RF
RFID+RFComm

UHF RFID Simulations - Identification performance in dependence on UII size

EVALUATION REPORT

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CONTENTS

1 EXECUTIVE SUMMARY

Based on simulations executed with the CISC RFID ASD Kit+Library for the UHF frequency range, the following key statements can be made in respect to the ISO/IEC 18000-6Amd1 Type C air interface under consideration of ISO/IEC 15962 data syntax:

- Throughput in terms of Anticollision Rate degrades by approximately 30% if the UII length is increased from 96 bits to 240 bits in the US regulatory dense interrogator environment. This has also a severe impact on mixed population environments of tags with 96 bit UII and 240 bit UII.

- User Memory can only be read in the course of tag anti-collision, which means that User Memory handling always means significant decrease of application performance versus an application that requires no use of user memory.

- If User Memory needs to be supported for application specific reasons anyway, then the UII should be kept short in order to have fast Anticollision Rate for mixed populations of tags and for those tags where the read of the user memory can be skipped. For tags where the User Memory needs to be read in any case, there is no difference between having information in the UII memory bank (MB01) or User Memory bank (MB11).

2 INTRODUCTION

This report contains the description and detailed analysis of the RFID communication simulations carried out for Michelin according the project offer DMIC0901-P1 issued by CISC Semiconductor.

The project covers the simulation and evaluation of a defined subset of the ISO/IEC 18000-6Amd1 Type C specification for UHF RFID (equivalent to EPCglobal Class-1 Generation-2) with focus on performance considerations related to varying amounts of data stored in memory banks 01_2 and 11_2.

The structure of this report is as follows:

First, the simulation setup including the architecture of the selected simulation environment, simulated command sequences and chosen parameter settings is described. The simulation setup is partitioned in several batch packages for convenience.

Second, terms and abbreviations required for understanding the simulation results provided in the following sections are explained.

Third, the simulation results are evaluated and conclusions are drawn.

Finally, an overview about the raw simulation output data is provided as an annex to this document and a brief description of the additional raw simulation data to be delivered under the scope of this project is given.

3 SIMULATION SETUP

3.1 Simulation Architecture Description

Based on the protocol implementations available in the CISC Application and System Design (ASD) Library a customized simulation model was built on top of The MathWorks Matlab® and Simulink® according to the following basic concepts:

- Support of variable UII memory bank size
- Support of variable User memory bank size
- Flexible definition of the interrogator command sequence and tag response handling
    - Adaptation of the implemented anticollision algorithm
        - i.e. support of additional read access handling
    - Adaptation of the corresponding tag state machine

Refer to www.cisc.at/asd for more details regarding the CISC RFID ASD Kit+Library.

3.2 Command Sequence

In order to enable evaluation of a pure tag inventory aiming at detecting all tags illuminated by the RF field of the interrogator as well as more sophisticated scenarios combining tag inventory with read access, the following command sequences have been simulated:

1. Inventory only (interrogator stops after receiving the UII)
    - Select
    - Query
    - RN16
    - Anticollision (QueryAdjust/QueryRep/NAK), if required
    - ACK
    - PC + UII + CRC16
2. Inventory + read access to user memory bank (read whole $MB11_2$ at once)
    - Select
    - Query

- RN16 (or interference)
- Anticollision (QueryAdjust/QueryRep/NAK), if required
- ACK
- PC + UII + CRC16
- Req_RN
- RN16 handle
- Read
- Content of User Memory

Figure 1 shows the mentioned sequence of interrogator commands and tag responses in overview. In this particular example, a single tag is queried by the interrogator and no anti-collision handling is required.

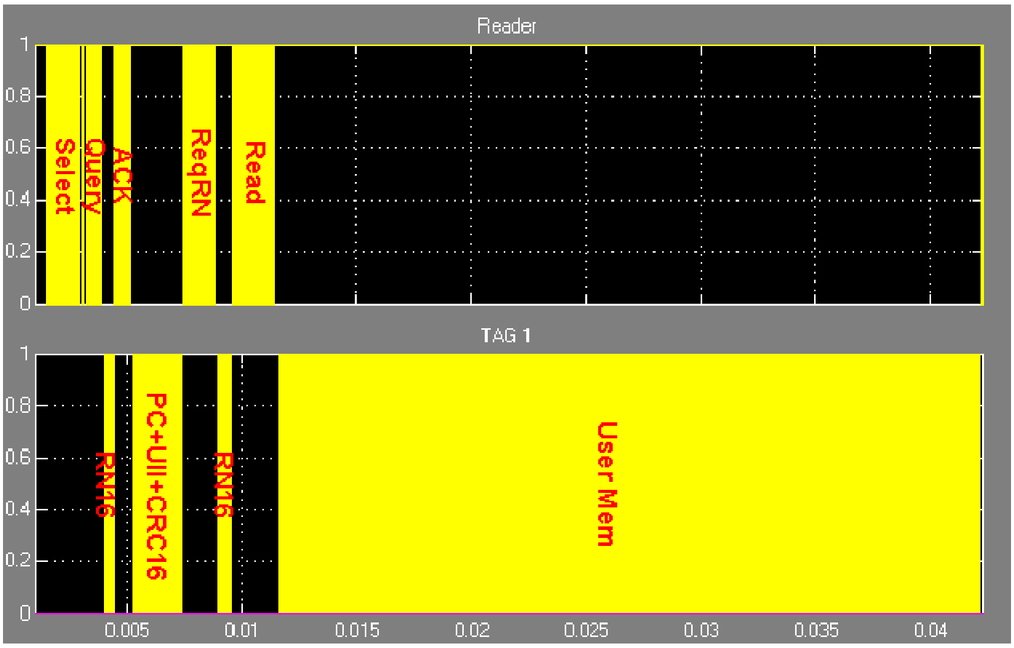


Figure 1: Simulated Tag Inventory and Read Scenario

3.3 Parameter Settings

3.3.1 General Parameters

In accordance with the simulated ISO/IEC 18000-6Amd1 Type C air interface specification, the fixed (non variable) simulation parameters listed in Table 1 have been chosen.

The selected parameter values represent typical values as they are used in real applications. Based on the fact that the focus of the simulations is on evaluation of the influence of varying UII- and User Memory sizes in respect to application performance, all other possible factors of influence have been excluded wherever applicable. In especially, no particular hardware-specific RF antenna radiation pattern, tag positioning, or movement path/speed combinations have been simulated but instead all tags have been sufficiently powered for the entire inventory round.

Table 1: Fixed Protocol Parameters

Parameter	**Values**	**Description**
Pilot tone	no	Do not use extended return link preamble
Anticollision Algorithm	Annex D, fixed C = 0.5	As described in the according Annex of the EPC Class-1 Gen-2 specification
Anticollision Parameter q	0	Assume unknown nr. of tags in the RF field
Unanswered queries	1	Number of inventory rounds without response to stop pass
Session	S2	Persistency of 5s
RNG one probability	0.5	Probability of tags RNG rolling a 1
Select target	Session flag	Target of Select command
Interrogator to tag bit error rate	0	No bit errors inserted
Tag to interrogator bit error rate	0	No bit errors inserted
Field nulls per second	10	Typical value
POR charge time	1e-4	Time for the tag to reach the minimum working voltage after a field null
Length of protocol control	16 bits	No support of extended protocol control (XPC)
Interrogator power up time	1.5e-3	Seconds
RF field	idealized	All tags are powered for the entire simulation

Furthermore, UII- and User Memory bank sizes have been varied to evaluate the emerging impact on the RFID application performance as shown in Table 2. In order to consider also the varying effort for handling tag collisions with different tag population sizes, tag populations of 1, 10, 30 or 60 tags have been simulated in combination with the described UII- and User Memory bank settings.

Table 2: Variable Protocol Parameters

Parameter	**Values**		
Memory bank sizes (in bits)	*UII Memory (MB 01_2)*	*User Memory (MB 11_2)*	*Sum*
	128	0	128
	272	0	272
	272	240	512
	272	728	1000
	128	144	272
	128	384	512
	128	872	1000
Number of tags in the RF field	1		
	10		
	30		
	60		

Please note that under the scope of this document always the full content of the according memory bank is quoted when referring to the UII- or User Memory. In detail, this means that a UII Memory size of 128 bits corresponds to a 96-bit UII whereas a UII Memory Size of 272 bits corresponds to a 240-bit UII, see also 4.2.

Note: In case of $MB11_2 = 0$, the simulated command sequence does not include Req_RN nor Read. It is assumed that the interrogator inspects the UMI indicator to determine that no user memory is supported.

3.3.2 Batch Packages

To simplify the start and stop of the single simulation runs and to provide a convenient way of automatic simulation result evaluation, the different parameter setups have been partitioned in several different batch simulation packages, see Table 3.

Table 3: Batch Simulation Package Definition

	Forward Link Rate (Interrogator to Tag)	**Return Link Rate** (Tag to Interrogator)	**Mixed Population**	**Other Parameters**
Batch1	Tari = 25µs	64kBit/s (DI FCC[1])	No	See 3.3.1
Batch2	Tari = 25µs	53.3kBit/s (DI CEPT old[2]) and 75kBit/s (DI CEPT new[3])	No	See 3.3.1
Batch3	Tari = 6.25µs	640kBit/s	No	See 3.3.1
Batch4	Tari = 12.5 µs	80 kBit/s	No	See 3.3.1
Batch5	Tari = 25µs	64kBit/s	Yes 128-bit UII/272-bit UII 33% / 66% 50% / 50% 66% / 33%	See 3.3.1 except no User Memory simulated

Note: DI = Dense Interrogator

As the interrogator to tag link rate is depending on the actual occurrence of logical "0" and "1" bits in the data stream, since Pulse Interval Encoding is used, the Tari value is given instead.

Each different setup (cluster of protocol parameters) has been repeated 10 times and the mean value has been calculated over each group of simulation runs to retrieve accurate results.

4 TERMS AND DEFINITIONS

4.1 Terms

Full Detection Time
Time required to detect all tags of a given tag population in the course of an inventory round. In this context a tag is considered detected if it has backscattered its UII after being acknowledged by the interrogator.

Full Read Time
Time required to detect and additionally read the full user memory of all tags of a given tag population.

[1] This setup reflects DRM (dense interrogator mode) in most regulatory enviornments in ITU region 2 including Argentina, Brazil, Canada, Chile, Mexico and USA
[2] This setup reflects DRM in Japan.
[3] This setup reflects DRM in most ITU region 1 countries, especially those that have adopted EN 302 208 V1.2.1 and the corresponding CEPT REC 70-03. Furthermore, it applies to South Africa, South Korea and India.

Anticollision Time
Time from the first tag detection until the last tag detection as logged by the interrogator.

Anticollision Rate
Theoretical number of tags that can be inventoried per second in a given RFID setup, calculated by using the following expression: `Total number of detections/Anticollision Time.`

All Data Received Time
Under the scope of this document this term denotes the time until all data stored on the tag has been received by the interrogator. If the data is split between the UII- and the User Memory this requires backscattering of the UII Memory content as well as a separate read of the User Memory content. This key figure is not at default implemented in the CISC RFID ASD Kit+Library products and has been added manually.

4.2 Abbreviations

ACR = Anticollision Rate (Tags/s)

FDT = Full Detection Time (s)

FRT = Full Read Time (s)

ADR = All data received (s)

UII Mem = UII memory bank (MB 01_2) size in bits; Comprises the full content of this memory bank, i.e. CRC-16 checksum, Protocol Control (PC) bits, and the UII itself

Usr Mem = User memory bank (MB 11_2) size in bits

5 RESULT EVALUATION

5.1 Homogeneous Tag Populations

5.1.1 Batch 1

Batch simulation package 1 is a typical setup as it is used in FCC[4] governed Dense Interrogator Mode environments.

5.1.1.1 Full Detection Time

The Full Detection Time is influenced by a series of different parameters. Among them the number of tags and the corresponding effort for resolving emerging tag on tag communication collisions is most significant. Furthermore, the time spent on backscattering the tag's UII after the tag has been singulated and optional User Memory access leads to a major increase depending on the actual amount of data to be transmitted.

[4] Federal Communications Commission

Figure 2 shows how the time for detecting all tags within a population changes with the different UII- and User Memory sizes.

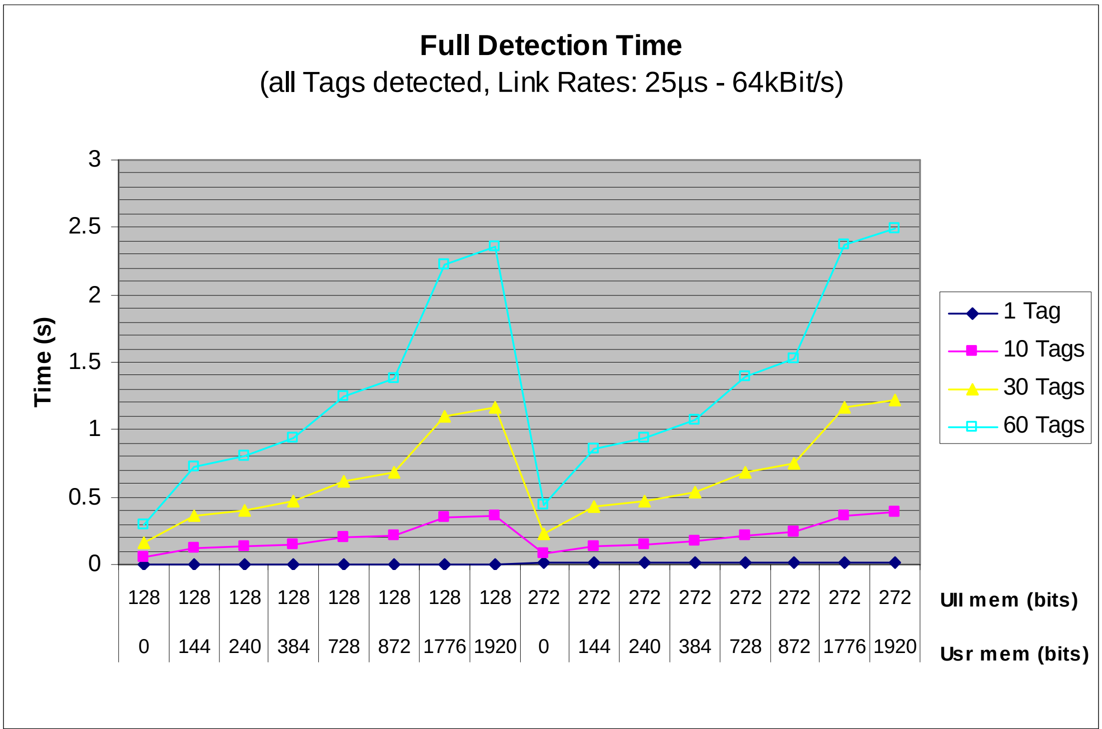
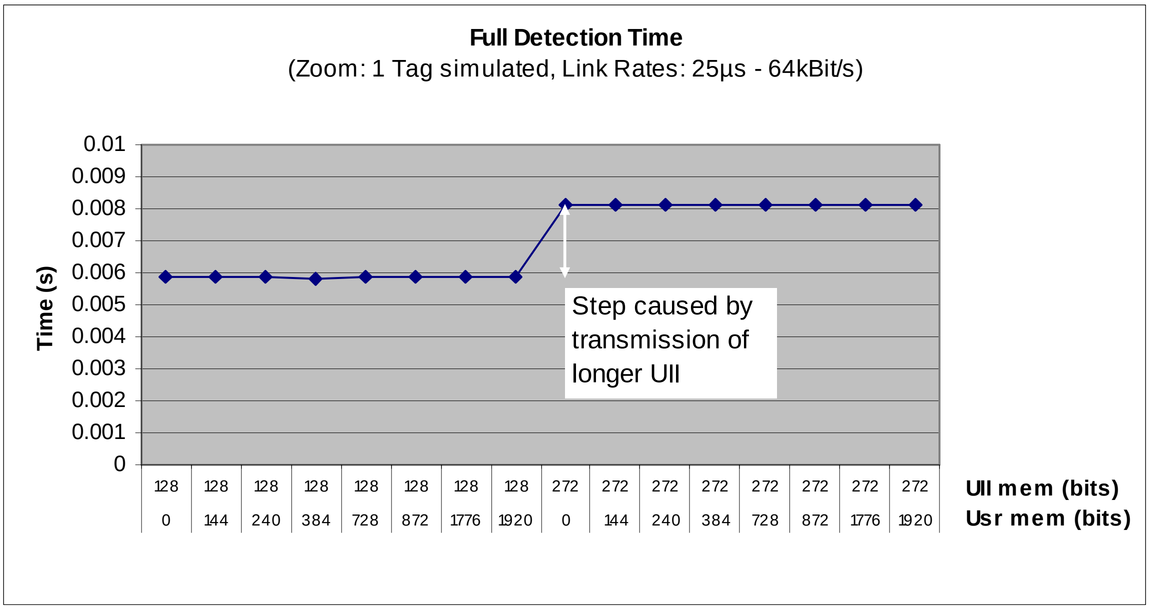


Figure 2: Time Required to Detect all Tags

Additionally, Figure 3 is providing a detailed view on the data series regarding small tag populations of 1 and 10 tags respectively. It is visible that in case of simulating just 1 Tag, the only visible increase in respect to the Full Detection Time is due to the increasing the UII length since the Full Detection Time is measured only until the last tag has transmitted its UII and the extra time to additionally read out its User Memory is not considered per definition.



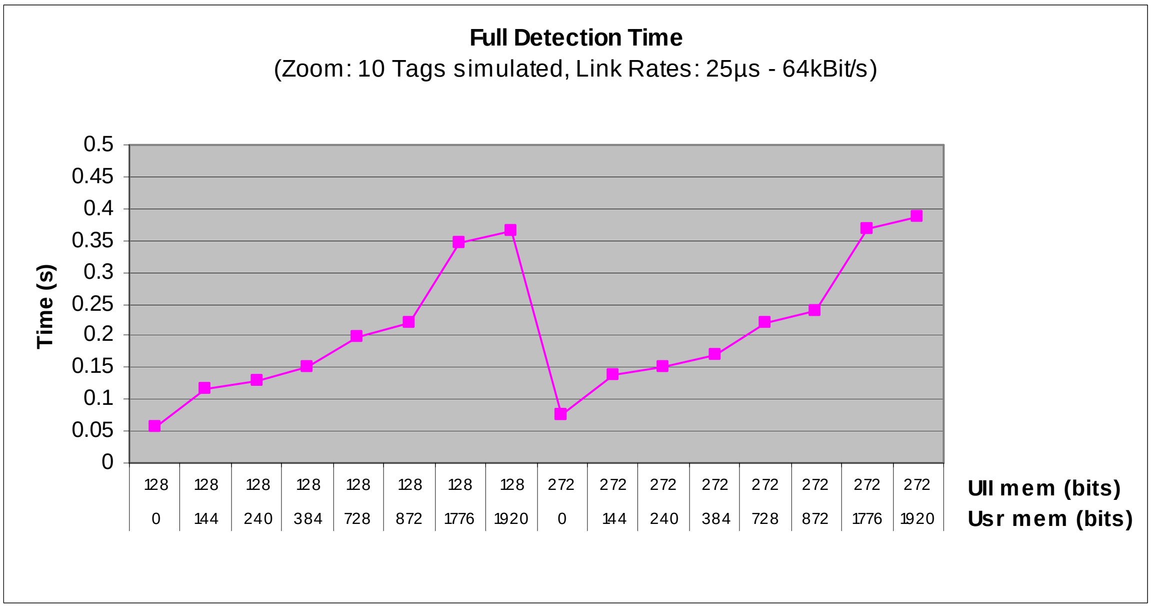


Figure 3: Time Required to Detect all Tags - Details

5.1.1.2 Full Read Time

In contrast to the Full Detection Time, the Full Read Time covers the time necessary to detect and fully handle all tags within a population. Therefore it tells us the exact period of time that is required to detect all tags by means of receiving their backscattered response to the ACK command as well as all sub steps additionally required to read their User Memory bank, i.e. Req_RN and Read command handling.

Figure 4 shows the emerging results in overview.

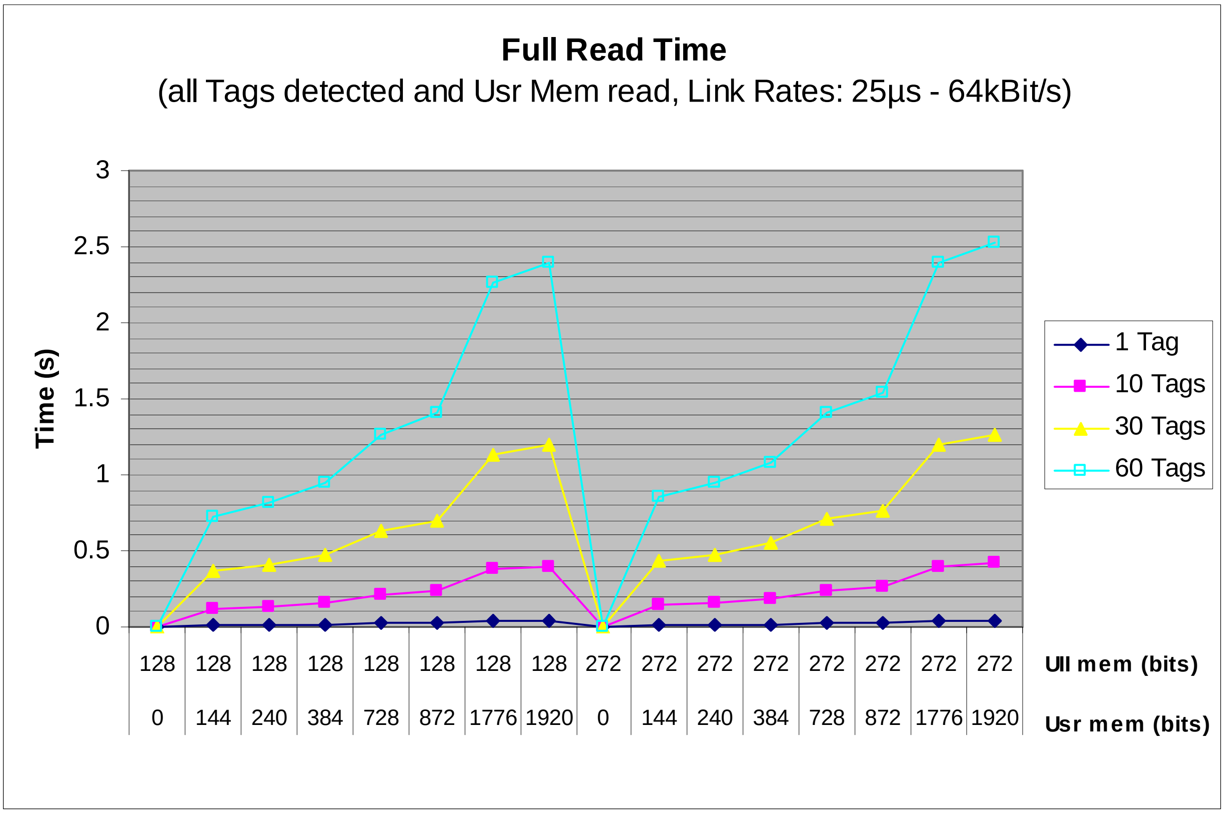


Figure 4: Time Required for Reading the User Memory of all Tags

If the results of Figure 4 are compared to the results of Figure 2, the extra-effort for reading the User Memory bank becomes obvious.

Figure 5 shows the comparison for the single tag scenario, where no anti-collision handling additionally affects the results. The worst possible scenario in respect to the simulated parameter settings shows an additional time of 694% related to the Full Detection Time for reading the content of a User Memory of 1920 bits. Results for smaller User Memory banks show a smaller but still significant impact.

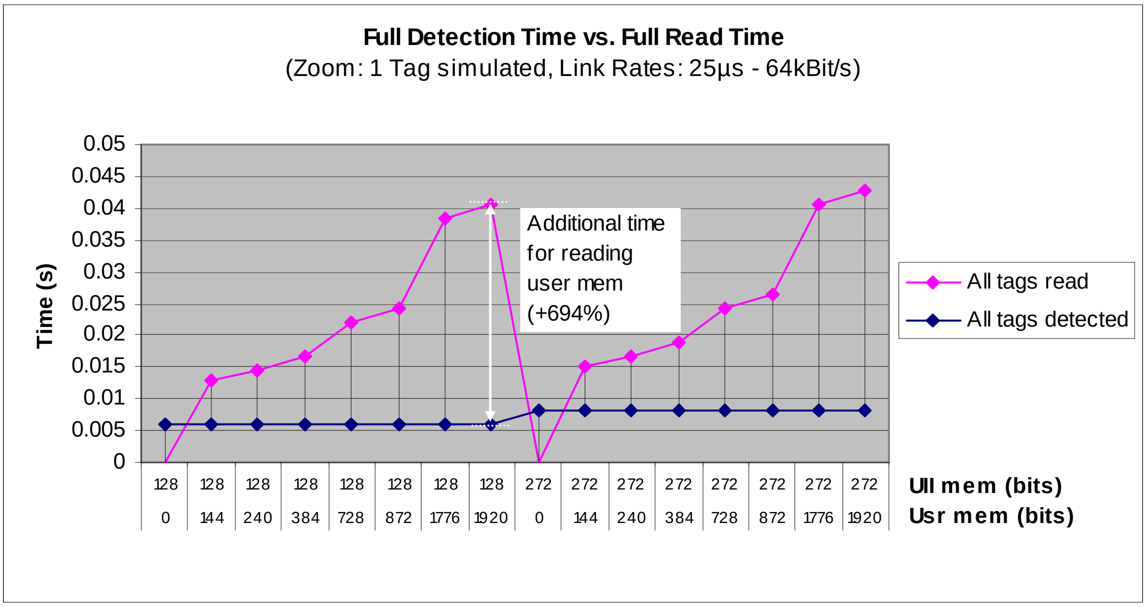


Figure 5: Difference between Full Detection Time and Full Read Time

5.1.1.3 All Data Received

In some application scenarios a major design issue is to decide whether to put all data into the UII Memory or to split the data between UII Memory and User Memory, if possible.

Based on the results presented in the previous two sub-sections, we are able to investigate the time until all data is received by the interrogator if a fixed total amount of data is assumed that is distributed between the two different memory banks. Figure 6 shows the results obtained for the batch simulation package 1.

In case of simulating a total amount of 272 bits of data, a major difference between the two different UII length settings is visible. If the 272 bits of application data are stored exclusively in the UII Memory no further read access to the tag's User Memory is required. In this particular case the All Data Received Time equals the Full Detection Time and a major speedup is visible compared to the case where a 128-bit UII Memory is assumed and the remaining 144 bits have to be stored in the User Memory (compare first data points of the two series in Figure 6). This gap is caused by the extra time for requesting an access handle and issuing a separate Read command.

In all other cases, data is stored in the UII Memory as well as in the User Memory and results show that in this case no major difference between the simulations carried out with 128 and 272 bits of UII Memory can be found. In other words, as soon as some data needs to be put into the User Memory the access method to this memory bank itself causes some overhead that cannot be avoided. However, this overhead becomes less significant if the overall amount of data to be read increases. There is no major difference if some small amount of user data is appended directly to the UII and the major amount of data is store in the User Memory and needs to be read separately, or if all user data is stored in the User Memory bank.

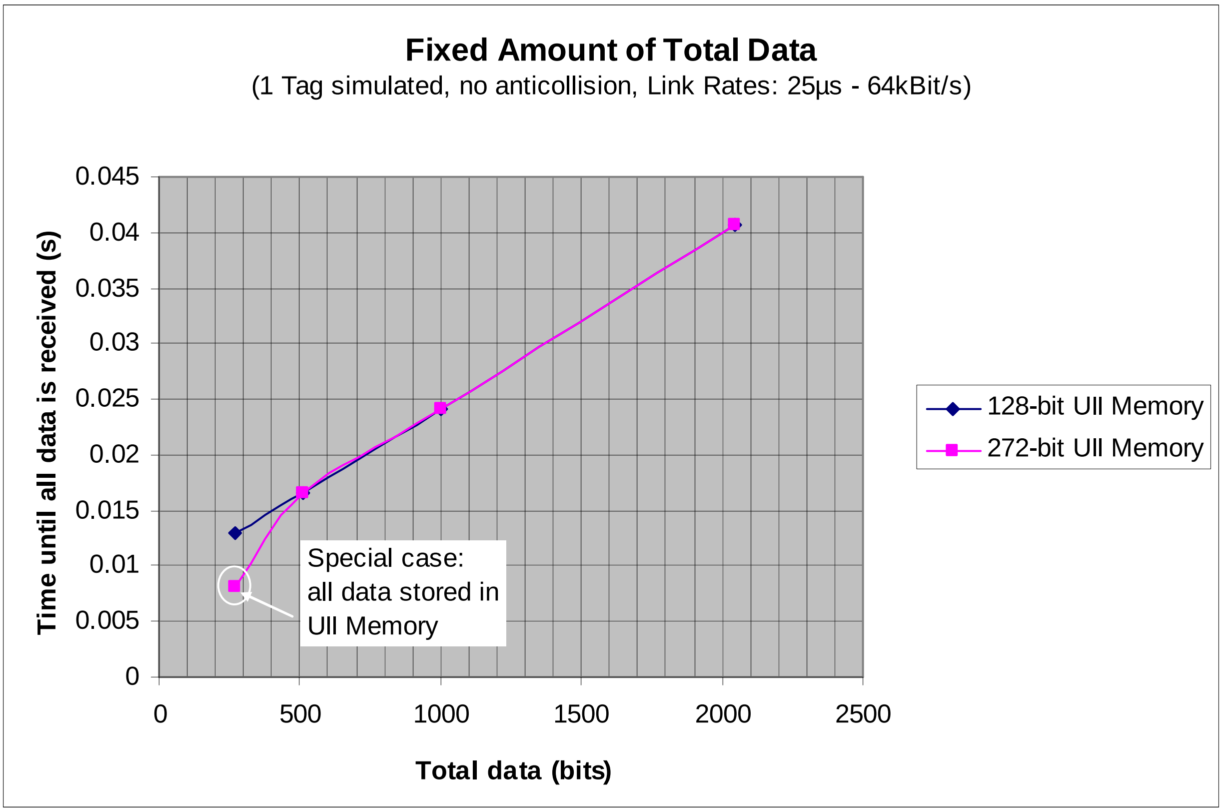


Figure 6: Data Split between UII and User Memory

5.1.1.4 Anticollision Rate

The Anticollision Rate is a key figure used to determine the overall throughput of an RFID application.

Figure 7 shows how the Anticollision Rate changes with the different UII- and User Memory sizes for the link rates given for Batch1.

Note: Due to its definition, at least two tag detections are necessary to calculate the Anticollision Time and hence the Anticollision Rate. Therefore no Anticollision Rate can be calculated for single tag setups. This is the reason why no "1 Tag" data series is included in Figure 7.

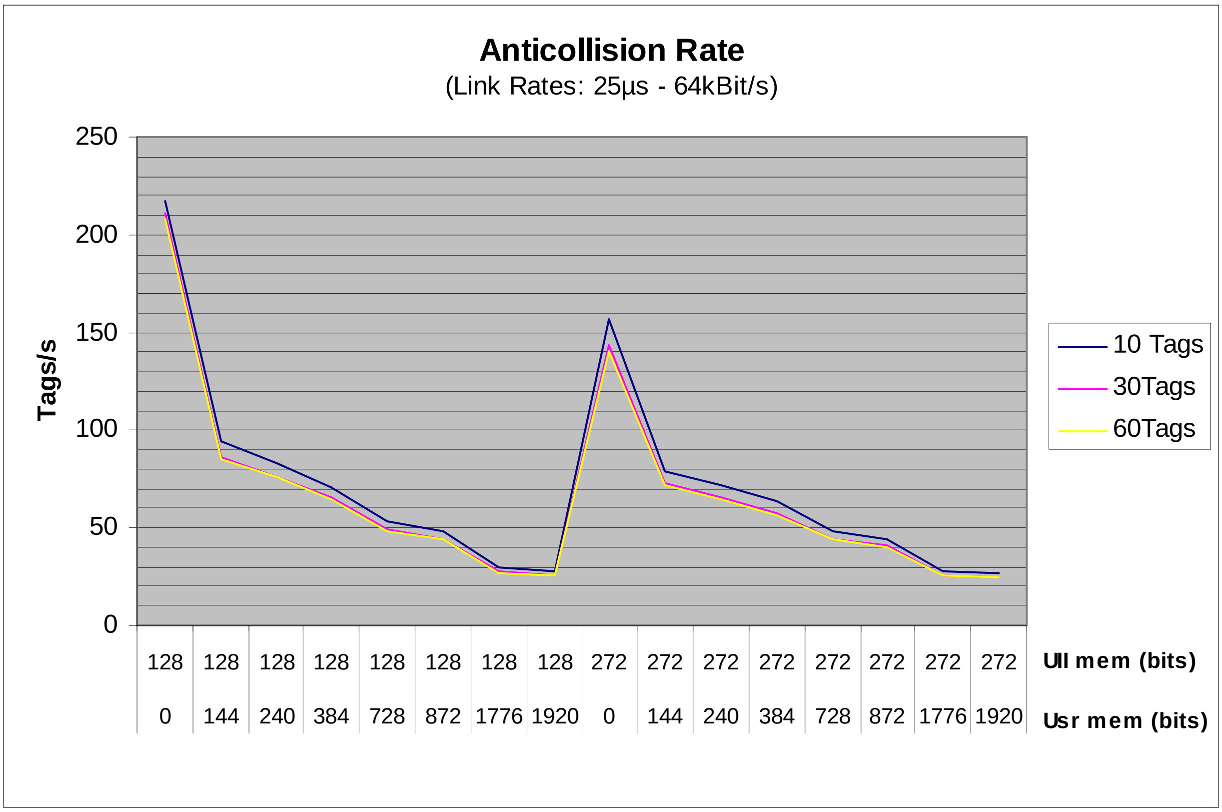


Figure 7: Application Throughput

In Figure 8 the dependency between Anticollision Rate and the User Memory size is outlined assuming a fixed UII Memory size of 128 bits. It can be observed that the expected throughput drops massively between the first two data points of 0 and 144 bits of User Memory bits. This is due to the fact that in the first case no User Memory is supported at all, whereas in the second case an access handle needs to be requested first by issuing a Req_RN command and later the User Memory is read out by means of the Read command for each tag. All in all, this means a deterioration of 56% in case of 10 tags.

This implies that it is important for the interrogator to have a user memory indicator that can be checked to determine whether the tag is equipped with a User Memory bank, or not, instead of blindly acquiring a handle and requesting the content of this memory bank by issuing a Read, which may be turned down by tag with an error code. Moreover, some kind of additional indicator regarding the importance of the actual content of the User Memory may help the interrogator to decide if and what section of the User Memory are to be read for which purpose. This is important in order to guarantee a high application throughput.

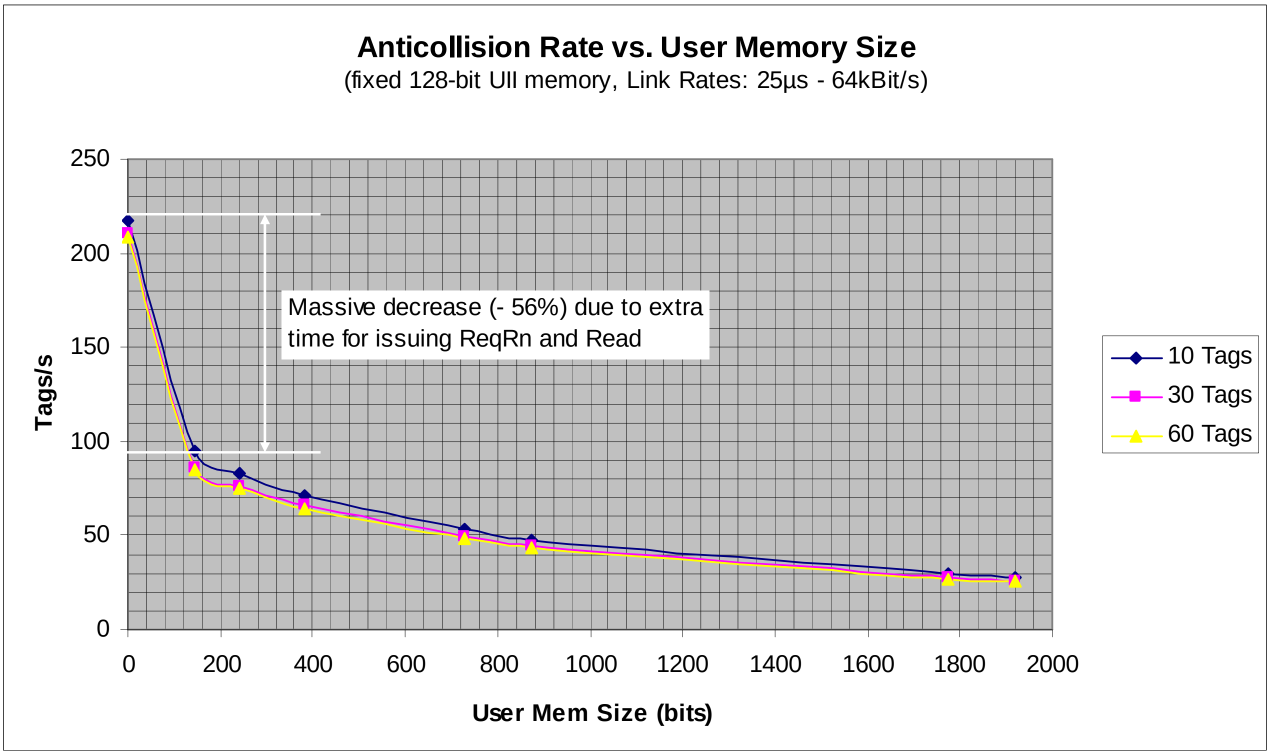


Figure 8: Application Throughput depending on User Memory Size

Moreover, the Anticollision Rate decreases if the UII size increases. For the selected UII Memory bank sizes of 128 and 272 bits, the observed results for the Anticollision Rate are given in Figure 9. Results indicate that the throughput measured in tags per second drops independently from the actual tag population size if the UII size is increased.

In general, it can be observed that the Anticollision Rate deteriorates with an increasing number of tags, which is due to the extra time spent on resolving collisions by issuing QueryAdjust and QueryRep commands.

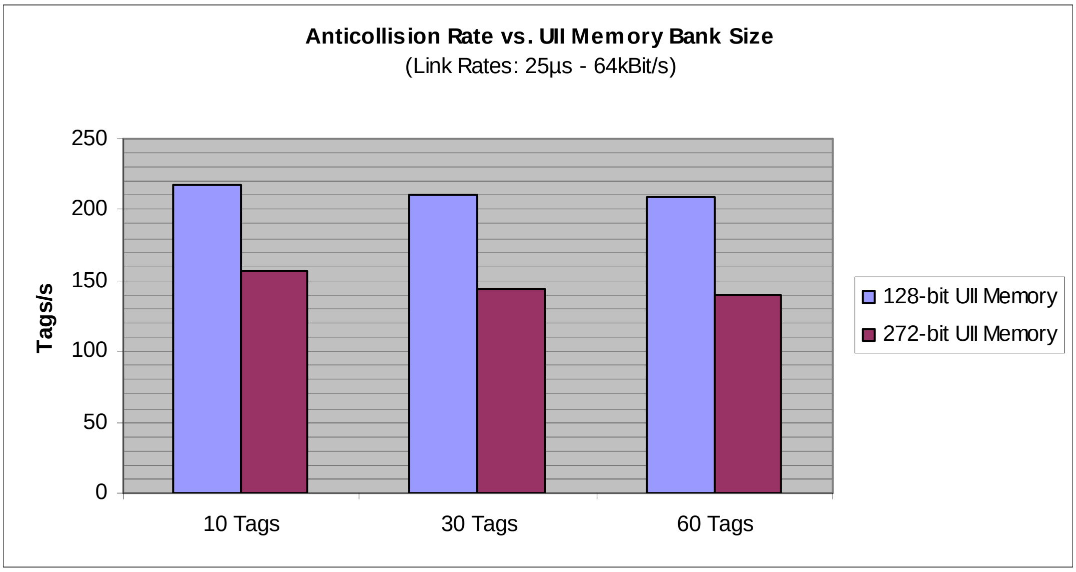


Figure 9: Application Throughput depending on UII Size

5.1.2 Batch 2

Batch simulation package 2 has been defined to evaluate the typical CEPT[5] governed Dense Interrogator Mode environments. First, the old European setup based on a 53.3kBit/s return link is simulated. Second, the results are compared to the results obtained for a current setup based on a 75kBit/s return link.

5.1.2.1 Full Detection Time

Figure 10 shows how the time required to detect all tags within a given population varies with the different UII- and User Memory sizes. Basically the results show a similar behavior as for Batch 1 except for a slight increase due to a slower return link rate of 53.3kBit/s typically used in the old CEPT Dense Interrogator Mode.

[5] European Conference of Postal and Telecommunications Administrations

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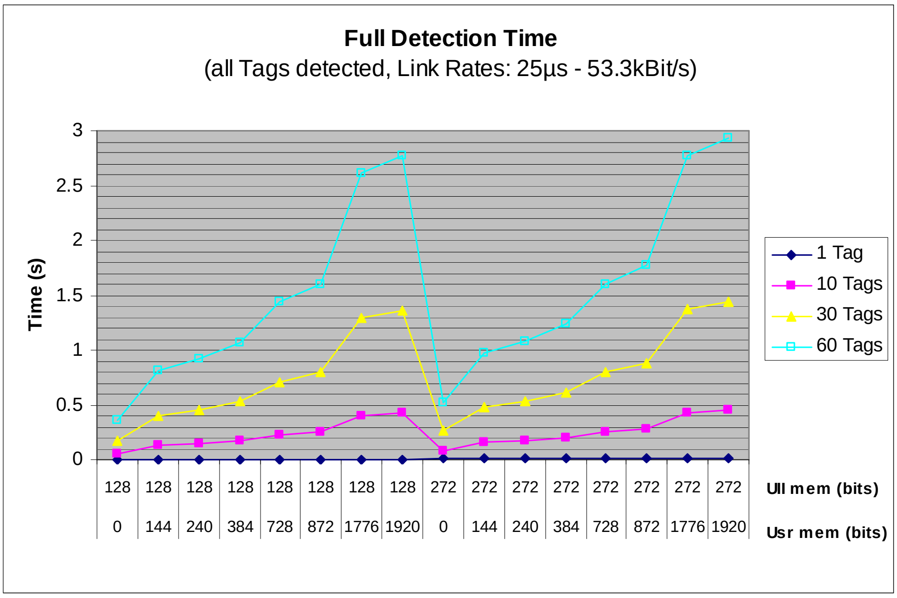

Figure 10: Time Required to Detect all Tags using a 53.3kBit/s Return Link

If a faster tag-to-reader link rate of 75kBit/s is used under current CEPT regulations, characteristics of the obtained results in terms of Full Detection Time are very similar to the results obtained for the Dense Interrogator Mode under FCC regulations, see Batch1, except for a general speedup due to a faster return link rate as shown in Figure 11.

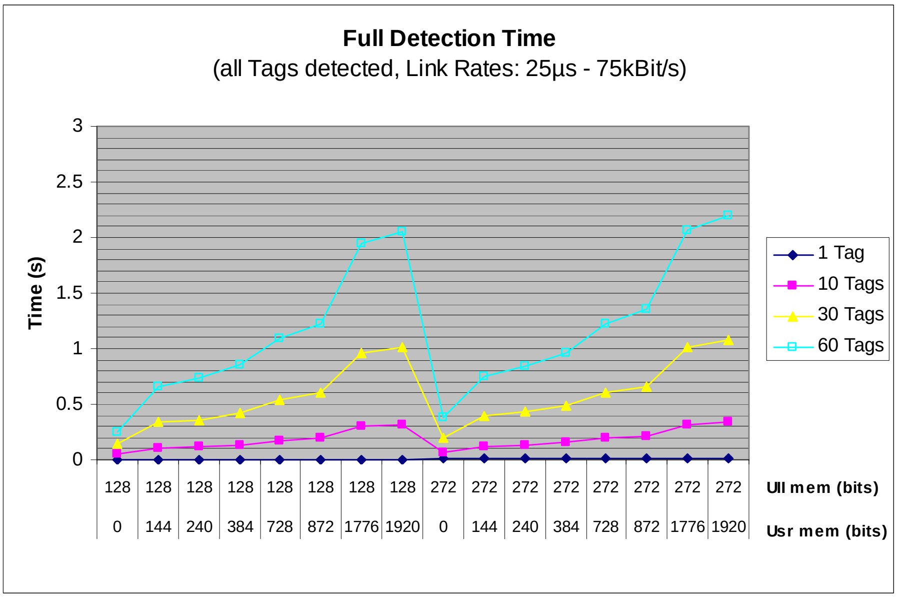

Figure 11: Time Required to Detect all Tags using a 75kBit/s Return Link

5.1.2.2 Full Read Time

Figure 12 shows the Full Read Time depending on the different UII- and User Memory sizes for Batch 2 in case of the 53.3kBit/s return link.

Additionally, the extra time for reading the whole User Memory bank is outlined for a single tag in Figure 13. In contrast to Batch 1, the negative influence of the read access is even higher for Batch 2 due to the fact that a slower return link rate is used and hence more time is required to transmit the same amount of data from the tag to the interrogator. In the worst case of transmitting 1920 bits of user data, the increase in time is 736% related to the Full Detection Time.

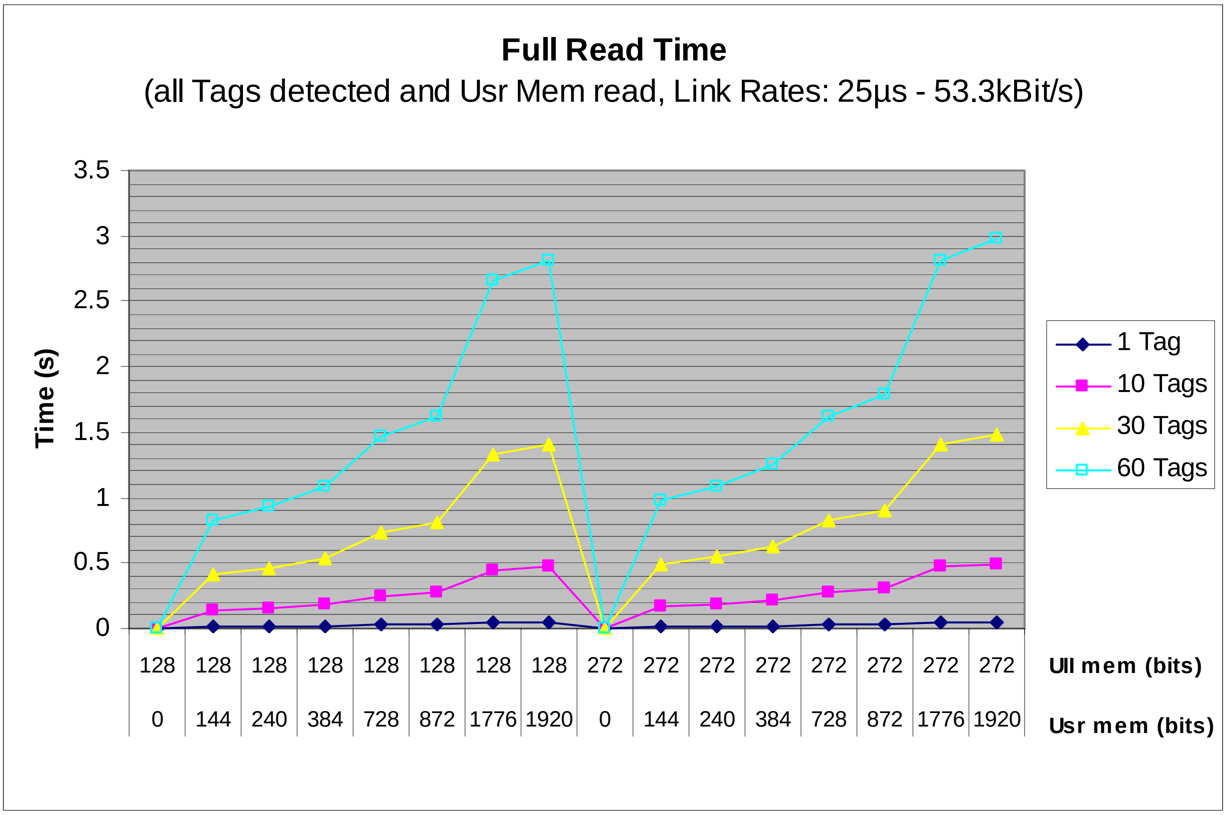

Figure 12: Time Required for Reading the User Memory of all Tags

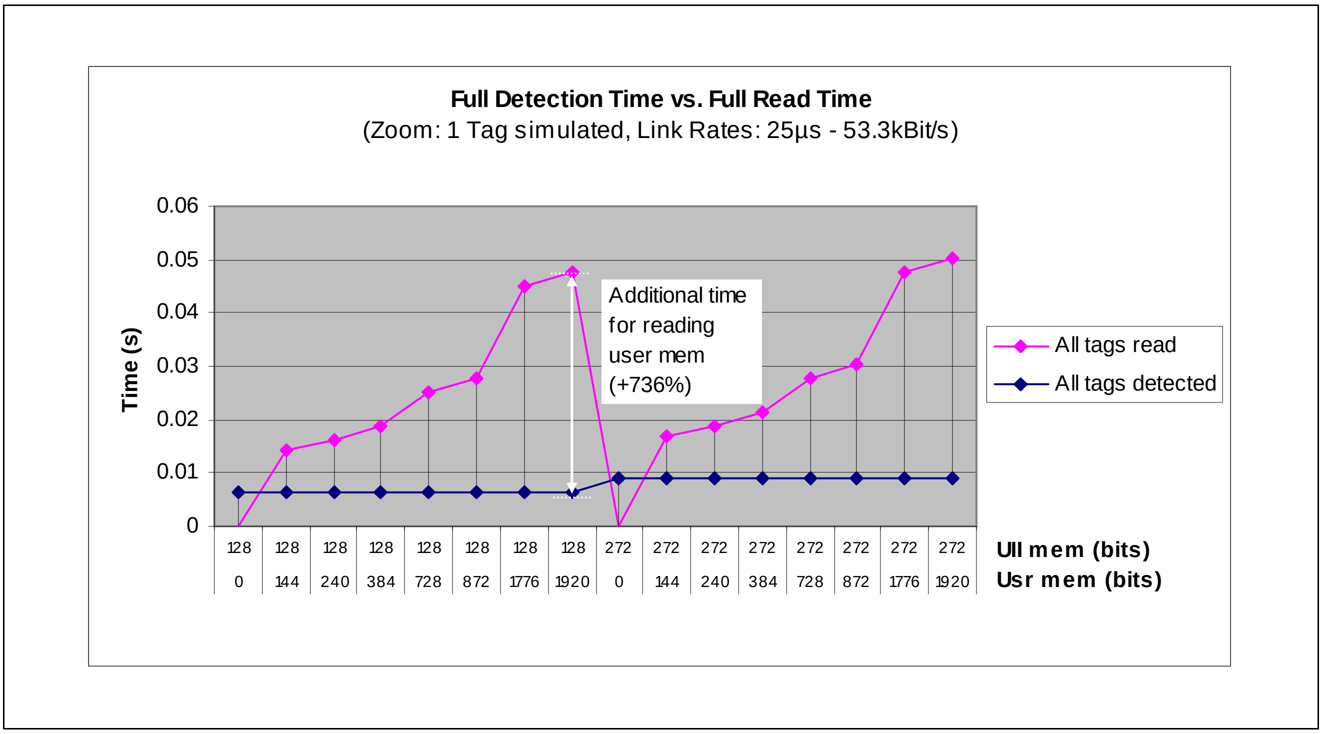

Figure 13: Difference between Full Detection Time and Full Read Time

If a faster tag-to-reader link rate of 75kBit/s is used under current CEPT regulations instead, results in respect to Full Read Time are very similar compared to the Dense Interrogator Mode under FCC regulations except for the general speedup due to a slightly faster return link. Therefore, no separate graphical evaluation is presented here but the calculated results can be found in Table 11 and Table 12 of the Annex on Simulation Results.

5.1.2.3 All Data Received

The cumulated All Data Received Time statistics for batch simulation package 2 based on the 53.3kBit/s return link are presented in Figure 14. Results are very similar compared to Batch 1, except for the overall increase in time caused by a slower tag to interrogator link rate.

Again, the results for setups using a 75kBit/s return link under current CEPT Dense Interrogator Mode rules are not provided in a separate graphical evaluation as they do not show any major difference compared to the results already presented, but can be found in Table 13 of the Annex on Simulation Results for later analysis.

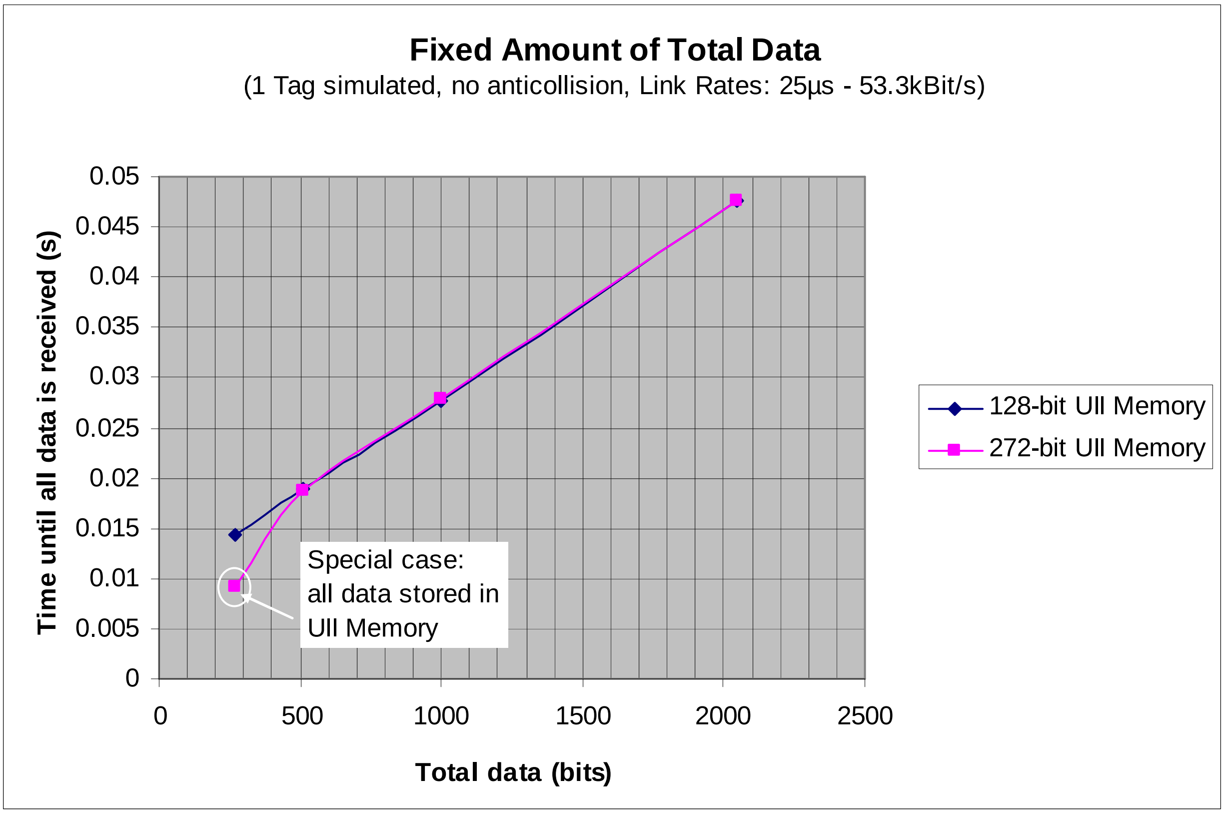

Figure 14: Data Split between UII and User Memory

5.1.2.4 Anticollision Rate

The calculated Anticollision Rate based on the simulation results of Batch2 using the 53.3kBit/s return link is presented in Figure 15.

Again, a major deterioration can be observed as the size of the User Memory increases.

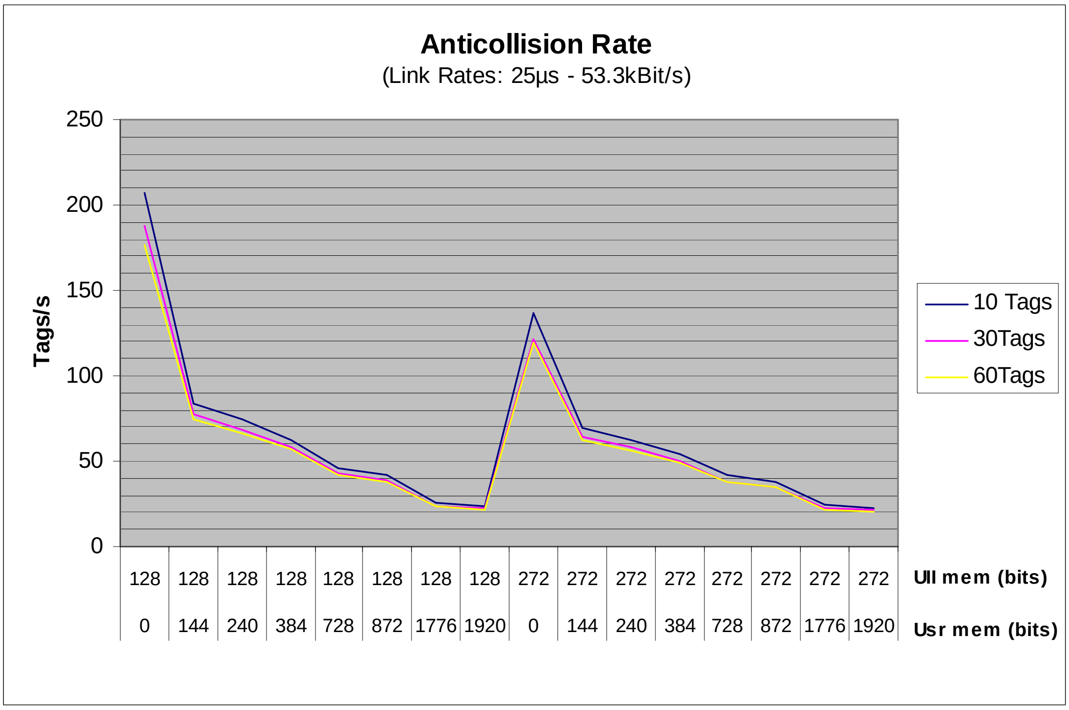

Figure 15: Application Throughput

Figure 16 provides a zoom into the results for a fixed UII Memory length of 128 bits. Again, a massive decrease of the Anticollision Rate between the first two data points is visible. In case of simulating 10 tags, reading additional 144 bits of user data equals a decrease of 123 tags per second or 59% in terms of theoretical protocol throughput.

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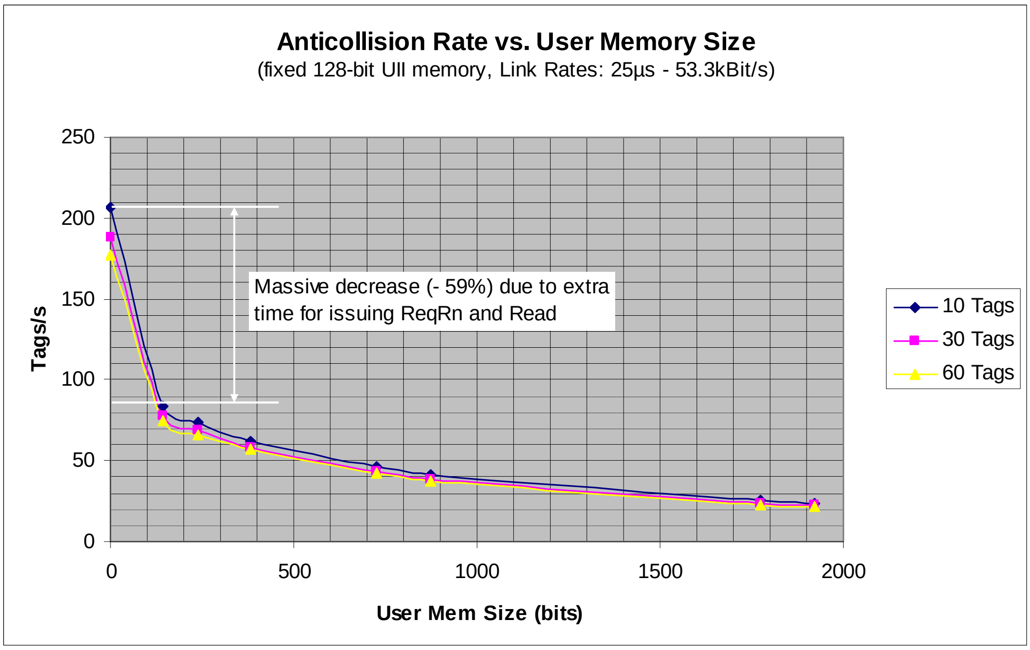

Figure 16: Application Throughput depending on User Memory Size

Figure 17 shows how the Anticollision Rate decreases if the UII Memory size is increased.

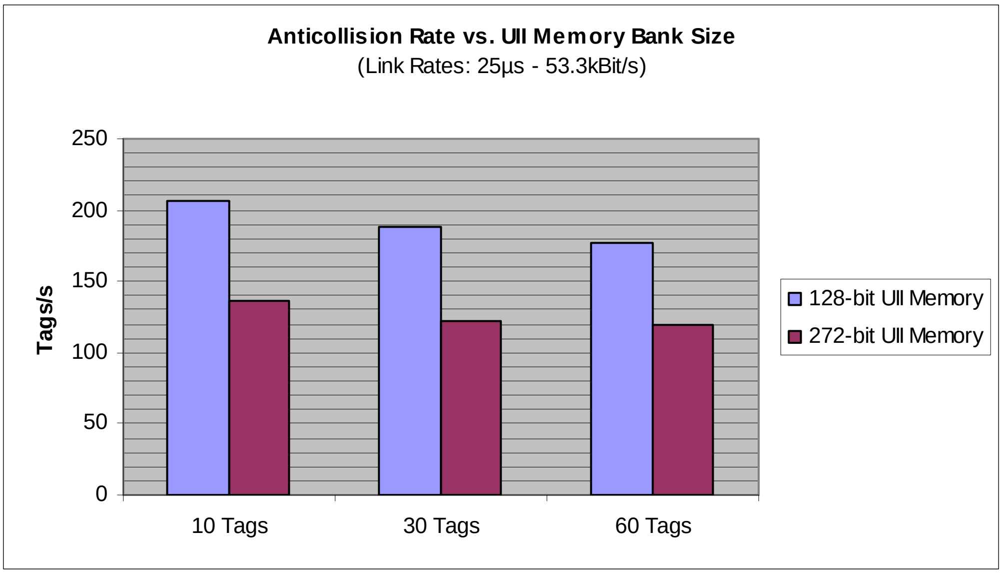

Figure 17: Application Throughput depending on UII Size

In case of the faster return link of 75.5kBit/s please refer to Table 11 and Table 12 of the Annex on Simulation Results.

5.1.3 Batch 3

Batch simulation package 3 has been selected to simulate a high performance UHF RFID setup with high forward and return link rates. This setup uses a 4 times higher forward data rate and a 10 times higher return link data rate than batch simulation package 1. This section contains an overview of the emerging results. Additionally, a comparison of Batch 1 and Batch 3 can be found in Section 5.3.

5.1.3.1 Full Detection Time

Figure 18 shows the Full Detection Time measured for the different combinations of UII- and User Memory lengths.

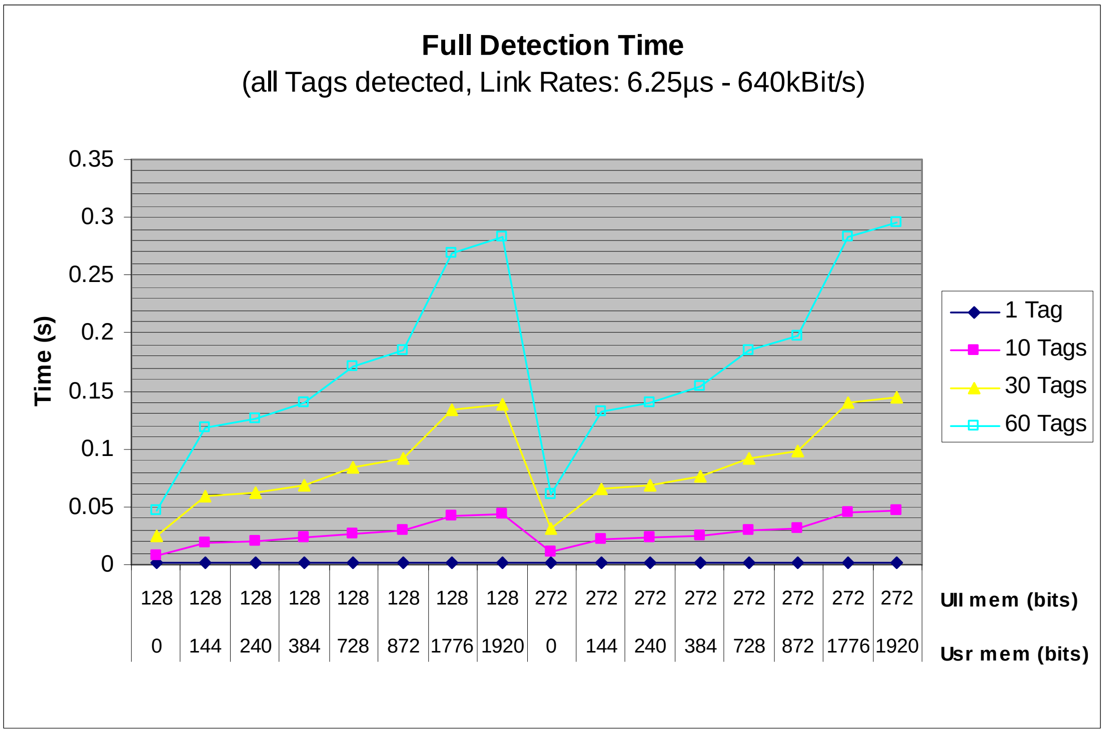

Figure 18: Time Required to Detect all Tags

5.1.3.2 Full Read Time

The results in respect to Full Read Time are shown in Figure 19.

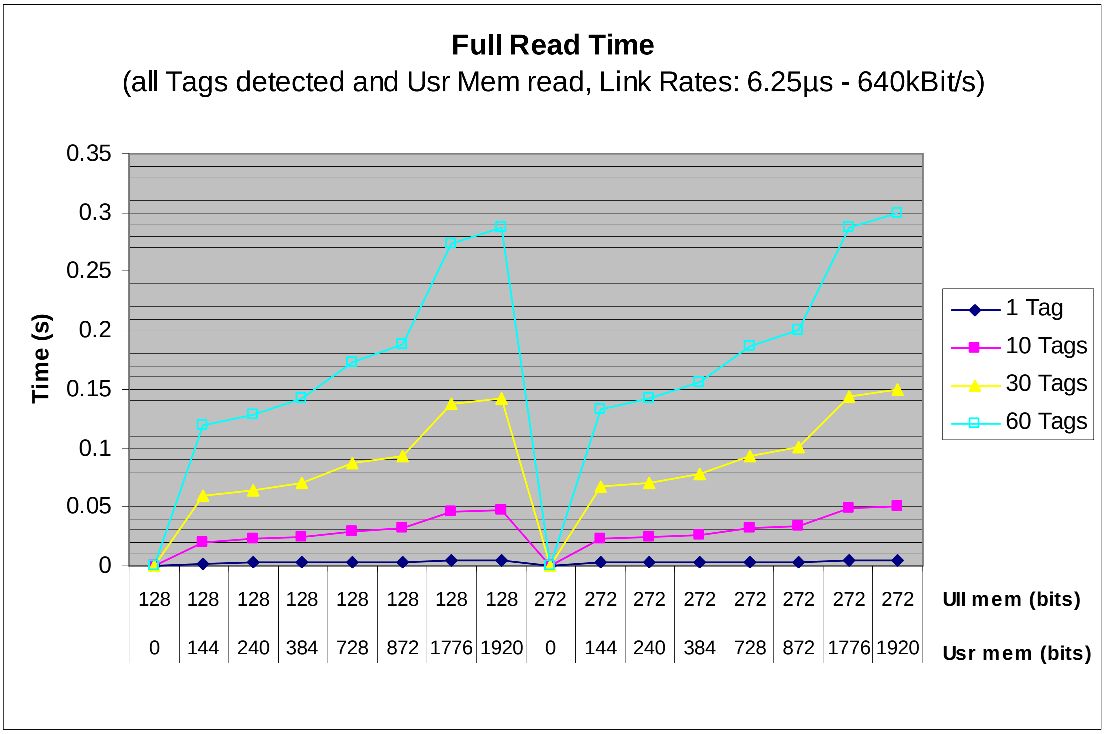

Figure 19: Time Required for Reading the User Memory of all Tags

Again, the Full Detection Time and Full Read Time can be compared for a single tag in order to make the extra time for reading the User Memory visible as done in Figure 20. In case of the current batch simulation package the maximum increase in time for reading additional 1920-bit of User Memory is about +472% according the simulation results.

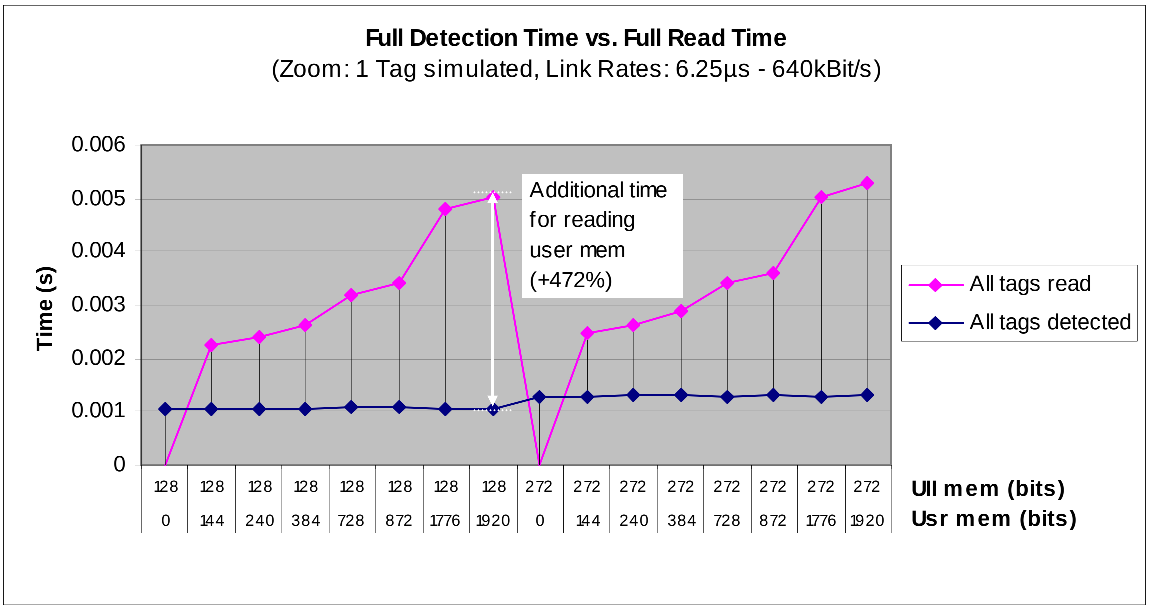

Figure 20: Difference between Full Detection Time and Full Read Time

5.1.3.3 All Data Received

Figure 21 shows the All Data Received Time. Again, no major difference is visible between the 128-bit and the 272-bit UII Memory option, if the total amount of data to be read remains the same.

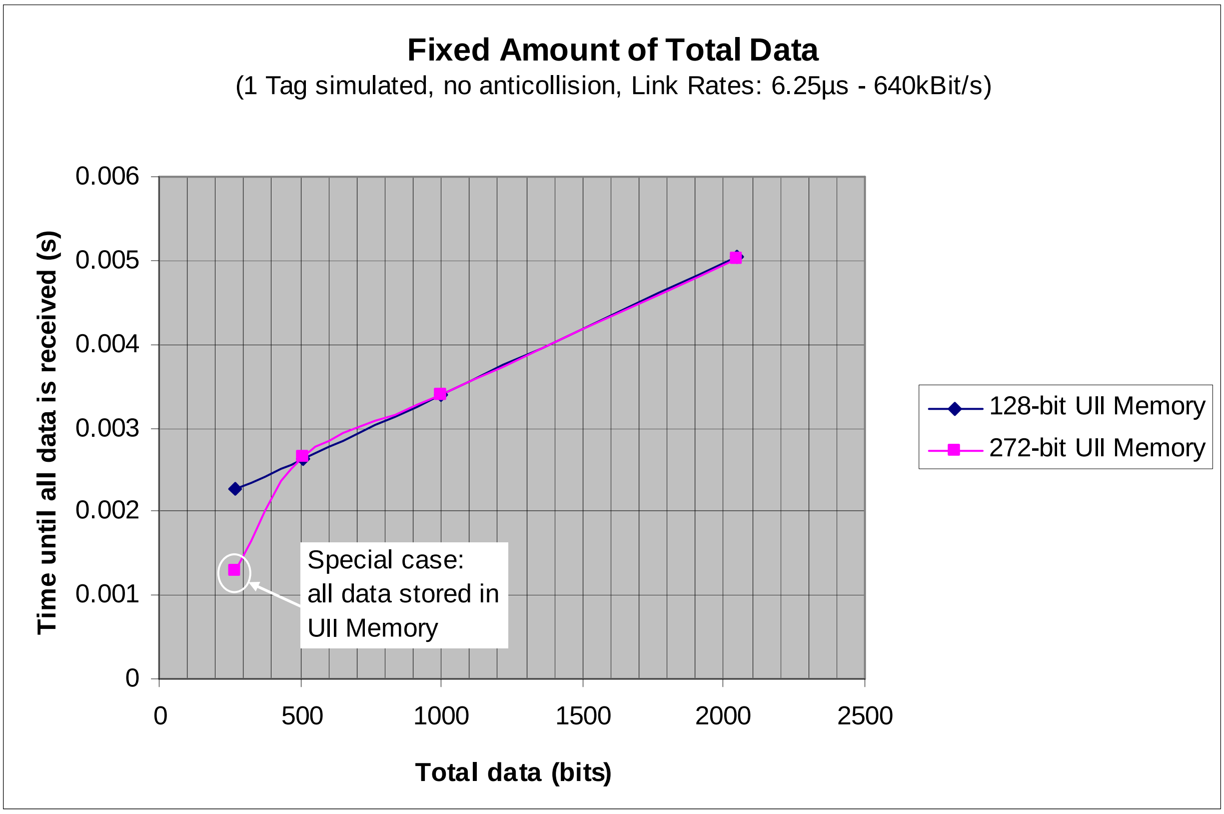

Figure 21: Data Split between UII and User Memory

5.1.3.4 Anticollision Rate

The Anticollision Rate for the current simulation package is presented in Figure 22, Figure 23, and Figure 24.

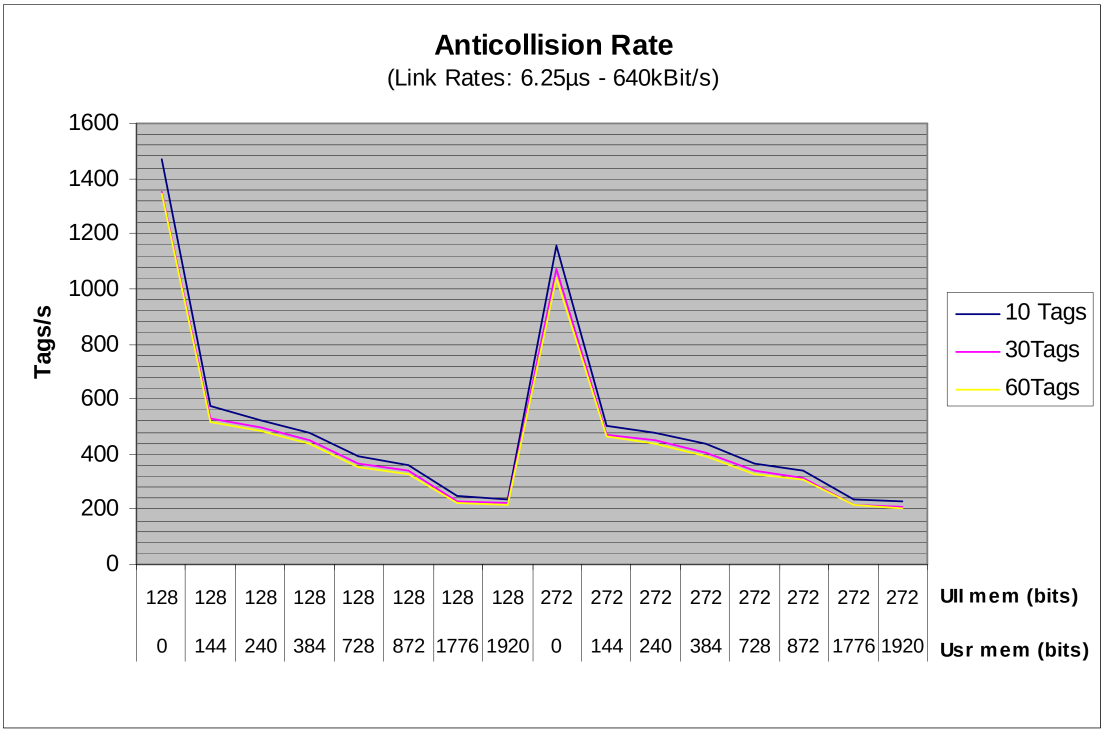

Figure 22: Application Throughput

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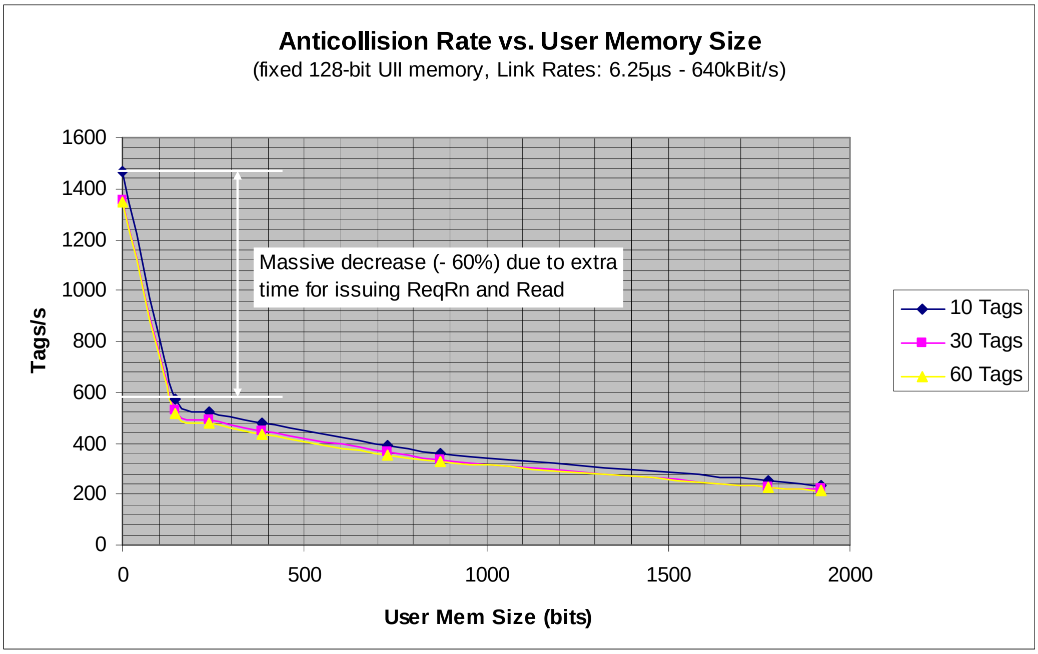

Figure 23: Application Throughput depending on User Memory Size

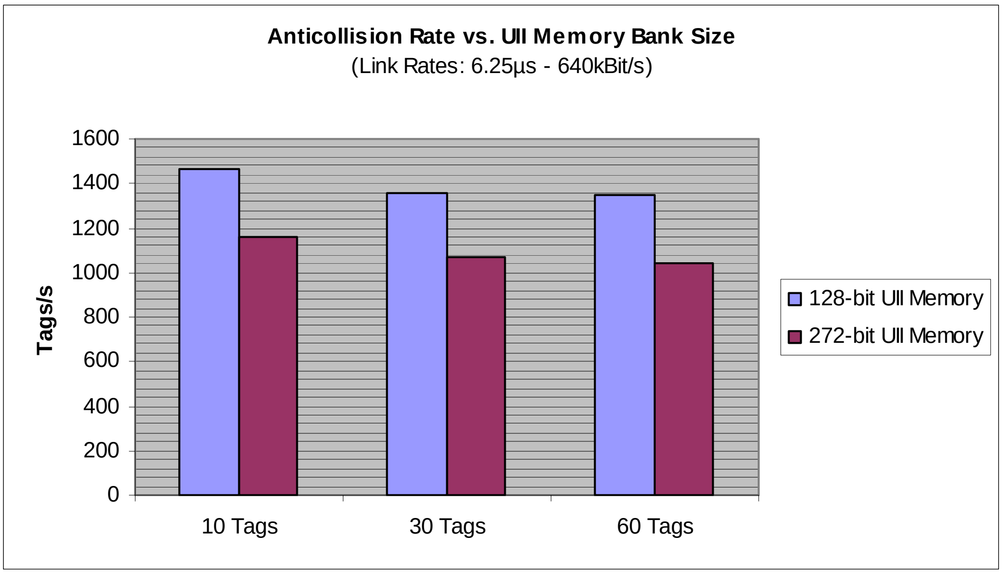

Figure 24: Application Throughput depending on UII Size

5.1.4 Batch 4

Batch simulation package 4 has been selected to evaluate a scenario where equal forward and return link rates are being used. In such a scenario the influence of interrogator to tag and tag to interrogator communication on the application key figures is balanced.

As supported by the results presented in the next sub-sections, application performance is similar in case of balanced forward and return links if high amounts of data need to be transmitted from the tag to the reader.

5.1.4.1 Full Detection Time

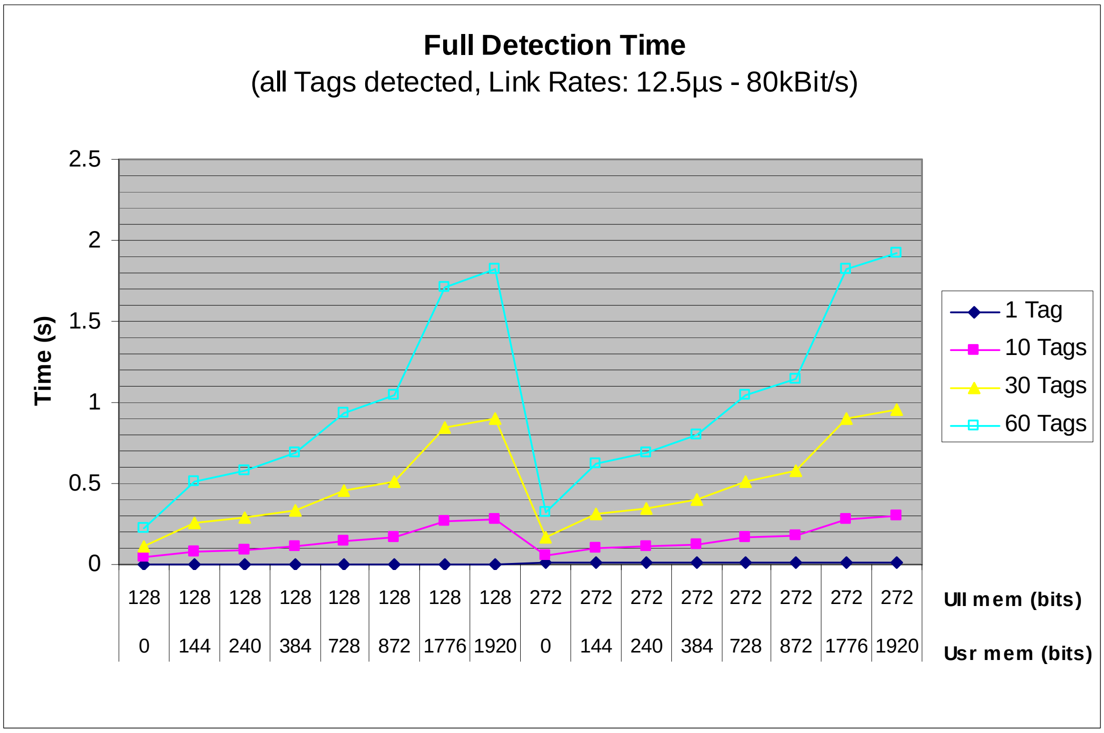

Figure 25: Time Required to Detect all Tags

5.1.4.2 Full Read Time

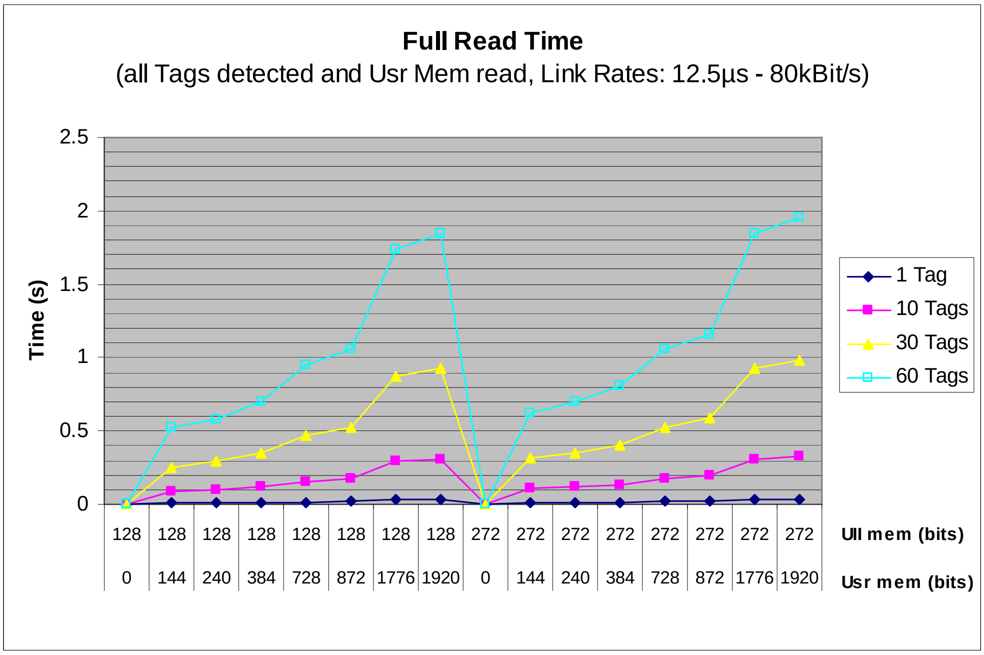

Figure 26: Time Required for Reading the User Memory of all Tags

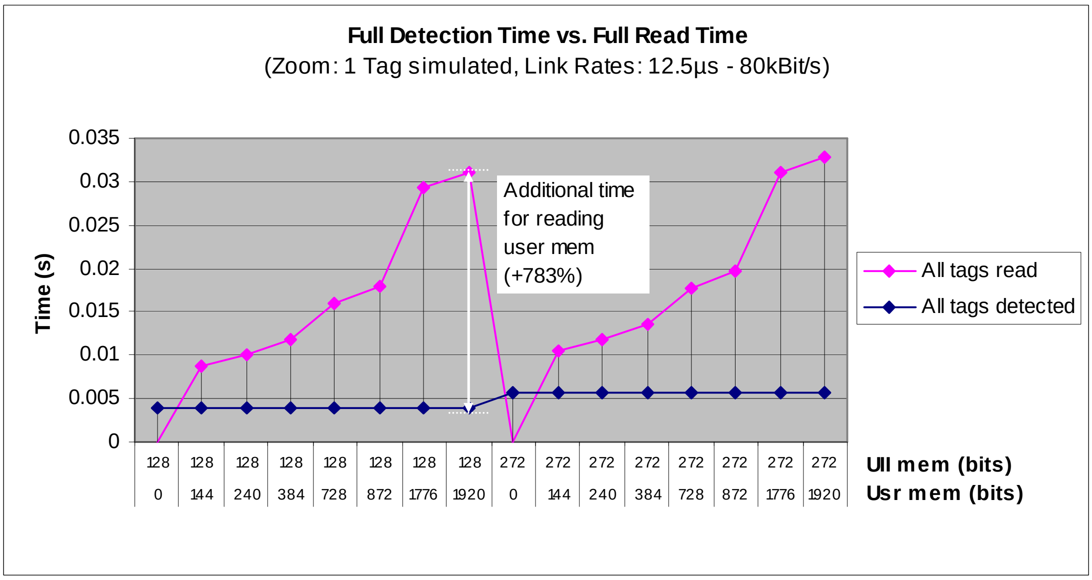

Figure 27: Difference between Full Detection Time and Full Read Time

5.1.4.3 All Data Received

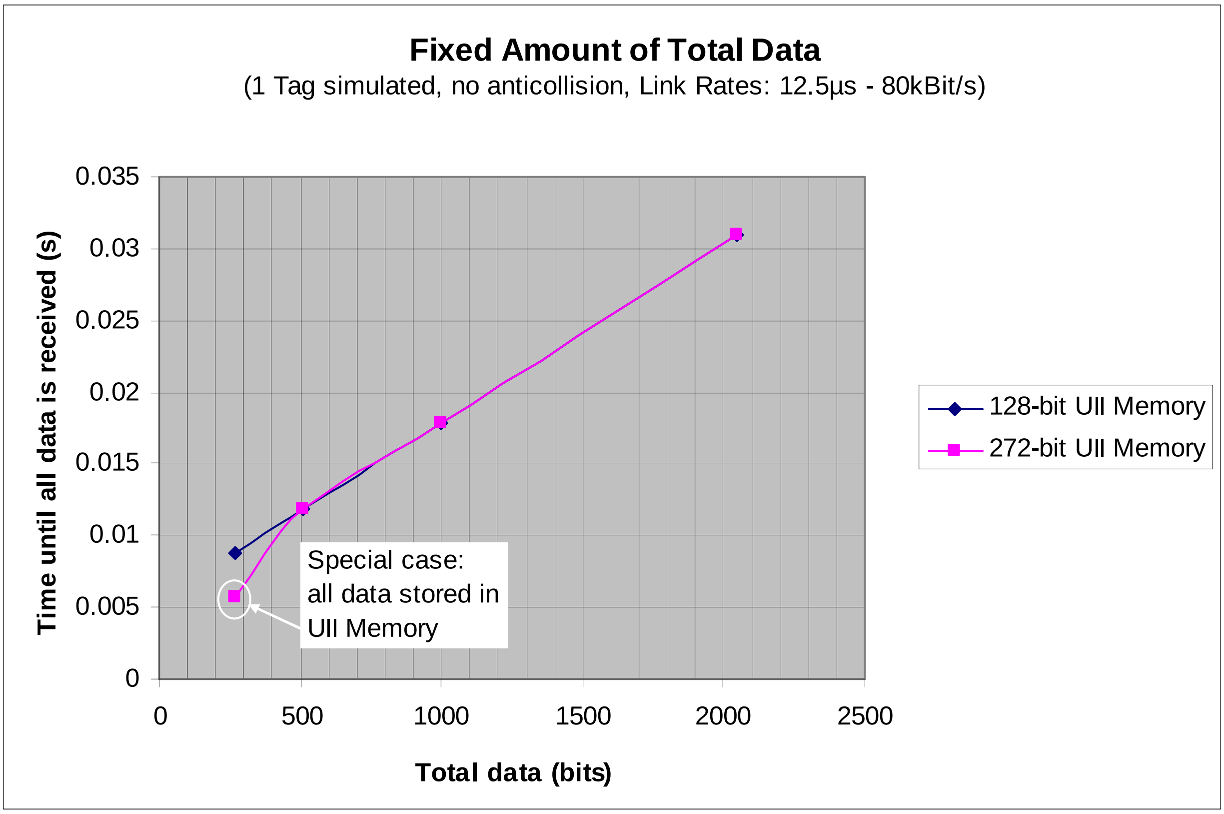

Figure 28: Data Split between UII and User Memory

5.1.4.4 Anticollision Rate

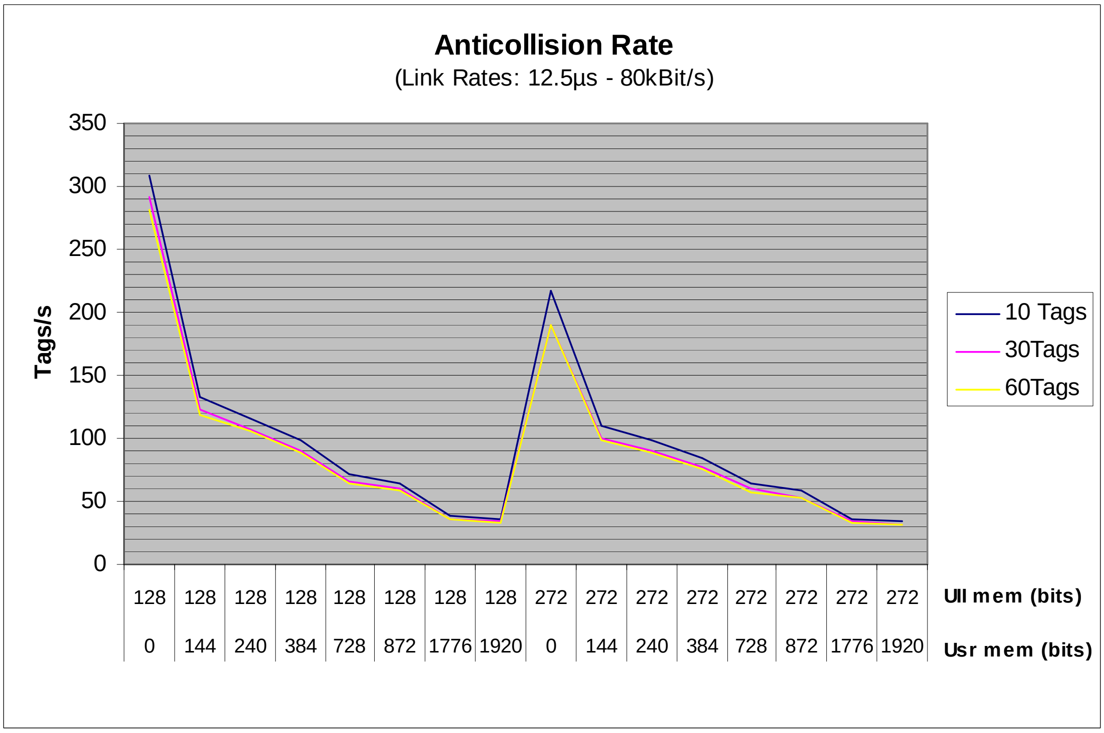

Figure 29: Application Throughput

UHF RFID Simulations - Identification performance in dependence on UII size

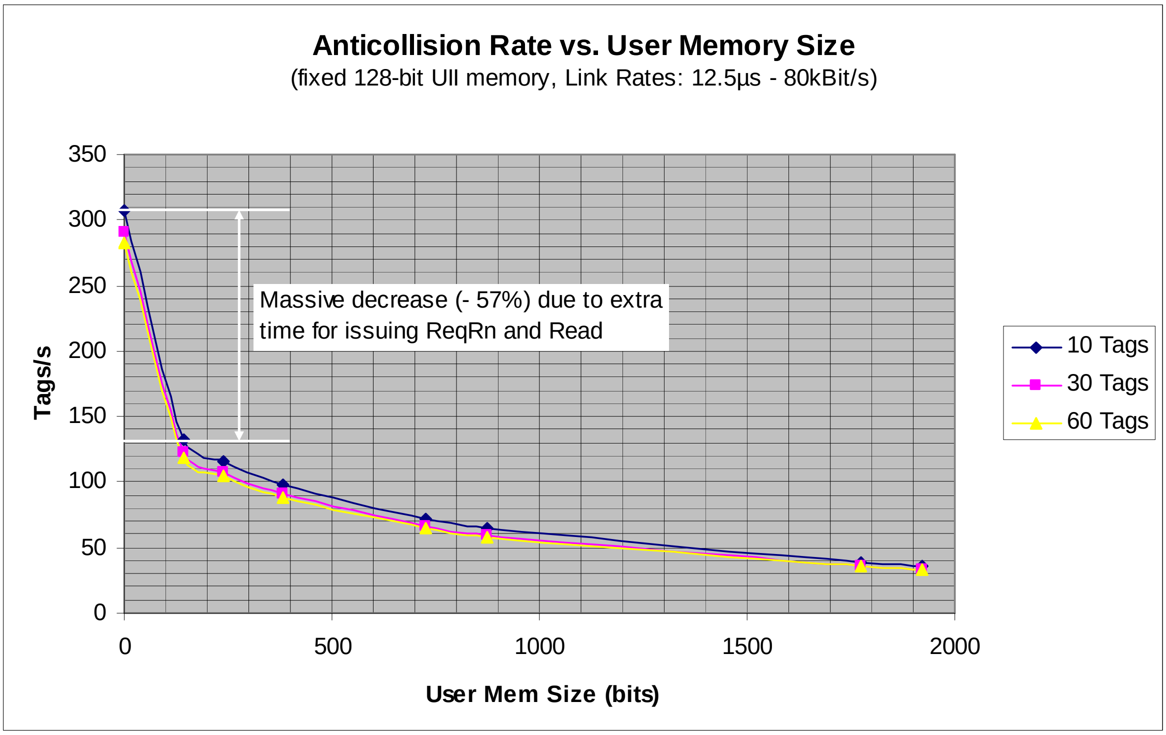

Figure 30: Application Throughput depending on User Memory Size

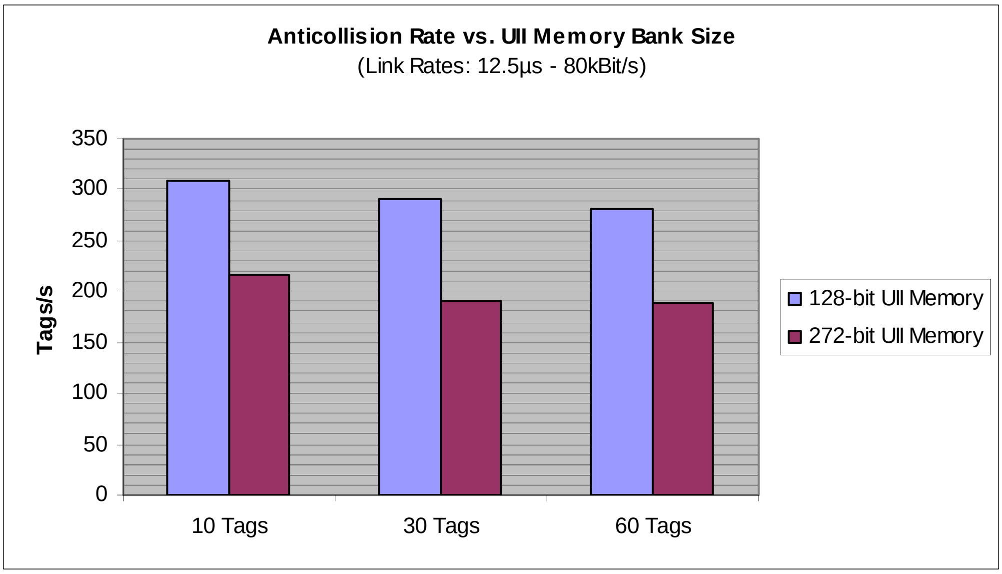

Figure 31: Application Throughput depending on UII Size

5.2 Mixed Tag Populations

5.2.1 Description of the Mixed Setup

So far, only homogeneous tag populations consisting of one type of tag have been evaluated and the emerging application performance has been documented. In reality, mixed populations between 128-bit and 272-bit UII Memory implementations may also occur, which applies especially for the logistics sector.

Therefore, batch simulation package 5 is aiming at revealing the relation between system performance and ratio of 272-bit UII Memory tags within a given population.

The following different mixed population setups have been simulated:

Table 4: Mixed Population Ratios

128-bit UII Memory Tags	272-bit UII Memory Tags
100%	0%
66.6%	33.3%
50%	50%
33.3%	66.6%
0%	100%

Note: Batch simulation package 5 uses a fixed total number of 30 tags. Results for smaller or higher numbers of total tags are not expected to significantly differ from the results obtained for 30 tags.

5.2.2 Batch 5

5.2.2.1 Full Detection Time

The Full Detection Time statistics for the chosen mixed population settings are given in Figure 32. The impact of a 1/3 ratio of 272-bit UII Memory tags is highlighted and equals a 19% increase in time.

The emerging curve is non-linear. For instance, a twice as high ratio of 272-bit UII Memory tags does not result in a twice as high increase of FDT but in a lower value.

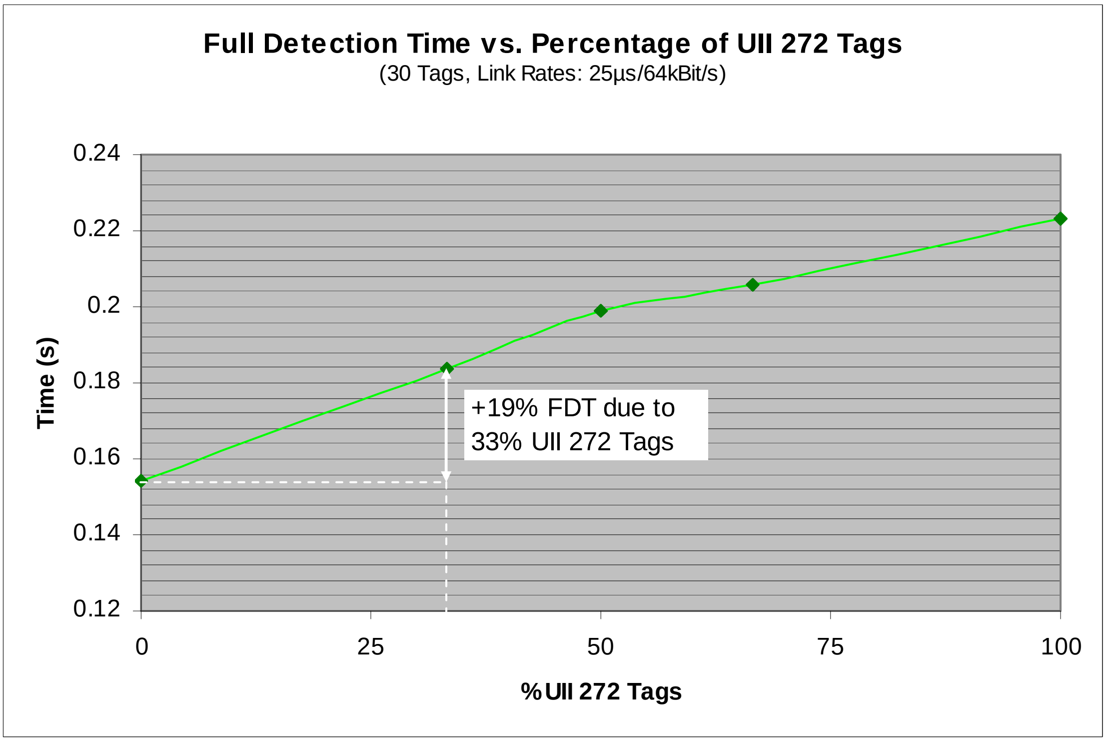

Figure 32: Full Detection Time in Mixed Populations

5.2.2.2 Anticollision Rate

An increasing ratio of long UIIs leads to a drop of performance in terms of tags per second as shown in Figure 33. Again, the impact of a 1/3 ratio of 272-bit UII Memory tags is highlighted and corresponds to a decrease in terms of tags per second of about -17%.

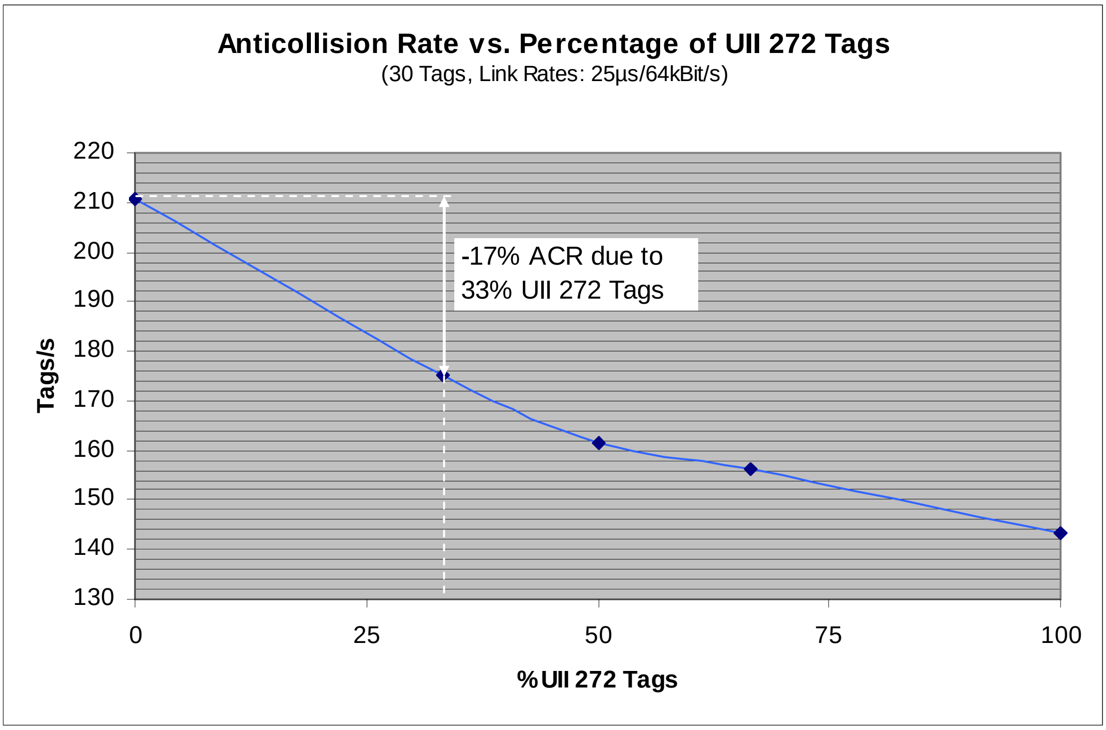

Figure 33: Anticollision Rate in Mixed Populations

5.3 Further Observations and Implications

5.3.1 Reading User Memory at Different Link Rates

As already indicated in the previous sub-chapters, simulations did show a very similar outcome for all of the selected link rate settings.

In general it can be said that the application throughput in terms of the Anticollision Rate decreases significantly if a read access to the User Memory is carried out. Moreover, it can be observed that the worst impact is always visible when comparing a "no User Memory" option with an option where a small amount of additional data needs to be stored in the User Memory. This is due to the extra time consumed by obtaining an access handle and by issuing a Read command.

Figure 34 and Figure 35 show results if the "no User Memory" option is compared to setups where additionally 144 or 1920 bits of User Memory have been read. It is shown that in case of reading additional 144 bits from the User Memory no more than 43% of the original throughput could be reached, depending on the actual link rates and number of tags and hence anti-collision in the field. It is notable that in this particular case, results were even slightly worse for the higher return link setting, which is due to anti-collision effects (since the gap between forward and return link rate is higher in the second case).

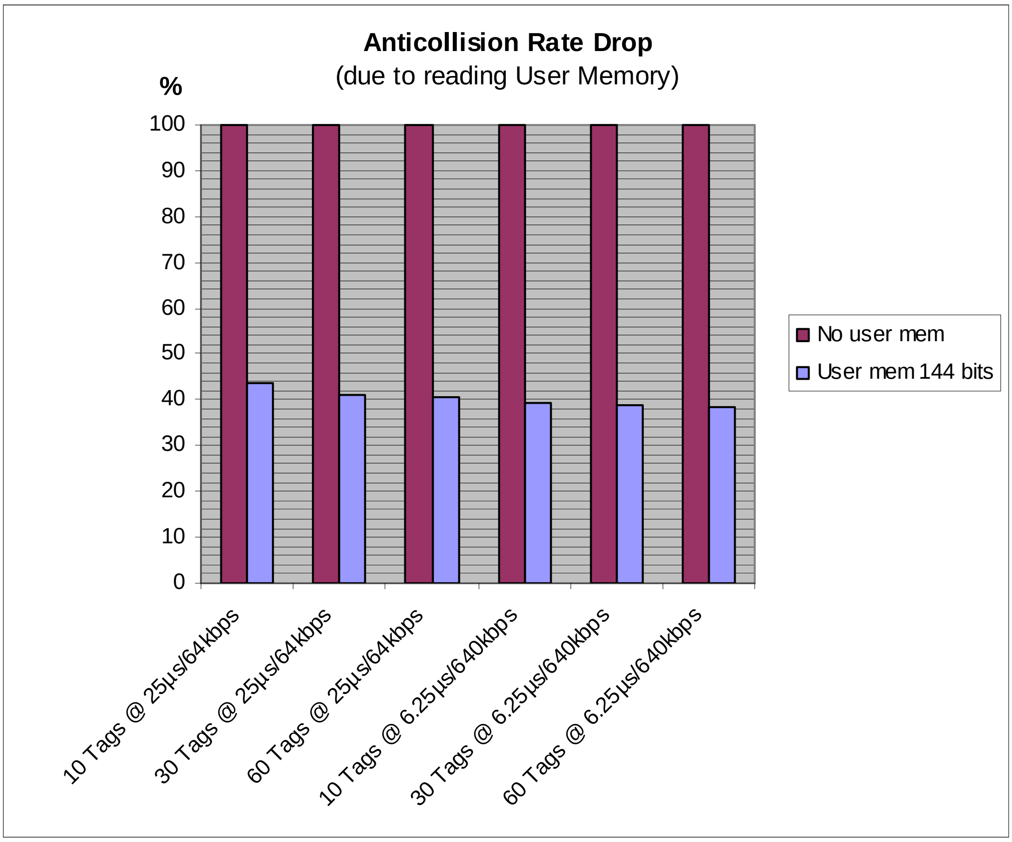

Figure 34: Anticollision Rate Decrease due to Reading 144 bits of User Memory

In case of reading additional 1920 bits of data from the User Memory, results in terms of throughput show that no more than approximately 16% of the original throughput can be reached. In this case, results are more encouraging in case of the higher link rates of batch simulation package 3. This is due to the fact that in this particular case the extra time for requesting the access handle and for issuing the Read command on the forward link become less important compared to transmitting the 1920 bits of data on the fast return link.

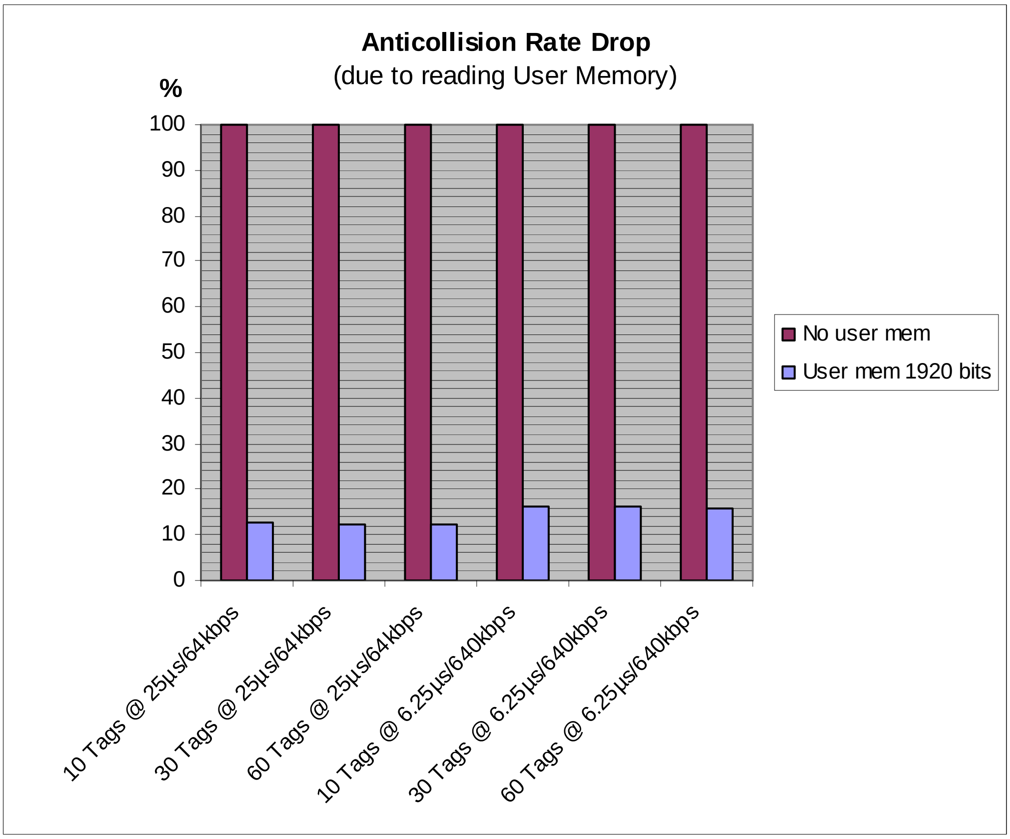

Figure 35: Anticollision Rate Decrease due to Reading 1920 bits of User Memory

When comparing options where read access to the User Memory is required and only the amount of data varies, the observed impact of reading some extra bytes is less significant.

Figure 36 shows a direct comparison between batch simulation packages 1 and 3. In general, it can be said that the higher the return link rate is chosen, the shorter the time required for transmitting the user data will be. But this also implies that the ratio of the time for transmitting the user data in relation to the total time for handling a tag decreases. As a consequence, one can observe that the difference between the simulated User Memory sizes in terms of throughput measured in tags/s is higher for the 640kBit/s return link than for the 64kBit/s return link. This phenomena is highlighted in Figure 36 for a tag population of 10 tags where an increase of user data from 144 to 1920 bits causes a decrease of the Anticollision Rate by 70% in case of the faster return link in contrast to a decrease of 59% in case of the slower return link.

In other words, if a communication channel is dominated by a fast return link, the expected effect of increasing the amount of data to be transmitted from the tag to the reader will always be higher in respect to application throughput.

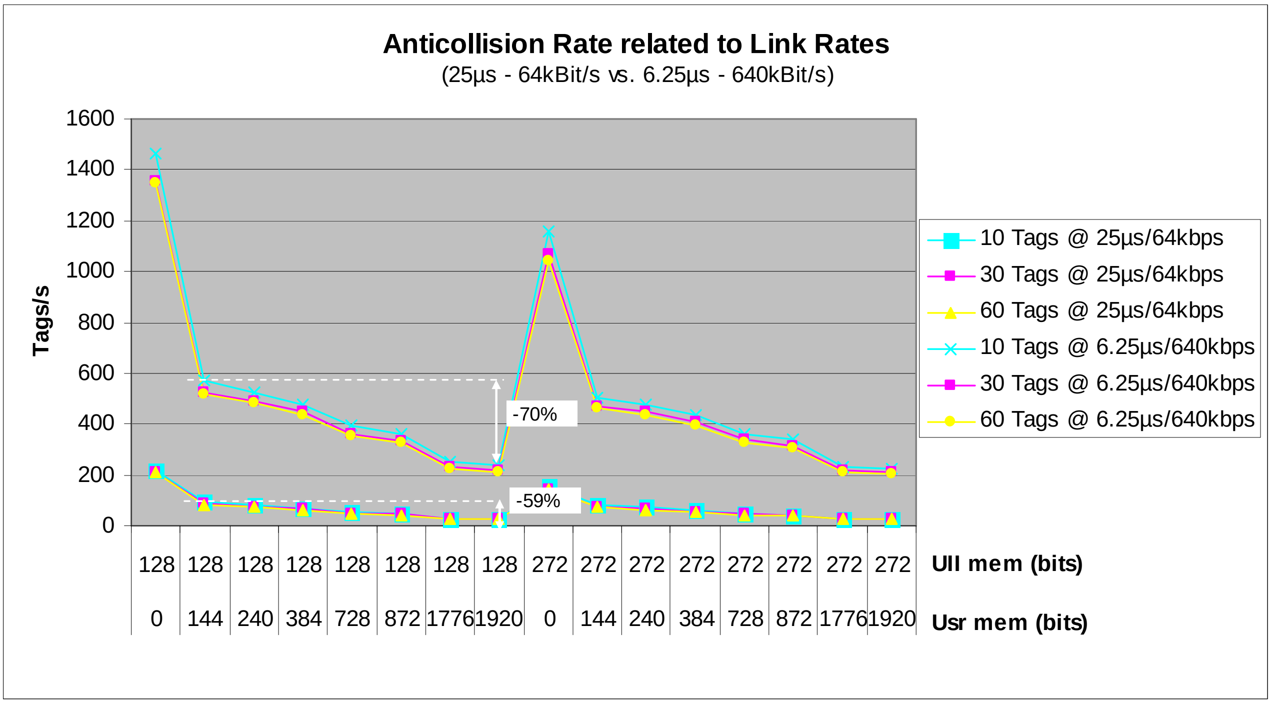

Figure 36: Anticollision Rate at different Link Rates

5.3.2 Different UII Lengths affecting the Overall Throughput

Figure 37 shows the effect of transmitting a longer UII at different link rates in terms of application throughput. It is shown that in case of supporting a 272-bit UII Memory instead of 128-bit UII Memory the Anticollision Rate drops below 80% of the original value for both of the compared link rates. In case of the Dense Interrogator Mode under FCC regulations (25µs - 64kBit/s), a decrease of about -30% can be expected.

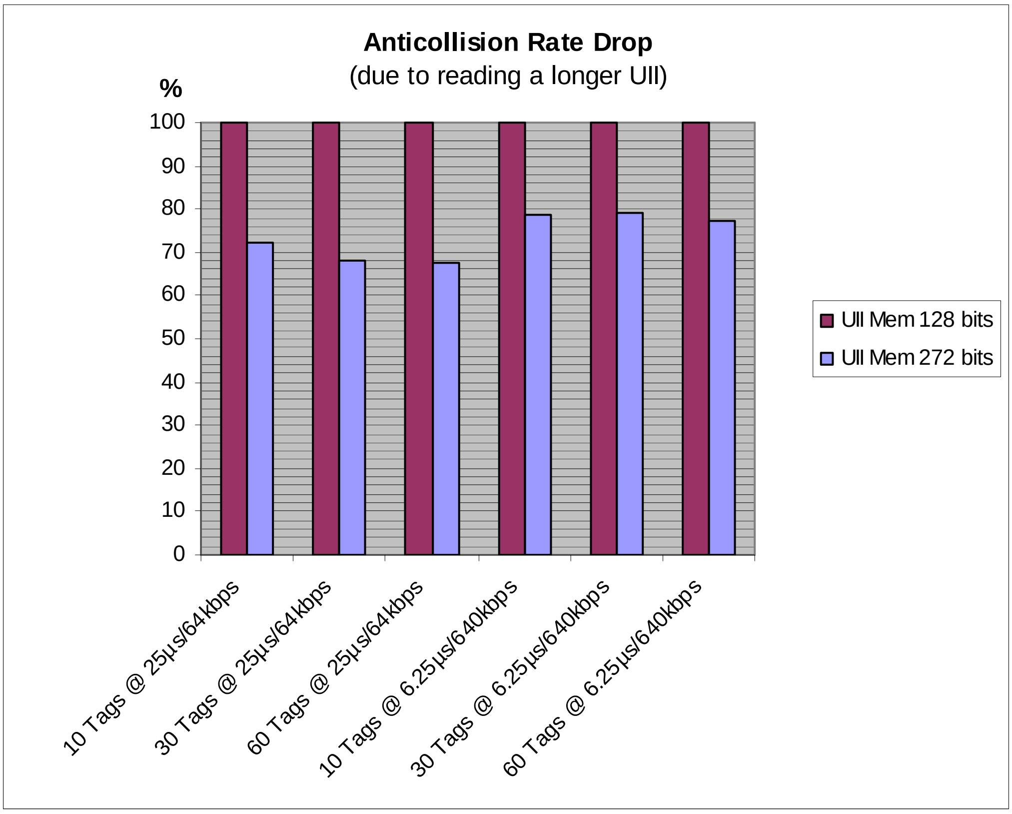

Figure 37: Anticollision Rate Decrease due to Supporting Different UII Lengths

5.3.3 Possible Further Areas of Interest

The current report puts an emphasis on the systematic evaluation of the effect of varying UII- and User Memory sizes on the RFID application performance. Therefore, a suitable evaluation setup has been built upon the CISC ASD Kit+Library and a set of typical simulation parameters has been defined in order to effectively evaluate the most common application setups.

However, beside the parameters chosen for this evaluation report the flexible structure of the CISC ASD Kit+Library products allows for the accurate simulation of further parameters that may be of interest and could be evaluated complementary to the current results.

Possible additional setups to be simulated in the future could be

- Custom RFID portal setups including different antenna setups
    - Antenna mounting and orientation
    - Antenna radiation patterns
    - Antenna switching sequence

- Custom pallet movement paths including varying movement speeds
- Interrogator to Tag and Tag to Interrogator bit error rates
- Random field null insertion
- Anticollision algorithm variations
- Different inventory sessions and persistency
- Mixed protocol tag populations
- …

Furthermore, environmental effects can be captured by means of the CISC RFID Field Recorder and recorded location specific field data can be used as an input to simulations carried out with the CISC RFID ASD Kit+Library.

6 CONCLUSION

Based on the simulations carried out with CISC RFID ASD Kit+Library, a series of general implications can be drawn for the use of UHF RFID tags according ISO/IEC 18000-6 Type C and User Memory use according ISO/IEC 15962.

First, it has to be outlined that application performance in terms of tags per second is directly dependent on the overall amount of data to be transmitted from the interrogator to the tag and vice versa. As a consequence, transmission of a longer UII and additional read access to the tag's user memory correspond to a significant decrease in performance. As a consequence, the proper use of the user-memory indicator (UMI, bit 15h of UII memory bank (MB01)) in the inventory algorithm implemented on the interrogator side is important to avoid unnecessary read attempts to this optional memory bank that might not exist on each tag, which may lead to unnecessary communication steps. Especially for mixed populations, additionally to the UMI bit, it is also recommended to check the NSI (bits 17h to 1Fh of MB01), which includes the AFI (bits 18h to 1Fh of MB01), any maybe even parts of the UII itself before deciding to the read the User Memory content.

Second, it has been shown that assuming a fixed amount of data that needs to be read there is no need to append part of this data to the UII for transmission in the response to the ACK command, if some more data needs to be read from the User Memory in a separate step later on. However, if it is possible to keep the overall amount of application specific data very small, it can perfectly make sense to transmit it subsequent to the UII.

Third, it has been shown that the occurrence of longer UII tags within a tag population slows down the application in terms of the Anticollision Rate depending on the actual ration of such tags.

Last but not least, it has to be considered that the higher the number of total tags in the field the higher the effort for singulating those tags by means of anti-collision will be, i.e. if the number of tags is not known in advance by the interrogator and the q-parameter can not be set accordingly, and hence the time for reading data from the tag plays a less dominant role in such cases.

7 ANNEX: SIMULATION RESULTS

7.1 Overview

7.1.1 Batch 1

Table 5: Simulation Results 25µs - 64kBit/s Part 1

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	128	128	128	128	128	128	128	128
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	217.0335	94.7469	83.333	71.1864	52.9858	47.6784	29.8866	28.0298
ACR	30 Tags	210.5725	86.4554	76.2261	65.8663	49.131	44.5237	27.6524	26.0082
ACR	60 Tags	208.3861	84.5772	75.4052	64.657	48.4803	43.6987	27.0633	25.6161
FDT	1 Tag	0.0058753	0.0058627	0.0058702	0.0058413	0.0058716	0.0058727	0.005854	0.0058628
FDT	10 Tags	0.056004	0.11522	0.12922	0.15009	0.19831	0.21932	0.34449	0.36595
FDT	30 Tags	0.15422	0.35817	0.40563	0.46683	0.62096	0.68492	1.0957	1.1644
FDT	60 Tags	0.30089	0.72133	0.80712	0.94019	1.2496	1.3841	2.2287	2.3535
FRT	1 Tag	0	0.012913	0.014425	0.016613	0.021931	0.024165	0.038409	0.04068
FRT	10 Tags	0	0.12225	0.13779	0.16088	0.21435	0.23761	0.37705	0.4007
FRT	30 Tags	0	0.36521	0.41417	0.47763	0.63701	0.70322	1.1283	1.1991
FRT	60 Tags	0	0.72838	0.81568	0.951	1.2657	1.4024	2.2613	2.3883

Table 6: Simulation Results 25µs - 64kBit/s Part 2

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	272	272	272	272	272	272	272	272
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	156.7632	78.8152	71.819	63.2124	48.245	44.0827	28.1104	26.6687
ACR	30 Tags	143.4356	73.0385	66.005	57.2081	44.495	40.7282	26.0601	24.7445
ACR	60 Tags	140.4037	71.6691	64.5319	56.7621	43.6371	39.7596	25.5019	24.1759
FDT	1 Tag	0.0081162	0.00811	0.0081127	0.0081129	0.0081226	0.0081065	0.0081178	0.0081131
FDT	10 Tags	0.076265	0.13868	0.15112	0.16972	0.22011	0.2386	0.36743	0.38648
FDT	30 Tags	0.22321	0.42345	0.46778	0.53788	0.68914	0.7505	1.1644	1.2254
FDT	60 Tags	0.44101	0.85229	0.94374	1.0714	1.3889	1.5238	2.3673	2.4954
FRT	1 Tag	0	0.015137	0.016642	0.01889	0.02419	0.026396	0.040655	0.042903
FRT	10 Tags	0	0.14574	0.15964	0.1805	0.23617	0.25689	0.39999	0.42128
FRT	30 Tags	0	0.4305	0.47634	0.54868	0.70518	0.76879	1.197	1.2601
FRT	60 Tags	0	0.85933	0.95229	1.0822	1.4049	1.542	2.3998	2.5302

Table 7: Simulation Results 25µs - 64kBit/s Part 3

	UII	128	128	128	128	272	272	272	272
	Total Data	272	512	1000	2048	272	512	1000	2048
ADR	1 Tag	0.012913	0.016613	0.024165	0.04068	0.0081162	0.016642	0.02419	0.040655
ADR	10 Tags	0.12225	0.16088	0.23761	0.4007	0.076265	0.15964	0.23617	0.39999
ADR	30 Tags	0.36521	0.47763	0.70322	1.1991	0.22321	0.47634	0.70518	1.197
ADR	60 Tags	0.72838	0.951	1.4024	2.3883	0.44101	0.95229	1.4049	2.3998

7.1.2 Batch 2

Table 8: Simulation Results 25µs – 53.3kBit/s Part 1

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	128	128	128	128	128	128	128	128
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	207.1438	84.1045	74.0962	62.1329	46.0346	41.4065	25.4129	23.959
ACR	30 Tags	188.0929	77.8312	68.6844	57.8747	43.0275	38.404	23.457	22.1749
ACR	60 Tags	176.6859	74.7072	65.9643	56.6366	41.8855	37.7797	23.0461	21.7169
FDT	1 Tag	0.0064741	0.0064693	0.006463	0.0064692	0.0064645	0.0064603	0.0064549	0.0064676
FDT	10 Tags	0.059248	0.12992	0.14471	0.17106	0.22803	0.25271	0.404	0.42731
FDT	30 Tags	0.17204	0.39825	0.44822	0.52953	0.70932	0.79362	1.2915	1.3657
FDT	60 Tags	0.35373	0.81625	0.92341	1.0727	1.4455	1.6012	2.6182	2.7768
FRT	1 Tag	0	0.014292	0.016103	0.018829	0.02507	0.027775	0.044865	0.047591
FRT	10 Tags	0	0.13773	0.15437	0.18335	0.24666	0.27401	0.44243	0.46843
FRT	30 Tags	0	0.40609	0.4578	0.54188	0.72795	0.81494	1.3299	1.4069
FRT	60 Tags	0	0.82407	0.93304	1.085	1.4641	1.6225	2.6567	2.818

Table 9: Simulation Results 25µs – 53.3kBit/s Part 2

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	272	272	272	272	272	272	272	272
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	136.2906	69.7505	61.823	54.1352	41.509	37.5668	24.0425	22.6304
ACR	30 Tags	121.7709	63.9415	57.7199	50.2945	37.9083	34.9817	22.1716	20.9696
ACR	60 Tags	118.9852	62.5298	56.3094	49.1269	37.7161	34.2512	21.7551	20.5279
FDT	1 Tag	0.0091553	0.0091769	0.0091642	0.0091626	0.0091665	0.0091457	0.0091453	0.0091606
FDT	10 Tags	0.085855	0.15726	0.17526	0.19929	0.25494	0.2801	0.43	0.45477
FDT	30 Tags	0.26089	0.48414	0.53446	0.61062	0.80571	0.8738	1.3674	1.4447
FDT	60 Tags	0.5202	0.97604	1.0819	1.237	1.6065	1.7683	2.7737	2.9394
FRT	1 Tag	0	0.01702	0.018794	0.02152	0.027792	0.030456	0.047578	0.050278
FRT	10 Tags	0	0.16508	0.18488	0.21161	0.27355	0.30141	0.46838	0.4959
FRT	30 Tags	0	0.49196	0.5441	0.62295	0.82434	0.89512	1.4059	1.4858
FRT	60 Tags	0	0.98386	1.0915	1.2493	1.6251	1.7896	2.8121	2.9805

Table 10: Simulation Results 25µs – 53.3kBit/s Part 3

	UII	128	128	128	128	272	272	272	272
	Total Data	272	512	1000	2048	272	512	1000	2048
ADR	1 Tag	0.014292	0.018829	0.027775	0.047591	0.0091553	0.018794	0.027792	0.047578
ADR	10 Tags	0.13773	0.18335	0.27401	0.46843	0.085855	0.18488	0.27355	0.46838
ADR	30 Tags	0.40609	0.54188	0.81494	1.4069	0.26089	0.5441	0.82434	1.4059
ADR	60 Tags	0.82407	1.085	1.6225	2.818	0.5202	1.0915	1.6251	2.8121

Table 11: Simulation Results 25µs – 75kBit/s Part 1

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	128	128	128	128	128	128	128	128
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	260.1876	103.1288	93.2462	79.1881	60.4585	54.8045	34.1768	32.1967
ACR	30 Tags	228.4444	91.4643	85.6257	72.423	56.5543	50.8356	31.4633	29.9279
ACR	60 Tags	243.4324	92.5215	81.8858	71.2924	55.4074	49.5631	31.0996	29.3981
FDT	1 Tag	0.0054386	0.005457	0.005441	0.0054434	0.0054434	0.0054638	0.005435	0.0054434
FDT	10 Tags	0.047312	0.10571	0.11738	0.13433	0.17361	0.1917	0.30065	0.31875
FDT	30 Tags	0.14108	0.33688	0.36136	0.42543	0.53938	0.60188	0.96244	1.0105
FDT	60 Tags	0.25627	0.65828	0.7434	0.85146	1.0927	1.2204	1.9417	2.0519
FRT	1 Tag	0	0.011939	0.013203	0.015119	0.019592	0.021587	0.033672	0.035617
FRT	10 Tags	0	0.11219	0.12514	0.14401	0.18776	0.2078	0.32886	0.34892
FRT	30 Tags	0	0.34342	0.3691	0.43514	0.55354	0.61794	0.99071	1.0406
FRT	60 Tags	0	0.66479	0.75124	0.86122	1.1068	1.2365	1.9699	2.0821

Table 12: Simulation Results 25µs – 75kBit/s Part 2

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	272	272	272	272	272	272	272	272
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	179.4641	87.4628	80.1618	69.5632	54.6211	49.9524	32.135	30.3964
ACR	30 Tags	164.5756	77.6922	71.7269	62.9295	50.4896	46.653	30.0562	28.1231
ACR	60 Tags	161.4322	80.9109	71.7969	62.8118	49.3818	44.8488	29.3133	27.5158
FDT	1 Tag	0.0073593	0.007362	0.007371	0.007358	0.007365	0.007374	0.007363	0.00737
FDT	10 Tags	0.066674	0.1249	0.13546	0.15483	0.1944	0.21145	0.32163	0.34008
FDT	30 Tags	0.19223	0.40045	0.42912	0.48758	0.605	0.65577	1.009	1.0776
FDT	60 Tags	0.38604	0.75239	0.84864	0.96695	1.2285	1.3504	2.0594	2.1923
FRT	1 Tag	0	0.013847	0.015137	0.017053	0.021527	0.023488	0.035634	0.037535
FRT	10 Tags	0	0.13139	0.14323	0.16453	0.20856	0.22756	0.34985	0.37023
FRT	30 Tags	0	0.40699	0.43686	0.49736	0.61915	0.67188	1.0373	1.1079
FRT	60 Tags	0	0.75895	0.85639	0.97659	1.2426	1.3664	2.0876	2.2225

Table 13: Simulation Results 25µs – 75kBit/s Part 3

	UII	128	128	128	128	272	272	272	272
	Total Data	272	512	1000	2048	272	512	1000	2048
ADR	1 Tag	0.011939	0.015119	0.021587	0.035617	0.0073593	0.015137	0.021527	0.035634
ADR	10 Tags	0.11219	0.14401	0.2078	0.34892	0.066674	0.14323	0.20856	0.34985
ADR	30 Tags	0.34342	0.43514	0.61794	1.0406	0.19223	0.43686	0.61915	1.0373
ADR	60 Tags	0.66479	0.86122	1.2365	2.0821	0.38604	0.85639	1.2426	2.0876

7.1.3 Batch 3

Table 14: Simulation Results 6.25µs – 640kBit/s Part 1

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	128	128	128	128	128	128	128	128
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	1466.2299	575.2357	524.9907	477.2317	393.5283	361.7935	249.2791	235.311
ACR	30 Tags	1353.2907	526.7828	493.3648	448.5377	363.578	336.5582	228.7103	220.321
ACR	60 Tags	1345.9936	515.6417	481.2528	436.0042	354.3852	328.1801	224.1822	213.528
FDT	1 Tag	0.0010676	0.0010681	0.0010687	0.0010653	0.0010698	0.0010708	0.0010682	0.0010658
FDT	10 Tags	0.008471	0.019121	0.020857	0.022671	0.026992	0.029569	0.041709	0.04413
FDT	30 Tags	0.024163	0.059018	0.06283	0.069031	0.084635	0.091062	0.13309	0.13824
FDT	60 Tags	0.046796	0.11848	0.1267	0.13986	0.17134	0.18503	0.26976	0.28311
FRT	1 Tag	0	0.0022605	0.0024135	0.0026371	0.0031699	0.0033997	0.0048168	0.0050341
FRT	10 Tags	0	0.020314	0.0222	0.024241	0.029085	0.031893	0.045457	0.048106
FRT	30 Tags	0	0.060222	0.064181	0.070607	0.08673	0.093379	0.13684	0.14221
FRT	60 Tags	0	0.11967	0.12804	0.14143	0.17345	0.18735	0.2735	0.28707

Table 15: Simulation Results 6.25µs – 640kBit/s Part 2

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	272	272	272	272	272	272	272	272
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	1156.1849	505.5076	474.1535	436.0888	363.7659	339.3394	233.8682	226.5908
ACR	30 Tags	1068.7515	471.6019	448.2183	406.5001	337.6363	310.6953	217.2372	209.6926
ACR	60 Tags	1038.401	461.651	436.0817	393.6192	329.7958	306.9716	213.6216	205.1169
FDT	1 Tag	0.0012929	0.001293	0.0012967	0.0012956	0.0012936	0.0012939	0.0012898	0.0012966
FDT	10 Tags	0.010842	0.021607	0.022905	0.024886	0.029406	0.031263	0.044965	0.046094
FDT	30 Tags	0.030367	0.06608	0.069071	0.076067	0.091003	0.098754	0.14025	0.14529
FDT	60 Tags	0.060086	0.13224	0.14004	0.15476	0.18445	0.19792	0.28329	0.29496
FRT	1 Tag	0	0.0024912	0.002643	0.0028761	0.0033966	0.0036151	0.0050312	0.0052688
FRT	10 Tags	0	0.022809	0.024254	0.026461	0.031503	0.033587	0.048714	0.050067
FRT	30 Tags	0	0.067275	0.070421	0.077639	0.0931	0.10108	0.14399	0.14925
FRT	60 Tags	0	0.13344	0.14138	0.15633	0.18655	0.20025	0.28703	0.29892

Table 16: Simulation Results 6.25µs – 640kBit/s Part 3

	UII	128	128	128	128	272	272	272	272
	Total Data	272	512	1000	2048	272	512	1000	2048
ADR	1 Tag	0.0022605	0.0026371	0.0033997	0.0050341	0.0012929	0.002643	0.0033966	0.0050312
ADR	10 Tags	0.020314	0.024241	0.031893	0.048106	0.010842	0.024254	0.031503	0.048714
ADR	30 Tags	0.060222	0.070607	0.093379	0.14221	0.030367	0.070421	0.0931	0.14399
ADR	60 Tags	0.11967	0.14143	0.18735	0.28707	0.060086	0.14138	0.18655	0.28703

7.1.4 Batch 4

Table 17: Simulation Results 12.5µs – 80kBit/s Part 1

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	128	128	128	128	128	128	128	128
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	307.8858	132.5667	115.7862	98.2366	71.4876	64.349	38.5263	36.2574
ACR	30 Tags	291.1263	122.9788	107.5517	90.6589	66.2528	59.4667	35.6371	33.6938
ACR	60 Tags	281.8879	118.5692	105.337	88.0595	64.7839	58.0944	35.1964	33.1514
FDT	1 Tag	0.0039439	0.003962	0.003952	0.0039476	0.0039488	0.0039646	0.0039584	0.0039626
FDT	10 Tags	0.039694	0.081849	0.09312	0.10851	0.14607	0.16199	0.2669	0.28245
FDT	30 Tags	0.11076	0.25168	0.28685	0.33868	0.46033	0.51224	0.84901	0.89791
FDT	60 Tags	0.22197	0.51405	0.57743	0.69029	0.93409	1.0415	1.7123	1.8188
FRT	1 Tag	0	0.008823	0.009992	0.011785	0.015986	0.017832	0.029224	0.031012
FRT	10 Tags	0	0.08668	0.099166	0.11635	0.15816	0.17584	0.29215	0.30948
FRT	30 Tags	0	0.25654	0.29292	0.34654	0.47235	0.52608	0.87425	0.92495
FRT	60 Tags	0	0.51889	0.58348	0.69814	0.94614	1.0554	1.7375	1.8458

Table 18: Simulation Results 12.5µs – 80kBit/s Part 2

	Usr Mem	0	144	240	384	728	872	1776	1920
	UII Mem	272	272	272	272	272	272	272	272
ACR	1 Tag	0	0	0	0	0	0	0	0
ACR	10 Tags	217.2698	109.9626	98.2081	84.2245	64.2978	58.0543	36.3795	34.3172
ACR	30 Tags	190.2661	100.5204	90.4386	77.8421	59.2995	53.2909	33.76	31.878
ACR	60 Tags	189.4165	97.9457	88.1976	75.9658	57.8423	52.7329	33.1514	31.3384
FDT	1 Tag	0.005751	0.0057484	0.0057528	0.0057587	0.0057469	0.0057648	0.0057477	0.0057621
FDT	10 Tags	0.054178	0.098916	0.10978	0.12736	0.16413	0.18072	0.28315	0.29992
FDT	30 Tags	0.16713	0.30825	0.34066	0.39566	0.51538	0.57227	0.89751	0.95019
FDT	60 Tags	0.32644	0.6228	0.69014	0.79972	1.0474	1.1484	1.82	1.9249
FRT	1 Tag	0	0.010608	0.011789	0.013611	0.017793	0.019627	0.030984	0.032816
FRT	10 Tags	0	0.10376	0.1158	0.13521	0.17619	0.19458	0.30841	0.32696
FRT	30 Tags	0	0.31312	0.34669	0.40351	0.52742	0.5861	0.92279	0.97723
FRT	60 Tags	0	0.62767	0.6962	0.80756	1.0595	1.1622	1.8452	1.952

Table 19: Simulation Results 12.5µs – 80kBit/s Part 3

	UII	128	128	128	128	272	272	272	272
	Total Data	272	512	1000	2048	272	512	1000	2048
ADR	1 Tag	0.0088231	0.011785	0.017832	0.031012	0.005751	0.011789	0.017793	0.030984
ADR	10 Tags	0.08668	0.11635	0.17584	0.30948	0.054178	0.1158	0.17619	0.30841
ADR	30 Tags	0.25654	0.34654	0.52608	0.92495	0.16713	0.34669	0.52742	0.92279
ADR	60 Tags	0.51889	0.69814	1.0554	1.8458	0.32644	0.6962	1.0595	1.8452

7.1.5 Batch 5

Table 20: Simulation Results for Mixed Populations at 25µs - 64kBit/s

% UII 272 Tags (of total 30 Tags)	0	33.3	50	66.6	100
FDT	0.15422	0.18384	0.199	0.20558	0.22321
ACR	210.5725	175.182	161.577	156.2332	143.4356

Note: The first row of the table denotes the percentage of tags equipped with 272 bits of UII Memory related to the given population of 30 tags. The remaining tags were simulated with 128 bits of UII Memory.

7.2 Detailed Result Format Description

A series of simulation output files are provided complimentary to this report and can be used for later evaluations beyond the simulation results given in 7.1.

7.2.1 Files Created During the Simulation

Diary Files

For every simulation run a so called diary file has been created. The diary file includes the complete output of the simulation run as it is also displayed in the MATLAB® command window.

The name of the diary file is chosen according the scheme diary_batch_{model_file_name}_{date}_{time}.txt, e.g. "diary_batch_portal_1_epc_07-Aug-2009_11-09-37.txt".

Among others, the diary file contains the timestamp and description of all relevant protocol events such simulation start and stop, tag detections and tag reads.

Parameter Files

The parameter file provides information about the parameters used for each different setup that is simulated under the scope of a batch simulation package. The name of this file is generated according the following scheme parameters_batch_{model_file_name}_{date}_{time}.txt, e.g. "parameters_batch_portal_1_epc_07-Aug-2009_11-09-37.txt".

The format of the content of a parameter file is as follows (values separated by blanks):

```
SimGroup FirstSim LastSim NrTags ParametersString
```

where "ParametersString" contains short description of the parameters used in the current simulation group "SimGroup". Each simulation group consists of 10 single simulations from "FirstSim" up to "LastSim", which are later cumulated for the purpose of result evaluation.

The link rates information included in the parameter string is encoded as follows:

- 3 = 12.5µs - 80kBit/s
- 6 = 6.25µs - 640kBit/s
- 7 = 25µs - 53.3kBit/s
- 8 = 25µs - 64kBit/s
- A = 25µs - 75kBit/s

The UII- and User Memory sizes are always given in bits and refer to the contents of the whole memory banks.

7.2.2 Files Created After the Simulation for the Purpose of Evaluation

Parsed Diary Files

For each batch simulation package a derivate of the original diary file is available. The name of this file is parsed_{diaryfile}.txt, e.g. "parsed_diary_batch_portal_1_epc_07-Aug-2009_11-09-37.txt".

This file contains the parsed tag detections in the following format (values separated by blanks):

```
SimNr Antenna TimeOfDetection TotalDetections DifferentDetections
```

where "Antenna" is always 1 (since no antenna switching is simulated) and "TimeOfDetection" is the exact time of the tag detection in seconds measured from the begin of the simulation until the occurrence of the event.

Tag Detections Evaluation File

The tag detections evaluation file is named eval_{diaryfile}.txt, e.g. "eval_diary_batch_portal_1_epc_07-Aug-2009_11-09-37.txt", and is created as an auxiliary evaluation file during result evaluation.

It contains the following evaluation data (values separated by blanks):

```
SimNr FirstTag LastTag FullDetectionTime AnticollisionTime ↓
TotalDetections DifferentDetections AnticollisionRate
```

Tag Detections Result File

The tag detections result file contains the performance key figures calculated in respect to tag detections for the current batch simulation package and is named according the scheme result_{diaryfile}.txt, e.g. "result_diary_batch_portal_1_epc_07-Aug-2009_11-09-37.txt".

The tag detections result file contains the following data for each simulation package:

```
SimGroup FirstTag NrValues LastTag NrValues FullDetectionTime NrValues
AnticollisionTime NrValues TotalDetections NrValues DifferentDetections
NrValues AnticollisionRate NrValues
```

where "NrValues" always denotes the number of single simulation runs that have been taken into account for the previous averaged value. For the given simulation setup this will always be 10 since the RF field is always on and all tags are detected in each single simulation run.

Tag Reads Evaluation File

The tag reads evaluation file is an auxiliary file used for evaluation of the tag read events and is named according the scheme eval_readUsrAll_{diaryfile}.txt, e.g. "eval_readUsrAll_diary_batch_portal_1_epc_07-Aug-2009_11-09-37.txt"

It contains data according the following structure (values separated by blanks):

```
SimNr AllTagsReadTimeStamp
```

where "AllTagsReadTimeStamp" is the exact point of time where all tags in the simulation have been detected and their user memory has been fully read by the interrogator.

Tag Reads Result File

The tag reads result file contains the performance key figure calculated in respect to tag reads for the current batch simulation package and is named according the scheme result_ readUsrAll_{diaryfile}.txt, e.g. "result_readUsrAll_diary_batch_portal_1_epc_07-Aug-2009_11-09-37.txt".

It contains data according the following structure (values separated by blanks):

```
SimGroup AllTagsReadTimeStamp NrValues
```

8 ANNEX: CORRELATION TO COMMERCIAL PRODUCTS

The simulation results have been compared to measurement results at the following measurement events and <u>furthermore extended in-house measurements</u>:

- ISO/IEC 18000-6 Type C artifact demonstration, Klagenfurt, Austria, December 1st, 2005
- ETSI RFID Tests Unna, Germany, September 2006

- ISO evaluation report on interoperability of ISO 18000-6C, iP-X and TOTAL, October 2006
- ETSI Plugtest™ RFID Interoperability Event, Düsseldorf, Germany, 11-15 June 2008
- ETSI Plugtest™ RFID Interoperability Event, Beijing, China 20-24 April 2009

This resulted in evaluations of the following readers in respect to [EPC C1G2] and [ISO 18000-6C]:

- Feig LRU 1000
- Feig LRU 2000
- Impinj Speedway
- Intermec IF4
- Kathrein RRUI4
- Sirit INfinity™ 510 UHF Reader
- ThingMagic Astra

This resulted in evaluations of the following tags in respect to [EPC C1G2] and [ISO 18000-6C]:

- Monza 1a
- Alien Higgs
- NXP UCODE EPC G2X
- Monza 2

The measurement results with these products confirmed the implementation of our simulation software, showing a match of results for same protocol options and settings of data rates in dependence of regulations requirements.

9 ANNEX: GLOBAL UHF RFID REGULATIONS

UHF RFID regulations are usually dominated by 3 facts:

1) RF transmit power (P)

2) Transmit channel (TX) bandwidth

3) Receive channel (RX) bandwidth

Table 3 summarizes the different data rates used for simulations. Table 21 contains all forward and return link data rates of that table.

Table 21: Batch Simulation Package Definition

	Forward Link Rate (Interrogator to Tag)	**Return Link Rate** (Tag to Interrogator)
Batch1	Tari = 25 µs	64 kBit/s (DI FCC)
Batch2	Tari = 25 µs	53.3 kBit/s (DI CEPT old) and 75 kBit/s (DI CEPT new)
Batch3	Tari = 6.25 µs	640 kBit/s
Batch4	Tari = 12.5 µs	80 kBit/s
Batch5	Tari = 25 µs	64 kBit/s

Batch 1 uses the term DI FCC, which means Dense Interrogator under FCC regulations, as FCC regulations for UHF RFID provide a channel width of 500 kHz, which needs to be split into a transmit (TX) and receive (RX) sub-channel. According [EPC C1G2] and [ISO 18000-6C] this means that there are around 200 kHz for transmit and 300 kHz for receive available, which results in Tari = 25 µs, BLF = 256 kHz to set the tag responses into the middle between two carriers and with M=4 in 64 kbps for the return link. Example 1 in Figure 38 illustrates this.

Batch 2 uses the term DI CEPT The term DI CEPT means Dense Interrogator under CEPT/ETSI regulations in Europe, as they provides transmit channels (TX) of 200 kHz bandwidth, which are separated through 2 channels that do not permit transmit and therefore are only used for receive. [CEPT 7003] and [EN 302 208 V1.2.1] define a 4 channel plan with 200 kHz for transmit and 600 kHz carrier separation, whereas the space in between is available for receive. According [EPC C1G2] and [ISO 18000-6C] this means that there are around 200 kHz for transmit and 400 kHz for receive available, which results in Tari = 25 µs, BLF = 300 kHz to set the tag responses into the middle between two carriers and with M=4 in 75 kbps for the return link. For DI CEPT old ([EN 302 208 V1.1.1]) the carrier separation was only 400 kHz, which ended up in a lower BLF and return link data rate respectively. Example 2 in Figure 38 illustrates this for the new European regulations.

Batch 3 uses the maximum data rates specified under [EPC C1G2] and [ISO 18000-6C]. Although there is no country in the world that allows that data rates and frequencies yet, this might be an option for the future.

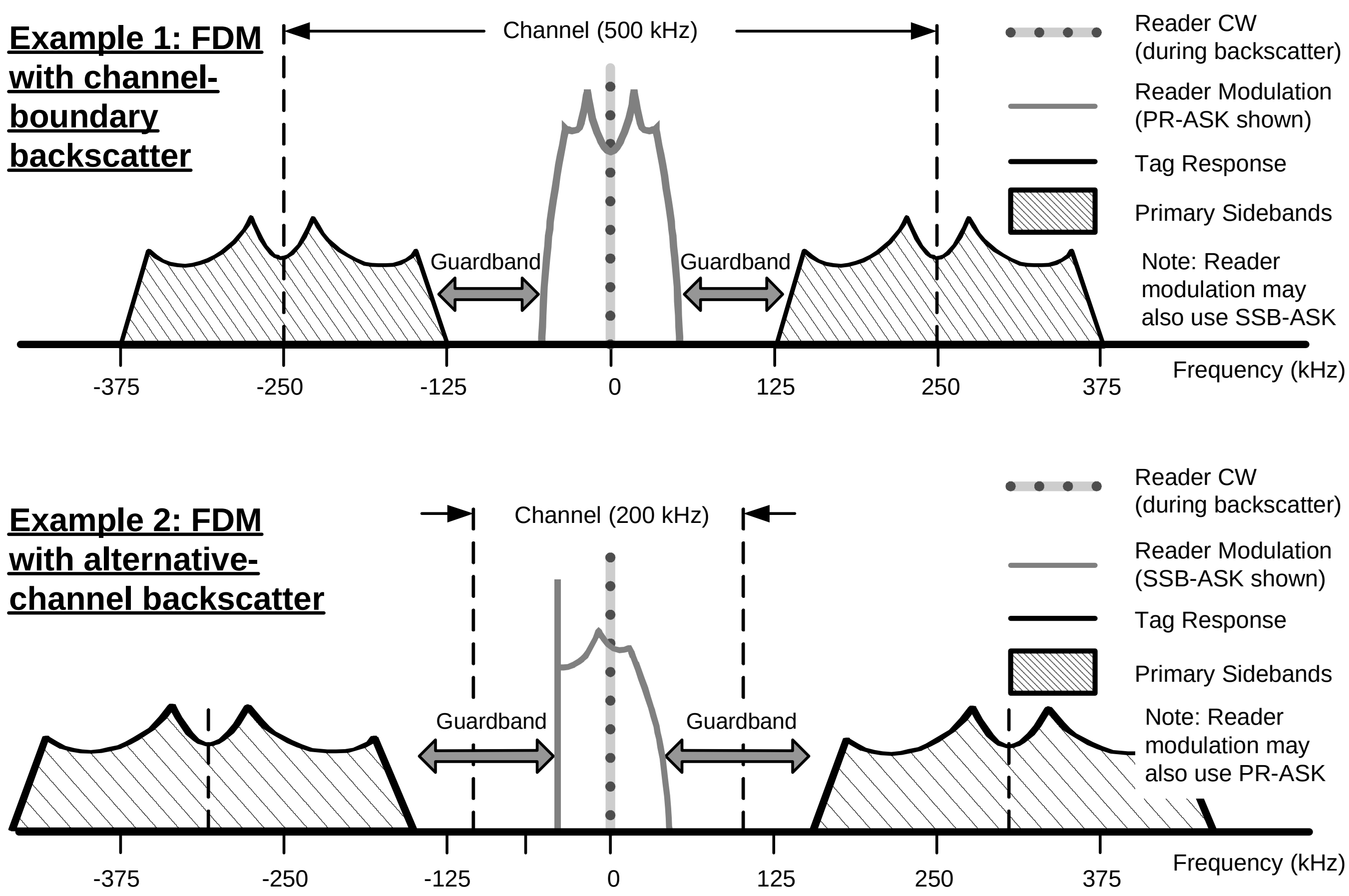

Figure 38 — Examples of dense-interrogator mode operation (Source: [ISO 18000-6C])

In respect to data rates all global UHF RFID regulations are either according DI CEPT or DI FCC. Table 22 shows an excerpt of those regulations.

Table 22: Batch Simulation Package Definition

COUNTRY	P	Channel width	TX channel width	TX carrier spacing	DI CEPT new	DI CEPT old	DI FCC
Europe new (1) (plus additionally India, New Zealand, South Africa, Hong Kong)	2 W erp	200 kHz	200 kHz	600 kHz	X		
Europe old (2) (plus additionally India, New Zealand, South Africa, Hong Kong)	2 W erp	200 kHz	200 kHz	400 kHz		X	
USA (incl. Canada Mexico Argentina, Uruguay)	4 W eirp	500 kHz	200 kHz	500 kHz			X
China	2 W erp	250 kHz	250 kHz	500 kHz(3)			X
Brazil	4 W eirp	500 kHz	200 kHz	500 kHz			X
Korea	4 W eirp	200 kHz	200 kHz	600 kHz	X		
Japan	4 W erip	200 kHz	200 kHz	400 kHz		X	

Note

(1) [EN 302 208 V1.2.1] defines a 4-channel plan with whereas a channel may be continuously utilized for 4 seconds followed by a 100 ms break

(2) [EN 302 208 V1.1.1] defines a 10-channel plan with LbT (Listen before Talk) whereas a channel may be continuously utilized for 4 seconds followed by a 100 ms break, if there is no signal detected immediately before use that exceeds -96 dBm

(3) Dense Interrogator Mode under Chinese UHF RFID regulations requires that only every second channel is used for transmit and the channel in between is used for tag replies and receive

10 REFERENCES

[CEPT 7003] ERC RECOMMENDATION 70-03 RELATING TO THE USE OF SHORT RANGE DEVICES (SRD), Version of 18 February 2009

[EN 302 208 V1.1.1] ETSI EN 302 208-1 V1.1.1 (2004-09), European Standard (Telecommunications series) 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; All parts

[EN 302 208 V1.2.1] ETSI EN 302 208-1 V1.2.1 (2008-04), European Standard (Telecommunications series) 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; All parts

[EPC C1G2] EPCglobal™ EPC™ Radio-Frequency Identity Protocols Class-1 Generation-2 UHF RFID Protocol for Communications at 860-960 MHz Version 1.2.0

[FCC 15.247] FCC PART 15 - RADIO FREQUENCY DEVICES, release of July 10, 2008, Section 15.247

[ISO/IEC 15962] Information technology -- Radio frequency identification (RFID) for item management -- Data protocol: data encoding rules and logical memory functions

[ISO/IEC 18000-6REV1] Information technology -- Radio frequency identification for item management -- Part 6: Parameters for air interface communications at 860 MHz to 960 MHz

[ISO/IEC 18000-6:2004/Amd1:2006] Extension with Type C and update of Types A and B

[ISO 18000-6C] ISO/IEC 18000-6 Information technology — Radio frequency identification for item management — Part 6: Parameters for air interface communications at 860 MHz to 960 MHz, Amendment 1

[TDS 1.4] EPCglobal™ Tag Data Standards Version 1.4

[TDS 1.5] EPCglobal™ Tag Data Standards Version 1.5

[UMIC0901-R1] Evaluation Report UMIC0901-R1: UHF RFID Simulations - Identification performance in dependence on UII size"

11 DISCLAIMER

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics section of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
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12 REVISION HISTORY

Table 23: Revision History

REVISION	DATE	PAGE	DESCRIPTION
1.0	16.09.2009		Initial version.
1.1	02.12.2009		Editorial updates.
2.0	10.12.2009		Combining report and annexes into one document

NOTES

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