured by different vendors were simultaneously present in the same interrogation field. The question had been raised by some members of ERM_TG34 who had observed reduced reading performance when using different tag types on loads containing multiple items. This had led them to suspect that there may be an incompatibility between different designs of tag built with different ASICs.

Since RFID is a global business that is frequently used in open systems, members of ERM_TG34 recognized that any interoperability between tags would be unacceptable. It was therefore considered necessary to carry out a series of tests at the earliest opportunity to determine whether there were any such problems existed. The tests simulated a number of real life scenarios in which tags manufactured by different vendors might be present simultaneously in the same interrogation zone. The tests are described in a test plan which was reviewed and approved by members of ERM_TG34 and are available at annex A. In addition, prior to the Plugtests, a practical investigation was made to measure certain characteristics of the ASICs. It was considered that these measurements might assist in understanding the reasons for any incompatibility observed during the Plugtests.

Three of the four test scenarios were preformed at the MGI centre in Neuss and comprised of the following:

- Reading tagged items of clothing using a hand-held reader.
- Reading of stacks of individually tagged DVDs using shelf antennas.
- Reading pallets containing multiple tagged items passing through a portal.

In addition tests were carried out on a conveyor system at VanDerLande on which items with multiple tags passed reading stations. These tests simulated, for example, airline baggage fitted with RFID tags or tagged goods moving along a production line.

Seven RFID manufacturers took part in the Plugtests. They all participated on the basis that the results of the tests on their equipment would remain confidential. The present document therefore only provides an overall summary of the results recorded for each of the tests. In addition all of the participants in the tests had completed the ETSI Non-disclosure Agreement.

1 Scope

The present document describes an RFID Plugtest that was performed at the MGI centre in Neuss and at the VanDerLande premises in Veghel during the period 11th - 15th June 2008.

The purpose of the tests was to investigate if there were any problems of interoperability when multiple tags manufactured by different vendors were simultaneously present in the same interrogation field.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
  - for informative references.

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2.1 Normative references

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Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ETSI EN 302 208 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W".

[i.2] ISO 18000-6C: "Information technology - Radio frequency identification for item management - Part 6: Parameters for air interface communications at 860 MHz to 960 MHz".

[i.3] ETSI TR 102 644-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); RFID Plugtests to investigate the interoperability of tags manufactured by different vendors; Part 2: Test plan and preliminary tests".

3 Definitions, symbols and abbreviations

3.1 Definitions

Void.

3.2 Symbols

Void.

3.3 Abbreviations

Void.

4 Executive summary

These Plugtests were held at the request of members of ERM_TG34 who were concerned at possible problems of interoperability between tags manufactured by different vendors. To determine if this was the case, a series of tests, simulating real life scenarios, were defined. The tests were carried out the Metro Innovation Center in Neuss and at VanDerLande in Veghel.

Seven manufacturers of interrogators and two tag vendors participated in the tests. A total of eleven different tag types were tested, which included some RFID baggage labels provided by Air France.

Prior to the Plugtests an investigation had been carried out under laboratory conditions to determine if there were any obvious differences in the behaviour of ASICs (in the tags) that were manufactured by different foundries. Measurements made during this investigation showed that there was a noticeable difference in the behaviour of the session flags, which appeared to be dependent on the foundry that had produced the ASIC. However it was not clear if the difference would give rise to a reduction in reading performance in normal operation where mixed populations of tags were present.

The results from the Plugtests showed that there was no apparent difference in reading performance, due to any interoperability issues associated with the ASICs, between populations of tags from a single manufacturer and with mixed populations of tags.

It was observed that there was a noticeable difference in the sensitivity of different tag types, which directly affects their reading range. In applications where mixed types of tag might be used, it will be important to specify all tag types correctly to ensure that they are compatible with the system requirements.

Two distinctly different types of tag are available for item level tagging. One type is designed to be operated by a conventional radio wave. The other type is energized by a field that is predominantly magnetic. The antennas designed to read these two tag types are different. In an environment where both tag types are present, care will be necessary during system design to ensure that acceptable reading performance is achieved.

Tests on a conveyor demonstrated that it is possible to operate satisfactorily in situations where the interval between successive reads of the same tag by different interrogators is less than 2 s. Additional tests showed that using the select command it is possible to read only the "wanted tags" from a large population of mixed tags.

During the Plugtests it became apparent that not all manufacturers had a proper understanding of the features in the ASICs. This applied in particular to the use of the "select" command and the session flags. The correct use of these features is essential if optimum performance is to be achieved. Guidance on the behaviour of these functions, and how best they should be configured, is provided in an annex to the present document.

The outcome from the Plugtests was satisfactory and, based on the samples presented for the tests, showed that there was no incompatibility between different tag and ASIC types.

5 General

The names of the seven manufacturers of interrogators who participated in the tests were Hoeft & Wessel, Impinj, Kathrein, Nordic ID, Panmobil, Sirit and ThingMagic. In addition 10 different tag types were provided by three label manufacturers using ASICS from two different foundries. Further details of the tags are included in annex A. Also a number of airline RFID baggage labels were supplied by Air France.

For three of the test scenarios a pre-programmed tag was attached to each of the objects under test. The objects were divided into groups with tags assigned by tag type to each group. In addition there was an additional group which comprised items that included tags manufactured by different tag vendors. This made it possible to compare the performance of tags by type against the performance of a mixed population of tags. For practical reasons, in the case of the conveyor system, each item had three different tag types attached to it, although it was possible at any time to disable any two of the three tags.

The ID number and type of all of the tags were pre-loaded into the IBM server prior to the Plugtests. In addition the server contained an application tool that enabled easy manipulation of the recorded results to provide useful information. Each participant recorded each of their results on log files, which were subsequently transferred to the server following each test sequence. The total number of individual records that were logged during the Plugtests exceeded half a million.

Prior to each test the participant provided the test supervisor with details of the configuration of his interrogator. The configuration selected was the one considered by the participant to be the most suitable for the application that was being tested.

Pictures of each of the test scenarios are provided in annex E.

One of the interrogators presented for the Plugtests differed from the configuration that had been assumed in the Test Plan. Instead of being designed to drive four external antennas, the unit was equipped with an in-built antenna and an option to drive one external antenna. Where relevant, details of the set-up for this equipment are included in the description of each of the test scenarios.

With the exception of one manufacturer all of the interrogators presented at the Plugtests operated in accordance with EN 302 208 [
]. (This describes the four-channel plan). One equipment operated in accordance with the earlier version of the standard which specifies "Listen before Talk" and permits transmission on any channel within the band 865,6 MHz to 867,6 MHz.

All of the tags used in the Plugtests were compliant with the specification in ISO 18000-6 C [i.2].

The tests were managed by three neutral test supervisors, who were John Falck (Chairman ERM_TG34), Josef Preishuber-Pfluegl (Vice Chairman ERM_TG34) and Manfred Jantscher (CISC).

6 Description of tests

The definition of the four test scenarios is contained in the Test Plan at annex A. Where time permitted some additional tests were carried out. Details of these additional tests are also included in the present document. The Appendix to the Test Plan also describes some preliminary tests that were carried out prior to the Plugtests.

6.1 Garment tests

Four racks were prepared, each comprising forty tagged nightdresses, as described in clause 6.10.4.2 of TR 102 644-2 [i.3]. Three tag types, A, B and C, were used for the tests. The garments on three of the four racks were each tagged with tags of a particular type. The fourth rack contained an equal number of tags of all three types. An identical arrangement was configured for four stacks of trousers. Details of all of the individual tag ID numbers were stored in the IBM server.

The output power of the different handheld readers ranged from 200 dBm e.r.p. to 500 dBm e.r.p. All manufacturers with one exception operated in accordance with the four channel plan. All handheld readers were operated using session S0. Subsequently one manufacturer tried setting his reader to session S1 and achieved an improvement in his reading performance.

Each participant was asked to configure their handheld reader for optimum performance for the application. To ensure consistency in the reading process, a representative from Metro scanned the garments on each rack using each of the handheld readers in turn. The results from each scan were transferred to the IBM server. This same process was repeated for the stacks of trousers.

The results, averaged for all handheld readers, is shown below in figure 1.

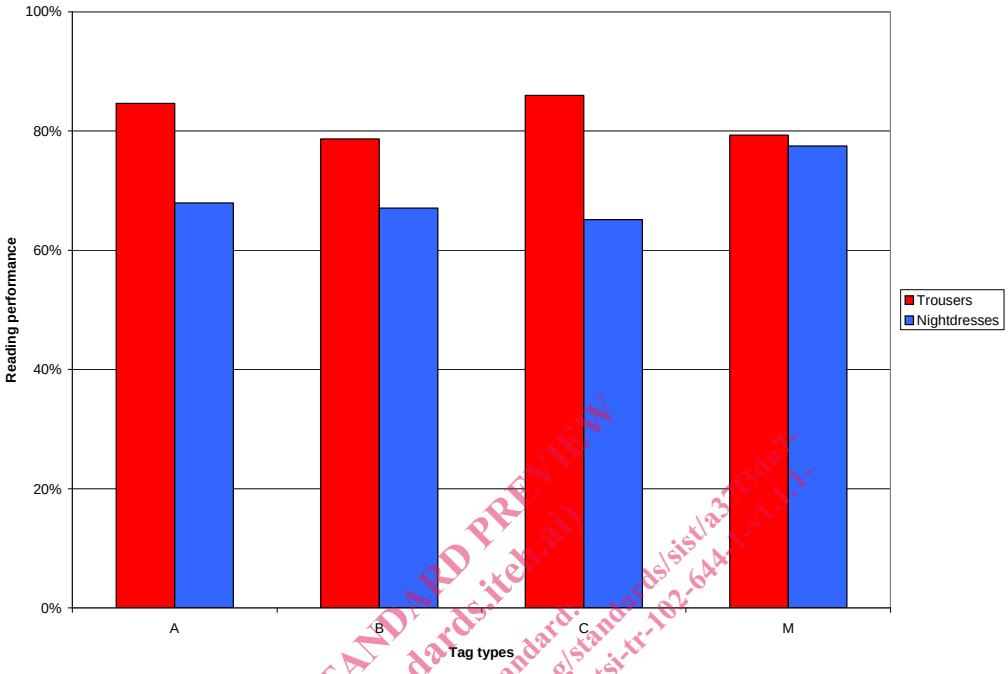

Figure 1: Averaged results for garment tests

The average results for the three tag types are shown in red for the trousers and in blue for the nightdresses. The two right hand columns show the results for the mixed types of tags.

Manufacturers of the handheld readers pointed out that in normal use operators would move garments hanging on racks as they scanned the tags. This would provide significantly better results than those recorded in the tests. However in order to obtain consistency in the testing of the different readers, it was decided scan the tags with only minimal movement of the nightdresses.

As might be expected there was a variation in the reading performance between interrogators. One reader consistently achieved reading rates of 96 % on the nightdresses and 100 % on the trousers.

6.2 DVD tests

The tests were performed using different stacks of DVDs each comprising ten cased DVDs. Each stack was tagged with different combinations of spine tags and inductive tags. A total of four different tags from three tag manufacturers were used in the tests. In every case each tag combination was repeated to give three identical stacks of a particular type. In total 31 different stack combinations were prepared for the tests.

The spine tags were fixed to the DVD cases while the inductive tags were attached directly to the DVDs. A particular feature of the inductive tag is that it is designed to be activated predominantly by a magnetic field. Three different manufacturers supplied tags that included both the spine and inductive varieties.

The test position comprised four shelf antennas arranged in a square and mounted immediately beneath a horizontal wooden surface. The antennas were connected to the interrogator under test and driven in turn sequentially. All participants operated using the "select" command but some interrogators used session S2, while others used either session S0 or session S1.

Initially three stacks of an identical tag type were positioned over three of the shelf antennas and the interrogator was activated for a period of 4 s. The number of tags read in each stack was recorded. This process was repeated with successively more complex combinations of stacks. Details of each of the combinations that were tested are shown in annex C.

The results from each of the combinations were analysed to provide an average figure for the reading performance of all of the interrogators that were measured. During the analysis it was discovered that two tags had been incorrectly programmed and two other tags were defective. These four faulty tags were excluded from the results. The corrected results are shown in figures 2 and 3 below in the form of bar charts. For ease of interpretation the results for the spine tags are shown in blue while the inductive tags are displayed in red. The tag types used in each test can be determined from the table in annex C.

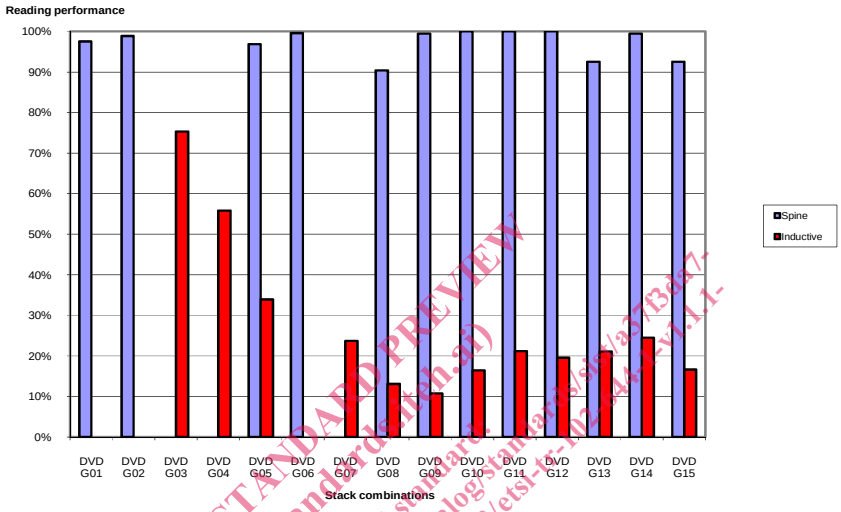

Figure 2: Averaged results for basic DVD tests

For some of the simpler DVD combinations a number of the interrogators achieved a reading performance that came close to 100 %.

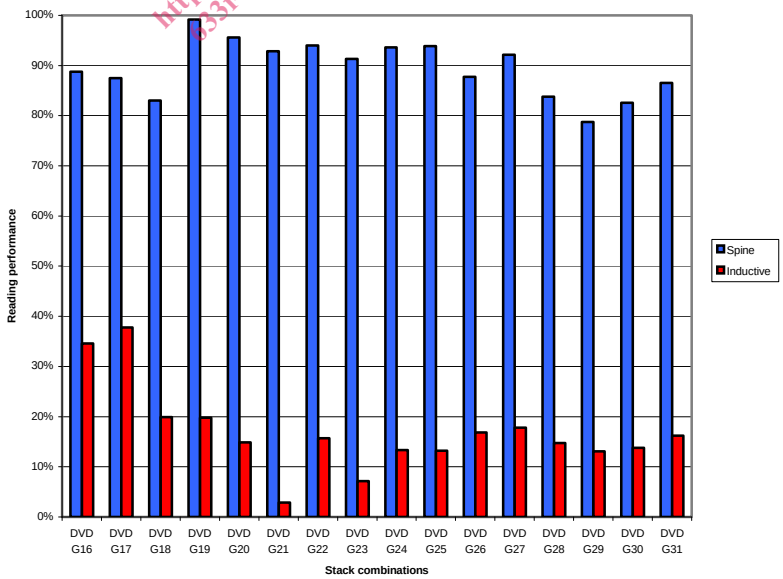

Figure 3: Averaged results for advanced DVD tests

From the results it is clear that the inductive tags performed less favourably than the spine tags. The reason for this was considered due to the use in the tests of shelf antennas that predominantly generated electro-magnetic transmissions. Additional tests were subsequently performed using one of the interrogators connected to a near field antenna. The conducted power level of the interrogator was left unchanged. The use of the near field antenna improved the reading performance of the inductive tags from 56 % to 71 %. It was still possible to read the spine tags although the reading performance dropped from 98 % to 90 %. It should be borne in mind that these tests were concerned solely with interoperability and comparisons between the performance of different systems is inappropriate.

It should be noted that one of the interrogators that participated in the tests was designed to drive just two antennas. To achieve compatibility in the results, two interrogators were used provide the four shelf antennas for the test set-up.

In certain orientations it was possible to read a spine tag at distances of up to 1 m from the near field antenna. It was also observed that type C (inductive) tags appeared to give a more consistent performance than type D (inductive) tags.

6.3 Portal tests

The portal tests were carried out using small pallets comprising 50 tagged cases and large pallets with 200 tagged cases. Details of the arrangement of the positions of tags and the type of tags are provided in annex D. This also includes details of the composition of the cases in each of the two sizes of pallet. Many of the cases contained items that were "r.f. unfriendly".

Four different tag types were used in the tests. For each pallet size there were four pallets each comprising tagged cases of one of the tag types. A fifth pallet comprised cases that were tagged with an equal number of the four different tag types.

Two test stations were used for the tests. One test station consisted of a portal positioned inside a dock door that led to a trailer parked outside. The portal was fitted with a pair of antennas on both sides and with a metal reflector positioned behind both pairs of antennas. A motioned detection device coupled combined with an infra-red curtain was mounted above the portal. This device was capable of determining the direction of motion of a pallet and could trigger an interrogator when a pallet was at a defined position in front of a portal.

The second test station used an identical design of portal but was positioned at the centre of a rail track testing system. This system could move a pallet repeatedly at a specified speed through the portal.

Each of the interrogators was set-up in turn to transmit at a power level of 33 dBm e.r.p. with a transmission period of 3 s for the dock door and 4 s for the rail track system. Manufacturers chose to operate their interrogators in either session S1 or session S2 and to use the select command.

The tests with the small pallets required each one in turn to be removed from the truck positioned outside the dock door and through the portal. Each pallet was carried by a fork lift that moved at an approximate speed of 1.5 m/s. The test was repeated five times for each pallet with each of the four different interrogators. The number of tags read each time that a pallet passed through the portal was recorded.

Due to their size the pallets with 200 cases could not readily be moved using the fork lift truck. To ensure repeatability of the testing procedure, the large pallets were tested on the rail track system. The format of the tests was identical to the procedure for the small pallets.

In order to test the interrogator with only two antennas, the system was configured using two interrogators, each one driving a pair of antennas on one side of the portal.

The combined results showing the average reading performance by tag type for small and large pallets is shown in figure 4. One anomaly in these results is that the reading performance for a mixed tag types improves with a small pallet, while the reverse is true for a large pallet. However this may not be significant.

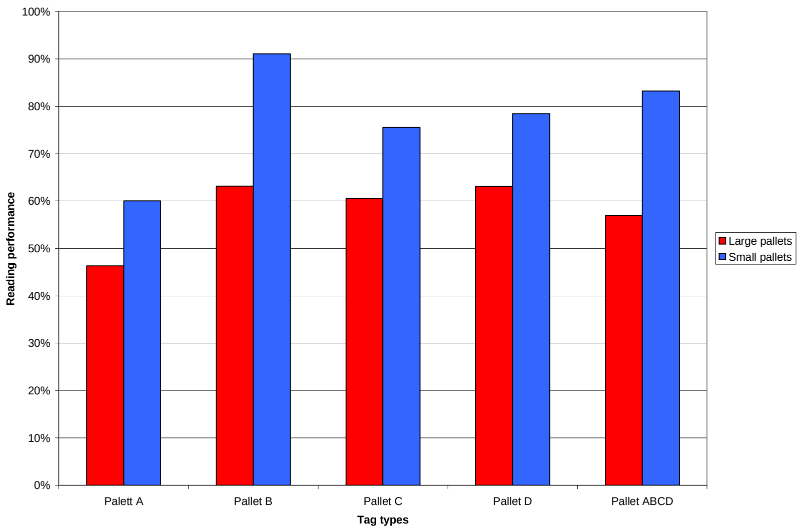

Figure 4: Averaged results for portal tests

Some interrogators achieved a better reading performance than others. The best performing interrogator achieved a figure, averaged over 5 runs, of 96 % with a "type B" 50 tag pallet. For a "type C" 200 tag pallet the equivalent figure was 78 %.

6.4 Conveyor tests

The conveyor tests were performed at the Innovation Centre of VanDerLande in Veghel. The conveyor used for the tests was of the type developed by VanDerLande for baggage handling at airports. The items used for the tests consisted of a variety of suitcases and bags. All twenty two of the suitcases and bags were filled with an assortment of objects, some of which were "r.f. unfriendly".

Three different tag types were used for the tests. One tag of each tag type was attached to the outside of each suitcase and bag. In addition a number of airline baggage labels, each incorporating an RFID tag, were provided for the Plugtests by Air France. These labels were attached to a selection of the suitcases.

The suitcases were placed on the conveyor in a known order with the tags facing upwards so that they could be observed during the tests. If required it was possible to read only a single tag type on a bag by covering the other two with adhesive-backed silver foil. The conveyor was set to run at a constant speed of 1 m/s.

Two types of reading station were used for the tests. One reading station comprised two patch MTI antennas mounted on pedestals on opposite sides of the conveyor. Each antenna was directed downwards towards the conveyor at an angle of approximately 45 degrees. Interrogators were connected in turn to the MTI antennas and adjusted to transmit at a level of 33 dBm e.r.p. The second reading station consisted of an array of two patch antennas arranged side by side within a moulded flexible mat. The mat was positioned beneath the conveyor belt. A metal hood above the belt contained the emissions from the antennas to the wanted reading area. The output from the interrogator driving the antenna array was set to a conducted power level of 22 dBm.

As a result of some initial experiments with the system, it was found that the reading performance was the same irrespective of the number of tags on the suitcases that were covered by silver foil. Similarly there was no apparent difference in the results when either one reading station was operated alone or both reading stations operated simultaneously. Based on these observations it was decided to conduct all of the tests with all silver foil removed and both reading stations in operation at the same time.

An interrogator with its select command enabled was connected to each reading station. Some manufacturers chose to use session S2 while others used session S0 or session S1. The tags were logged for five complete revolutions of the conveyor. The same procedure was repeated for the other remaining interrogators. For practically every interrogator the reading performance was 100 %. The only exceptions were when a tag came away from a suitcase and when one of the airline labels became damaged.