APPLICATION NOTE

I•CODE1
System Design Guide

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Summary

This application note describes a contactless electronic label system using the PHILIPS I•CODE1 Label IC. The reader generates the 13.56 MHz magnetic field to transfer the power and the data to the labels. A coil in the label converts the magnetic field to voltage, which supplies the I•CODE1 Label IC.

The I•CODE1 system supports an operation with several labels even when they are in the field at the same time (anticollision). The communication between the label and the reader uses a timeslot anticollsion principle.

The timeslot procedure and the corresponding commands are explained in this document. The number of timeslots is adjustable. The transaction time can be minimised when an appropriate number of timeslots is chosen.

The reader functionality is described based on the PHILIPS reader module SL RM 900. The reader module has the typical configuration used in contactless identification systems. The modulator and the demodulator are the component of the RF link to the labels. A fast microcontroller perform the encoding / decoding of the data transmission to the labels and controls the serial link to a host computer. The principles of the demodulation and the detection of collision are explained.

Contents

1 INTRODUCTION

The figure below shows a typical I•CODE1 contactless label system. The I•CODE1 reader detects the labels in the operating volume and controls the power supply and communication to the I•CODE1 labels.

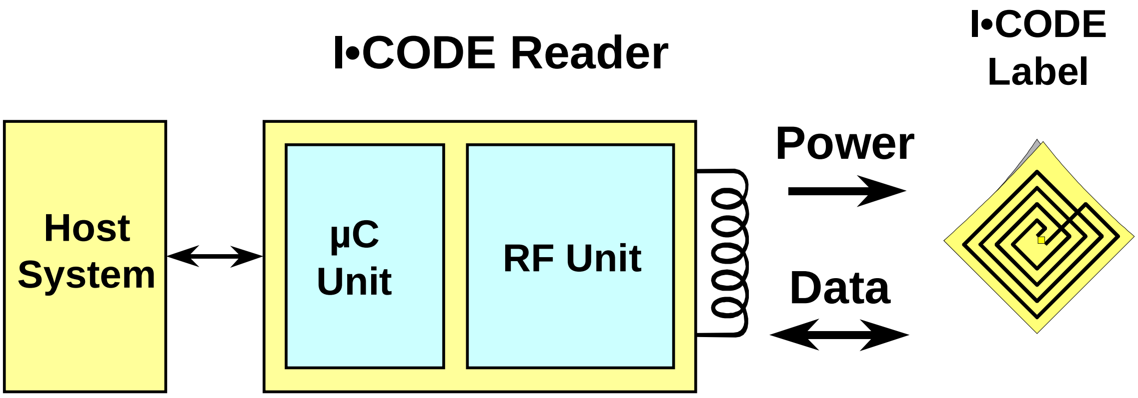

Figure 1-1: System configuration

The I•CODE1 reader usually operates with a host system. The host can set the configuration of the I•CODE1 reader and exchange data with the labels.

The I•CODE1 Label IC and a label coil are the components of a contactless and batteryless electronic label. The overview of the I•CODE1 Label IC is given in chapter 3. Please refer to the data sheet [1] for further electrical characteristics. The design of the label coil is described in [5].

The reader (e.g. PHILIPS I•CODE SL RM 900) generates a magnetic field by driving a 13.56 MHz current through the antenna coil. An antenna design guideline for the reader antenna is described in [6]. The magnetic field is the physical link for energy and data transmission. The voltage induced into the label coil supplies the I•CODE1 integrated circuit.

The I•CODE1 system supports an operation with several labels even when they are in the field at the same time (anticollision). The communication between the label and the reader uses a timeslot anticollsion principle. In chapter 4, the timeslot procedure and the corresponding commands are explained. The document [2] gives a detailed description of the air interface protocol.

The number of timeslots is adjustable from the reader side. The transaction time can be minimised when a appropriate number of timeslots is chosen (see chapter 5.1).

The chapter 5.2 gives an overview of the reader module SL RM 900 (the hardware, the detection of data collisions and the principle of the data decoding, see also [4]). The serial interface protocol to the host is described in [3].

1.1 Abbreviations

AI	Application Identifier
CRC	Cyclic Redundancy Check
EAS	Electronic Article Surveillance
EEPROM	Electrically Erasable and Programmable Read Only Memory
FC	Family Code
IC	Integrated Circuit
LSB	Least Significant Bit or Byte
MSB	Most Significant Bit or Byte
SNR	Serial Number
N_{slot}:	Number of timeslots
N_{label}:	Number of labels that are simultaneously in the field
N_{com}:	Mean number of reader commands to detect all labels
P_n:	Probability that all labels are detected with n reader command sequences
t_{com}:	Command execution time
$t_{overhead}$:	Command overhead time
t_{instr}:	Reader instruction time
t_{slot}:	Timeslot duration time
t_{mean}:	Mean access time per label

1.2 Notation

COMMANDS	are written uppercase.
Command parameters	are written italic.
hex	Value in hexadecimal notation

2 I•CODE1 LABEL IC

2.1 Basics characteristics

The I•CODE1 Label IC is a 512 bit EEPROM memory chip for electronic label applications. The I•CODE1 reader is able to serve several labels when they are in the field at the same time. The system is optimized for long range applications.

• EEPROM capacity	64 bit Serial Number (SNR) 32 bit Access Conditions 32 bit special function (EAS, QUIET) 384 bit User
• Anticollsion	Timeslot technique
• Operating frequency	13.56 MHz
• Maximum gate operation distance (Square label with 50 mm edge length)	approx. 1.2 m Read and Write approx. 1.5 m Detection (EAS)
• Transaction speed	30 labels/sec

- In compliance with relevant regulations (EN, FCC)

2.2 Block Diagram

The block diagram in Figure 2-1 shows the three basic building blocks of a contactless label IC.

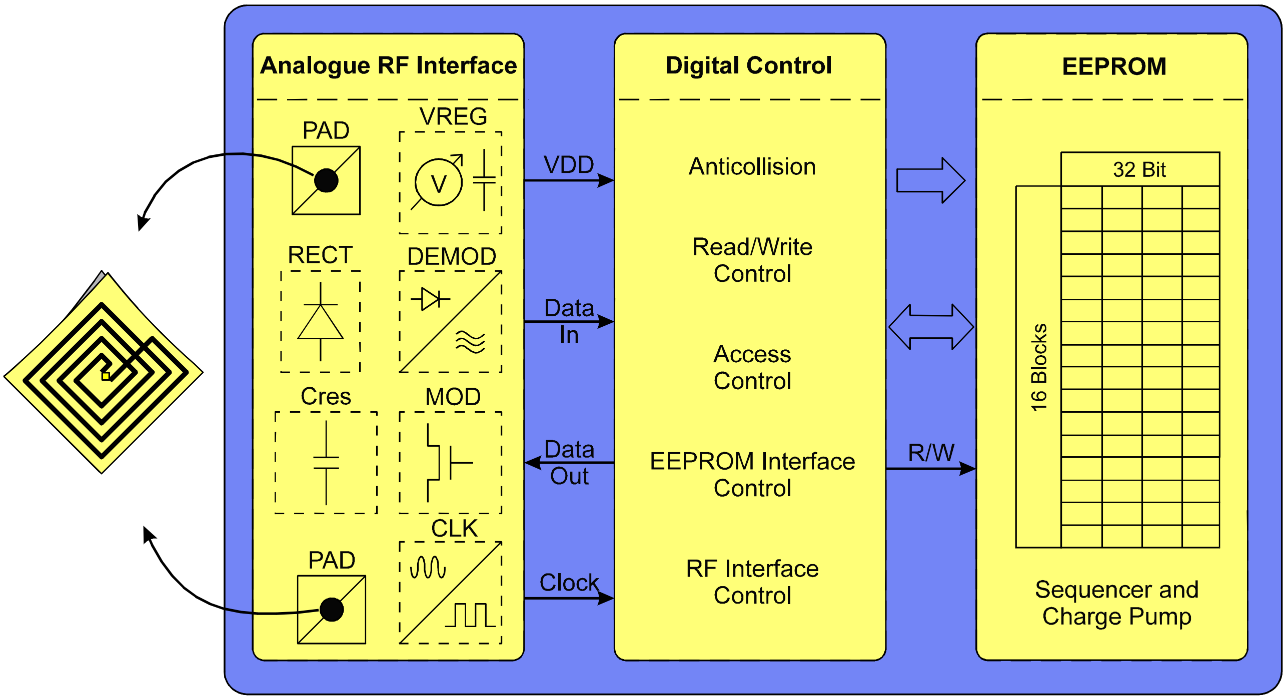

Figure 2-1 : Block diagram I•CODE1 Label IC

The Analogue RF Interface is connected to the label coil. The label coil and an on-chip capacitor (C_{res}) form a resonance circuitry. The rectifier (RECT) and the parallel voltage regulator (VREG) convert the 13.56 MHz coil voltage to the internal power supply. The demodulator (DEMOD) detects the ASK modulation at the coil pads and generates the binary "Data In" signal. The modulator (MOD) is controlled by the "Data Out" signal and performs the load modulation at the coil. The system clock is derived from the induced coil voltage.

The Digital Control encompasses the functions as listed in the corresponding block in Figure 2-1.

Data are stored in a non-volatile memory (EEPROM). The EEPROM has a memory capacity of 512 bit. The EEPROM contains the serial number (read only), configuration data (write access condition, application identifier, family code…) and 384 bit user data.

2.3 EEPROM Memory Organisation

The 512 bit EEPROM memory is divided into 16 blocks. A block is the smallest unit, that can be read and written. Each block consists of 4 bytes (1 block = 32 bits). Bit 0 in each byte represents the least significant bit (LSB) and bit 7 the most significant bit (MSB), respectively.

Table 1: I•CODE1 EEPROM Memory Map

	Byte 0	Byte 1	Byte 2	Byte 3	
Block 0	SNR0	SNR1	SNR2	SNR3	Serial Number (lower bytes)
Block 1	SNR4	SNR5	SNR6	SNR7	Serial Number (higher bytes)
Block 2	F0hex	FF hex	FF hex	FF hex	Write Access Conditions (factory default)
Block 3	x	x	x	x	Special Functions (EAS/QUIET)
Block 4	x	x	x	x	Family Code / Application Identifier / User Data
Block 5	x	x	x	x	User Data
Block 6	x	x	x	x	:
Block 7	x	x	x	x	:
Block 8	x	x	x	x	:
Block 9	x	x	x	x	:
Block 10	x	x	x	x	:
Block 11	x	x	x	x	:
Block 12	x	x	x	x	:
Block 13	x	x	x	x	:
Block 14	x	x	x	x	:
Block 15	x	x	x	x	User Data

Note: The content of the bytes marked with ‘x’ have no defined factory settings.
Further information about restrictions on memory access is given in the data sheet.

- **Serial number**

  The 64 bit serial number is unique and stored in block 0 and 1. The value is set at factory side and is programmed during the production process. SNR0 in the table represents the least significant byte and SNR7 the most significant byte, respectively.

- **Write Access Conditions:**
  The access conditions can either be "read/write" (=1|1) or "read only" (=0|0). Once set to "read only", the write permission is inhibited, which can not be changed anymore.

  The access conditions can be set individually for each block.

  Note: Setting the "read only" on block 2, stops any further modification of the access conditions. Writing of bit combinations 1|0 or 0|1 shall not be used. This may cause unpredictable results.

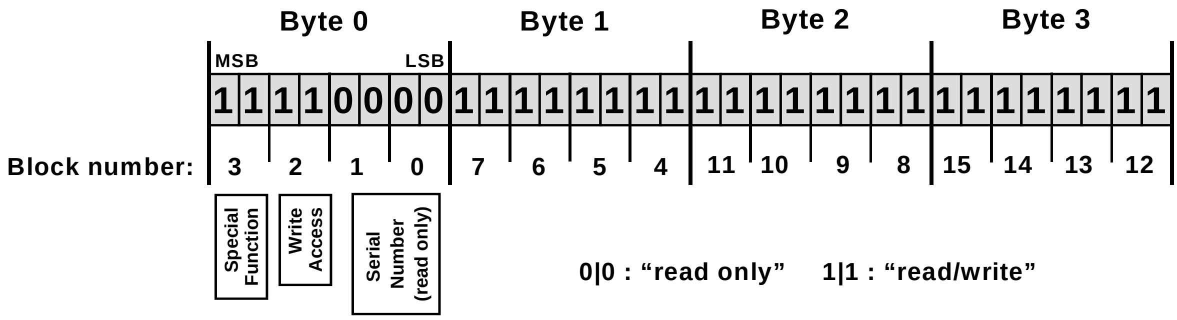

Figure 2-2: Block 2 - Write access conditions

- **Special Functions: Electronic Article Surveillance (EAS) and Quiet Mode:**
  Block 3 contains the special function control bit for EAS and Quiet Mode.
  The EAS function is used as anti theft protection. The reader sends an EAS command to the label and the label responds with a special EAS pattern. If the EAS function is disabled, the label ignores a received EAS command.

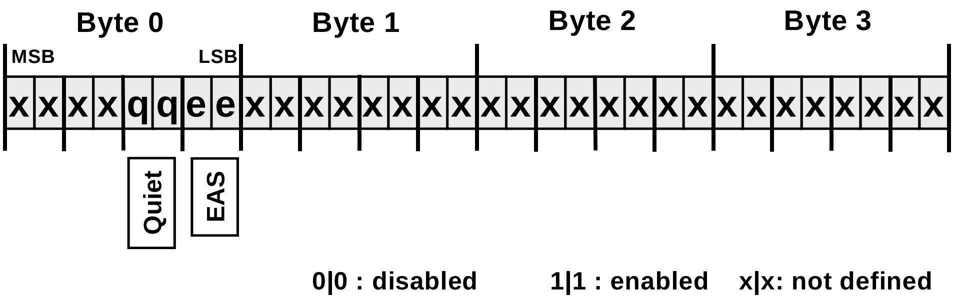

Figure 2-3: Block 3 - Special functions

In Quiet Mode, the I•CODE1 label ignores all reader commands excluding commands "RESET QUIET BIT" and "EAS".

- **Family Code and Application Identifier:**

  The I•CODE1 system offers the feature to use independently Family Codes and Application Identifiers. The Application Identifier and the Family Code are 8-bit values. These values are stored in block 4 of the I•CODE1 Label memory (see Figure 2-4).

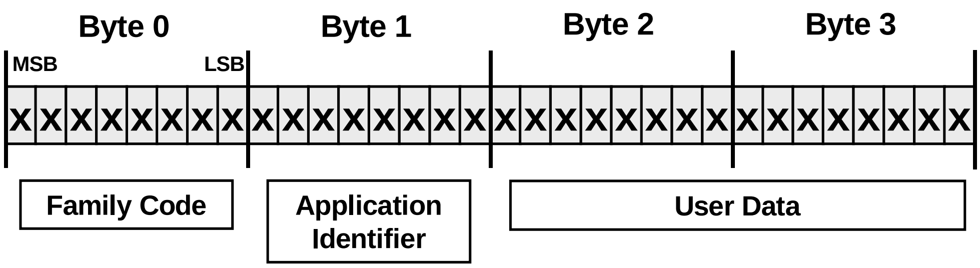

Figure 2-4: Block 4 – Family Code and Application Identifier

Some commands that the reader sends to the label use the parameters *Family Code* and the *Application Identifier* (see chapter 4). The I•CODE1 Labels compare this reader parameter *Family Code* and *Application Identifier* with data in Block 4 and respond depending on the conditions in Table 2. Thus the reader is able to select labels with the same Family Code and/or Application Identifier.

Table 2: Label response conditions using Family Code and Application Identifier

Reader command parameter		Label response
Family Code	*Application Identifier*	
0	0	All labels respond
1 … 255	0	Only the labels respond which have the requested *Family Code:* byte 0 in block 4 = *Family Code*
0	1… 255	Only the labels respond which have the requested *Application Identifier:* byte 1 in block 4 = *Application Identifier*
1 … 255	1… 255	Only the labels respond which have the requested *Family Code* and *Application Identifier:* byte 0 in block 4 = *Family Code* and byte 1 in block 4 = *Application Identifier*

3 COMMAND SET AND STATE DIAGRAM

The I•CODE1 system operates in a so called ”reader talks first” principle. This means, that first the reader sends a command. The labels execute the instruction and send back their responses to the reader. If more than one label is in the field, a mechanism is needed to separate the responses. The I•CODE1 Label system supports the separation, as the labels are sending their responses in different timeslots. Each label calculates its timeslot for the response.

The state diagram for the label is shown in Figure 3-1. The bubbles present the four possible states “Unselected”, “Selected”, “Halt” and “Quiet”. The transition to a new state is launched by a reader command.

In the state “Unselected”, the label calculates its timeslot position by a pseudo random algorithm. The superposition of colliding label information is not legible for the I•CODE1 reader, but the collision can be detected. In this case the reader can repeat the last command in order to resolve the collision. Please refer to chapter 4.1 and 4.2 for a detailed description of the commands UNSELECTED READ and ANTICOLLSION/SELECT.

The label changes to the state “Selected” by an ANTICOLLISION/SELECT command. Each selected label always responds in the same timeslot positions. The selection is mandatory required for the commands SELECTED READ, WRITE BLOCK and HALT.

For the WRITE BLOCK and HALT command, all selected labels respond with their serial number in different timeslots. The label executes the command only, if the reader sends the acknowledge signal QUIT immediately after the label has sent the serial number (please refer to chapter 4.4 and 4.5).

For EAS command, all labels respond with the same EAS data pattern at the same time.

The label does not respond on a RESET QUIT BIT command. The RESET QUIET BIT erase the quiet mode bits in the EEPROM block 3 and set the label into the “Unselected” state. Due to the erase EEPROM time a minimum delay is required before sending the next command.

Table 3: Command List

I•CODE1 Command	Description
ANTICOLLISION/SELECT	Selects labels in the field.
UNSELECTED READ	Reads one or more consecutive memory blocks of not selected labels.
SELECTED READ	Reads one or more consecutive memory blocks of selected labels.
WRITE BLOCK	Writes one block into the memory of the selected label.
HALT	Set the label in state “Halt”. The label does not respond to any further command.
RESET QUIET BIT	The quiet mode bits are set to 0|0. The Quiet function is disabled.
EAS	Invokes the EAS function if the value corresponding control bits are 1|1.

Table 4: Reader Acknowledge

Reader Acknowledge	Description
QUIT	Individual acknowledge for each label.

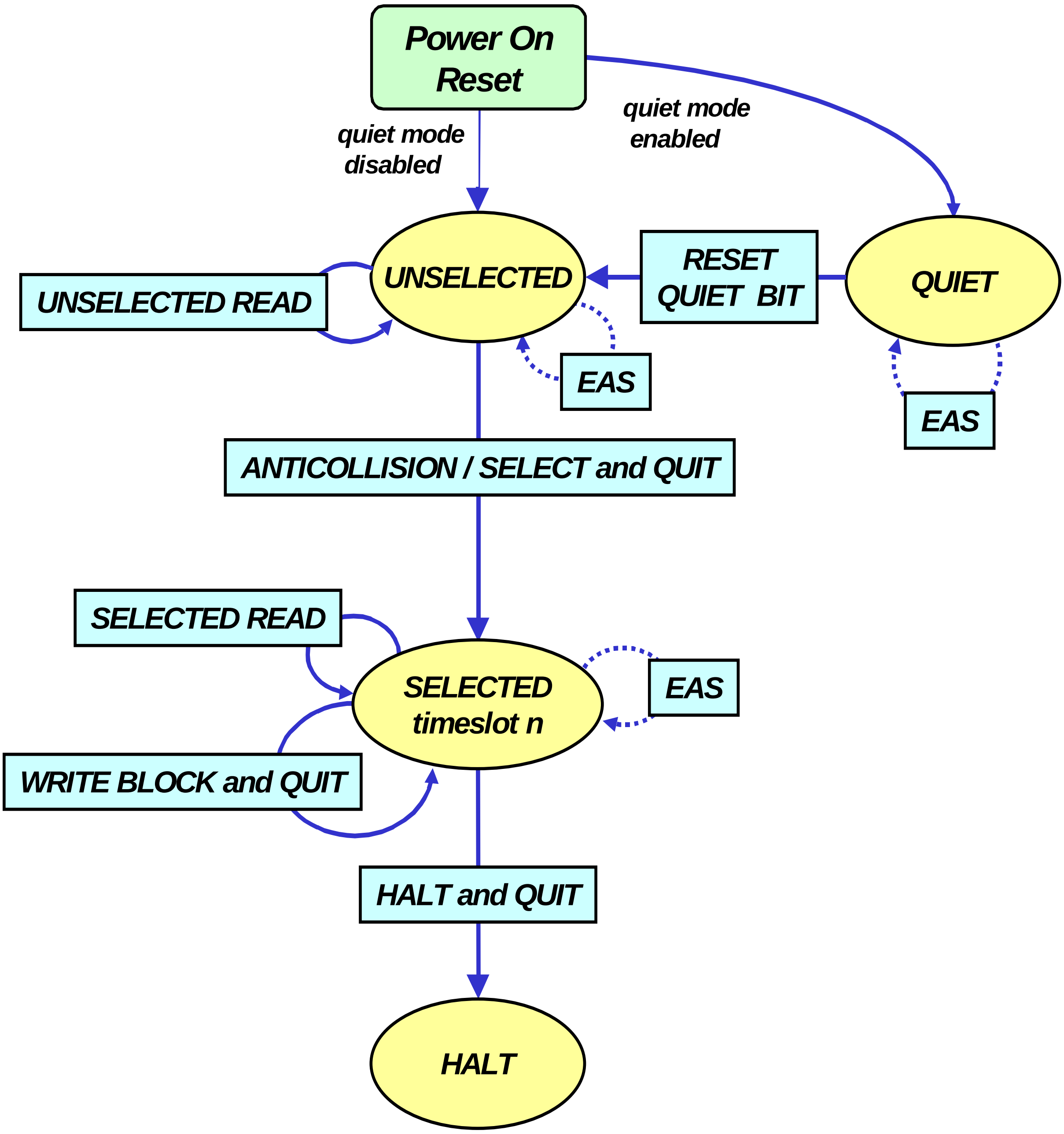

Figure 3-1 : State diagram of the I-CODE Label

4 COMMANDS USING THE TIMESLOT PROCEDURE

The following chapters do not describe the encoding of command and parameters. Also the timing is not given. For this information please refer to data sheet documents [2].

4.1 UNSELECTED READ

The UNSELECTED READ command reads consecutive memory blocks of the label. The Family Code and the Application Identifier allows an application-subordinated selection.

Parameters:

- *Hashvalue*
  Bit address of the serial number to calculate the position of the timeslot.
- *Family Code*
  This parameter is used to read labels with the same Family Code (see Table 2).
- *Application Identifier*
  This parameter is used to read labels with the same Application Identifier (see Table 2).
- *Timeslot index*
  The timeslot index defines the number of timeslots for this command.

Timeslot index	0	1	2	3	4	5	6	7
Number of timeslots	1	4	8	16	32	64	128	256

- *Number of blocks*
  the value gives the number of blocks to be read decreased by one. Valid values are 0 ...15. This corresponds to reading 1…16 blocks from the EEPROM.
- *Start block address*
  defines the first block to be read. Valid values are 0 ... 15.

Response from the label:

The label transmits "*Number of block* +1" EEPROM memory blocks beginning with the *Start block address*.
After the transmission of block 15 (highest memory block address), the label continues the transmission at block address zero (modulo 16 calculation).

For example: On an UNSELECTED READ with parameter *Start block address* =14 and *Number of blocks=3*, a label responds 4 memory blocks:

block 14,
block 15,
block 0,
block 1,

Timeslot calculation

The position of the timeslot is calculated as follows:

- After power on reset, an 8 bit timeslot register is set to the preset value 01_{hex}.
- With each UNSELECTED READ command, the timeslot register is loaded as preset value into the CRC 8 calculation unit.
- The parameter *hashvalue* is the offset bit position within the serial number. The CRC 8 calculation unit takes from the serial number the next 8bit following this offset.
- The CRC 8 result is stored back into the timeslot register.
- The parameter *timeslot index* also defines the timeslot mask.

Timeslots index	0	1	2	3	4	5	6	7
Timeslot mask (hex)	00	03	07	0F	1F	3F	7F	FF

- The timeslot position is given by a logical AND operation of the timeslot mask and the timeslot register.

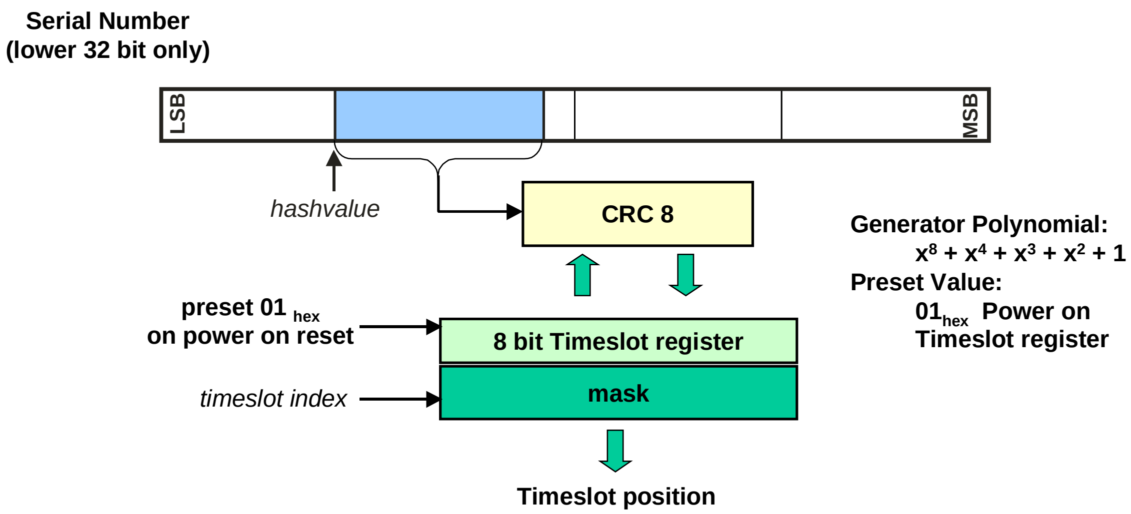

Figure 4-1: Timeslot calculation

Example:

Assuming there are four labels in the magnetic field with following serial numbers.

Label	A	B	C	D
SNR_{hex} (lower 32 bit)	EB 1E 99 00	55 1B 99 00	F2 14 99 00	A4 14 99 00

All labels are in the "Unselected" state. The reader sends an UNSELECTED READ command with following parameters.

UNSELECTED READ

Hashvalue:	0	
Family Code:	0	
Application Identifier:	0	
Timeslot index :	2	(Number of timeslots =8, timeslot mask =07_{hex})
Number of blocks:	0	(N_{read}=1)
Start block address:	0	

The labels respond the content of blocks 0. The table below shows the calculation of the timeslots for all labels.

	Label A	Label B	Label C	Label D
SNR (lower 32 bit)	**EB** 1E 99 00	**55** 1B 99 00	**F2** 14 99 00	**A4** 14 99 00
Hashvalue = 0 -> CRC input	**EB**	**55**	**F2**	**A4**
Timeslot register (after power on)	01	01	01	01
CRC result	B1	AA	71	13
Timeslot mask	07	07	07	07
Timeslot position	01	02	01	03

The labels A and C respond in the same timeslot position 1. The data of these both labels are superposed which results in a data collision. The reader can not read the SNR of label A and C but recognizes the collision. Figure 4-2 shows the timing of the first UNSELECTED READ command.

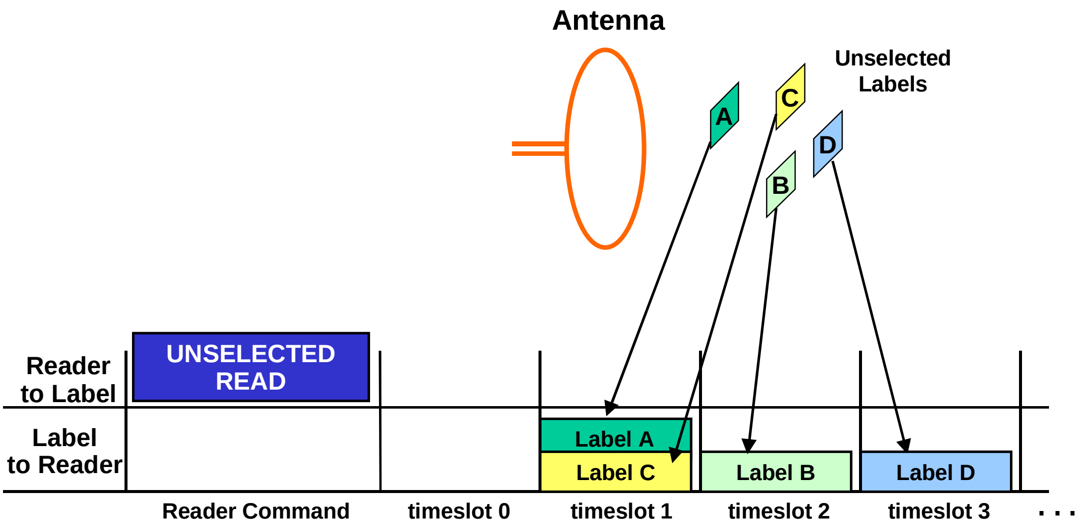

Figure 4-2: Timing of UNSELECTED READ

In order to read also the data of label A and label C, the reader sends a second UNSELECTED READ using the same parameters. Now, the CRC 8 seed value is the previous CRC 8 result.

	Label A	Label B	Label C	Label D
SNR (lower 32 bit)	**EB** 1E 99 00	**55** 1B 99 00	**F2** 14 99 00	**A4** 14 99 00
Hashvalue = 0 -> CRC input	**EB**	**55**	**F2**	**A4**
Timeslot register preset (see CRC result in previous table)	B1	AA	71	13
CRC result	30	23	14	CC
Timeslot mask	07	07	07	07
Response in timeslot	00	03	04	04

Now the label A can be read, but the label C has a collision with label D in timeslot 4. A further UNSELECTED READ is necessary to read the data of label C:

	Label A	Label B	Label C	Label D
Hashvalue = 0 -> CRC input	EB	55	F2	A4
Timeslot register preset See CRC result in	30	23	14	CC
CRC result	EC	4C	E3	C1
Response in timeslot	04	00	03	07

All labels have been read successfully.

Primarily, the calculation of the timeslot position depends on the serial number. If the part of the serial number depicted by the curly bracket in Figure 4-1 is identical for two labels, the content of these two labels can not be read.

Example:

	Label A	Label B	Label C	Label D
SNR (lower 32 bit)	EB 1E **99** 00	55 1B **99** 00	F2 14 **99** 00	A4 14 **99** 00
Hashvalue = 16 -> CRC input	**99**	**99**	**99**	**99**
Timeslot register preset	01	01	01	01
CRC result (1. Unsel. Read)	1C	1C	1C	1C
Response in timeslot (1. Unsel. Read)	04	04	04	04
CRC result (2. Unsel. Read)	3D	3D	3D	3D
Response in timeslot (2. Unsel. Read)	05	05	05	05
CRC result (3. Unsel. Read)	77	77	77	77
Response in timeslot (3. Unsel. Read)	07	07	07	07
CRC result (4. Unsel. Read)	50	50	50	50
Response in timeslot (4. Unsel. Read)	00	00	00	00

This undesired behavior is avoided by changing the *hashvalue*. An appropriate method to change the *hashvalue* is given in chapter 5.1.5.

4.2 ANTICOLLISION/SELECT

The ANTICOLLISION/SELECT command is used to select a subset of labels. A selected label always responds in the same timeslot to all further commands. The *Family Code* and the *Application Identifier* allows an application-subordinated selection.

Parameters:

- *Hashvalue*
  Bit address of the serial number to calculate the position of the timeslot.
- *Family Code*
  This parameter is used to read labels with the same Family Code (see Table 2).
- *Application Identifier*
  This parameter is used to read labels with the same Application Identifier (see Table 2).
- *Timeslot index*
  defines the number of timeslots.

Timeslot index	0	1	2	3	4	5	6	7
Number of timeslots	1	4	8	16	32	64	128	256

Response from the label:

Serial number.

Timeslot calculation

Same as for UNSELECTED READ.

QUIT calculation

- The preset of the CRC 8 is a constant FF_{hex}.
- The parameter *hashvalue* +8 is the offset bit position within the serial number. The CRC 8 calculation unit takes from the serial number the next 8bit following this offset.
- The value of the QUIT is result of CRC 8 calculation.
- The label compares the received QUIT with its own internal calculation. The label enters the selected state only if both values are identical.
- The QUIT puts the label into the selected state (see Figure 3-1). In the selected state, the label maintains the current timeslot position.
- The table in Appendix A contains all possible 256 QUIT values.

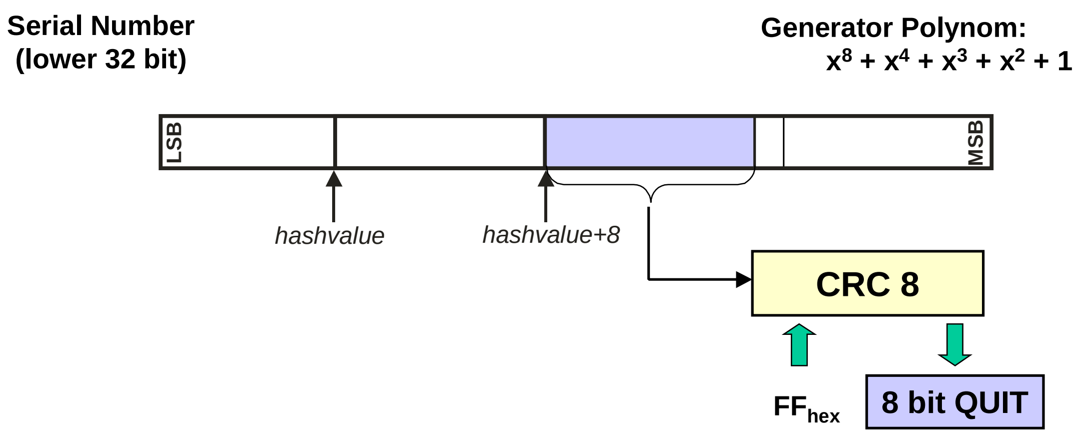

Figure 4-3: Quit value calculation

Example

The timing of the ANTICOLLISION/SELECT and usage of QUIT is described in the following example:

Hashvalue:	0	
Family Code:	0	
Application Identifier:	0	
Timeslot index:	2	(Number of timeslots =8, timeslot mask $=07_{hex}$)

Figure 4-4 shows the timing of ANTICOLLISION/SELECT. The reader sends the QUIT immediately after having received the serial number.

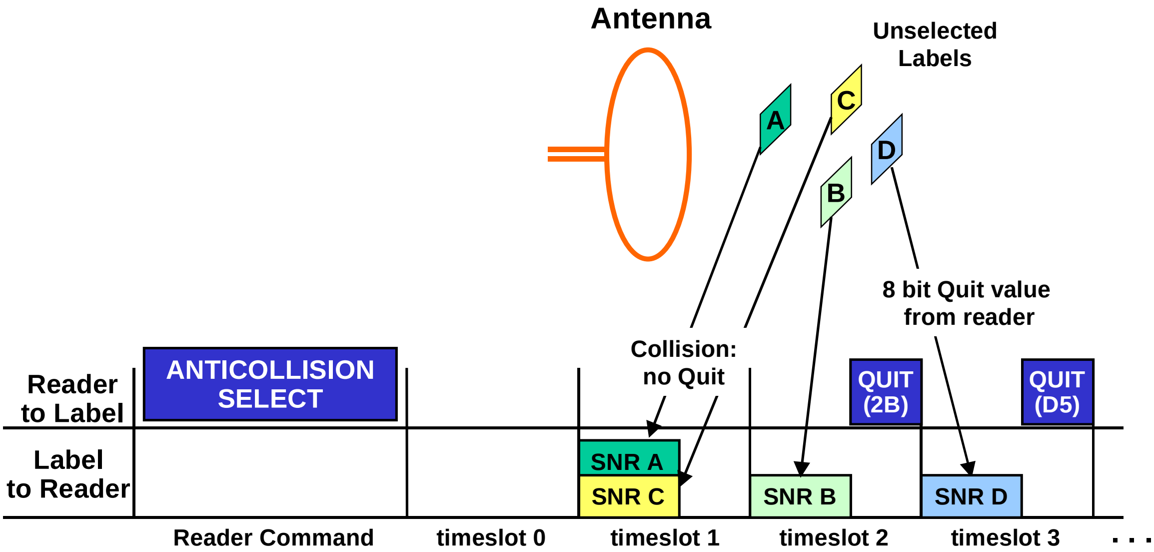

Figure 4-4: Timing of ANTICOLLISION /SELECT

The collision in timeslot 1 makes it impossible to read the serial numbers of label A and C. In order to obtain a unique assignment of the label to a timeslot, QUIT shall not be launched by the reader. The label B and D are selected by a QUIT.

	Label A	Label B	Label C	Label D
SNR (lower 32 bit)	**EB** 1E 99 00	**55** 1B 99 00	**F2** 14 99 00	**A4** 14 99 00
Hashvalue = 0 CRC input for timeslot calculation	**EB**	**55**	**F2**	**A4**
Timeslot register preset	01	01	01	01
CRC 8 result	B1	AA	71	13
Timeslot mask	07	07	07	07
Timeslot	01	02	01	03
QUIT value calculation: CRC input for hashvaue+8	1E	1B	14	14
CRC preset value	FF	FF	FF	FF
QUIT value = CRC result (see Appendix A)	(AE)*	2B	(D5)*	D5

*) Note: The reader does not send these QUIT values due to the data collision of label A and label C.

The reader sends the QUIT values 2B for label B in timeslot 2 and D5 for label D timeslot 3. Now, label B (D) respond always in timeslot 2 (3) for all valid commands in the “Selected” state. All other commands are ignored from label B and D.

The ANTICOLLISION/SELECT command can be repeated several times. Only the unselected labels reply with their serial number in different timeslots in the same way as the timeslot procedure of the UNSELECTED READ command. The QUIT is always fixed for the same hashvalue.

The reader has to consider the timeslots, which are already allocated by the selected labels. For the example above, the timeslot 2 and 3 are already allocated. For the next ANTICOLLISION/SELECT the reader shall not select a label in the allocated timeslots 2 and 3.

4.3 SELECTED READ

The SELECTED READ command reads consecutive memory blocks of selected labels. The Family Code and the Application Identifier have been addressed before by ANTICOLLISION/SELECT.

Parameters:

- *Number of blocks*
  the value gives the number of blocks decreased by one. Valid values are 0 ...15. This corresponds to reading 1…16 blocks from the EEPROM.
- *Start block address*
  defines the first block to be read. Valid values are 0 ... 15.

Response from the label:

The label transmits "*Number of block* +1" EEPROM memory blocks beginning with the *Start block address*. After the transmission of block 15 (max memory block address), the label continues the transmission at block address zero (modulo 16 calculation).

Example:

Labels A and C are in the state "Unselected". Labels B and D are selected and assigned to timeslot 2 and 3. The reader sends an SELECTED READ command with following parameters.

SELECTED READ

Number of blocks: 2

Start block address: 5

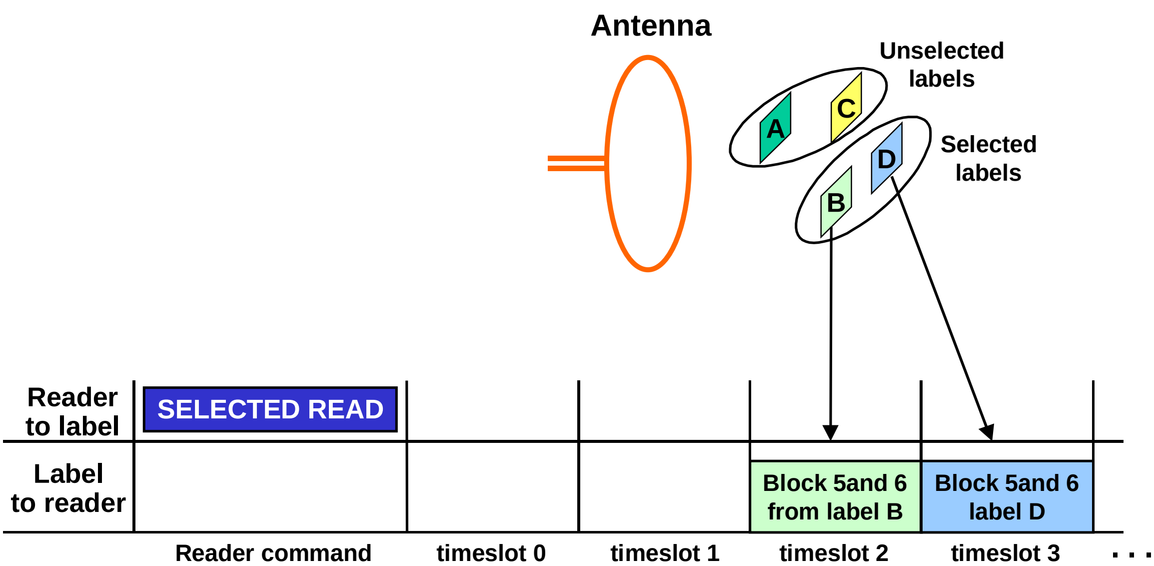

Figure 4-5: Timing of SELECTED READ

4.4 WRITE BLOCK

WRITES BLOCK writes one single block into the memory of the selected labels. The Family Code and the Application Identifier have been addressed before by ANTICOLLISION/SELECT.

Parameters:

- *Hashvalue*
  used to calculate the QUIT.
- *Write block number*
  Address of the label memory block
- *Write data*
  four data bytes to be written into the label EEPROM

Response from the label:

Serial number.

QUIT calculation:

The calculation of the QUIT is the same as for ANTICOLLSION/SELECT.

<u>Example:</u>

Labels A and C are in the state “Unselected”. Labels B and D are selected and assigned to timeslot 2 and 3. The reader sends a WRITE BLOCK command with following parameters.

WRITE BLOCK

Hashvalue:	8
Write block number:	6
Write data:	four data bytes

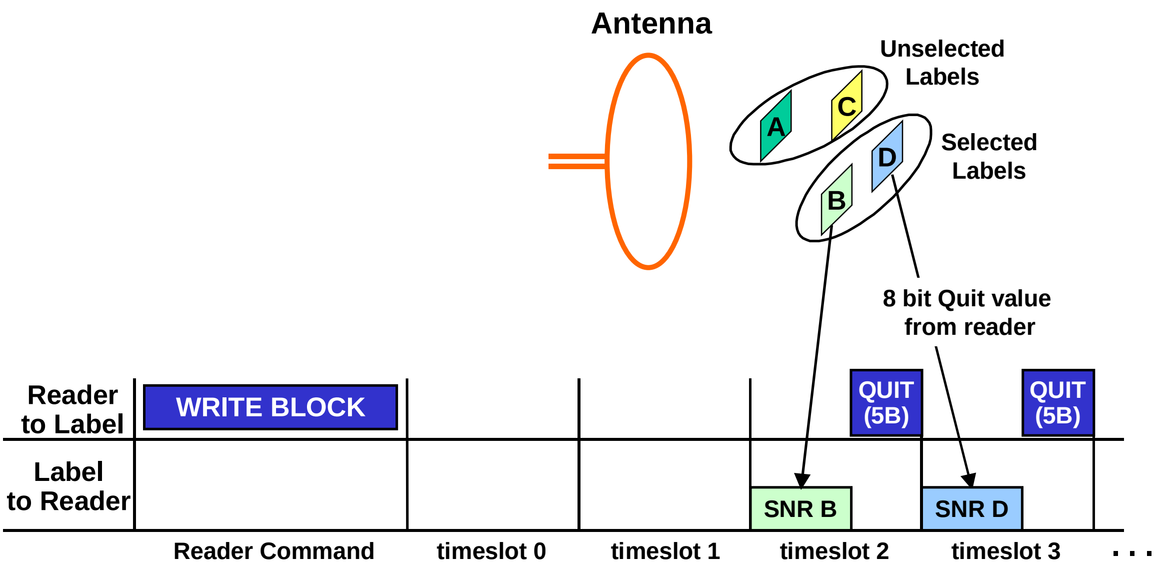

Figure 4-6: Timing of WRITE BLOCK

The example in Figure 4-6 shows the writing of the data in both selected labels.

	Label A	Label B	Label C	Label D
SNR (lower32 bit)	EB 1E **99** 00	55 1B **99** 00	F2 14 **99** 00	A4 14 **99** 00
Response in timeslot	not selected	02	not selected	03
QUIT value calculation: CRC input for hashvaue+8=16	not selected	99	not selected	99
CRC preset value	not selected	FF	not selected	FF
QUIT value = CRC result (see Appendix A)	not selected	5B	not selected	5B

4.5 HALT

HALT forces one or more of the selected labels in the state “Halt”. The Family Code and the Application Identifier have been addressed before by ANTICOLLISION/SELECT.

Parameters:

- *Hashvalue*
  used to calculate the QUIT.

Response from the label:

Serial number.

QUIT calculation:

The calculation of the QUIT is the same as for ANTICOLLSION/SELECT.

Note: Difference between “Halt” and “Quiet”

The HALT command forced into the state “Halt”. In the state “Halt”, the label does not response to any command till the next power on reset. If the label leaves and re-enters the field (or the reader switches the field off and on) the label returns to the state “Unselected”. If a large number of labels are in the field, the HALT can be used to temporarily disable some labels.

The state “Quiet” is entered immediately after power on when the state “Quiet” mode bits are set (see block 3 in chapter 2.3). In the state “Quiet” the label does not respond to any command except the EAS and RESET QUIET BIT commands. The RESET QUIET BIT erases the “Quiet” mode bits in block 3 and sets the label in the “Unselected“ state. The “Quiet” mode bit in block 3 can be set to 1 using the WRITE BLOCK command. If an application doesn’t need a label anymore, the “Quiet” mode can be used to disable the communication to the label.

Example:

Labels A and C are in the state “Unselected”. Labels B and D are selected and assigned to timeslot 2 and 3. The reader sends a HALT command with following parameters.

HALT:

Hashvalue: 16

Figure 4-7 shows the timing to force the label D into the halt state. The *hashvalue* is 16. Now, the timeslot 3 is released. Another label can be assigned to this timeslot by an ANTICOLLISSION/SELECT.

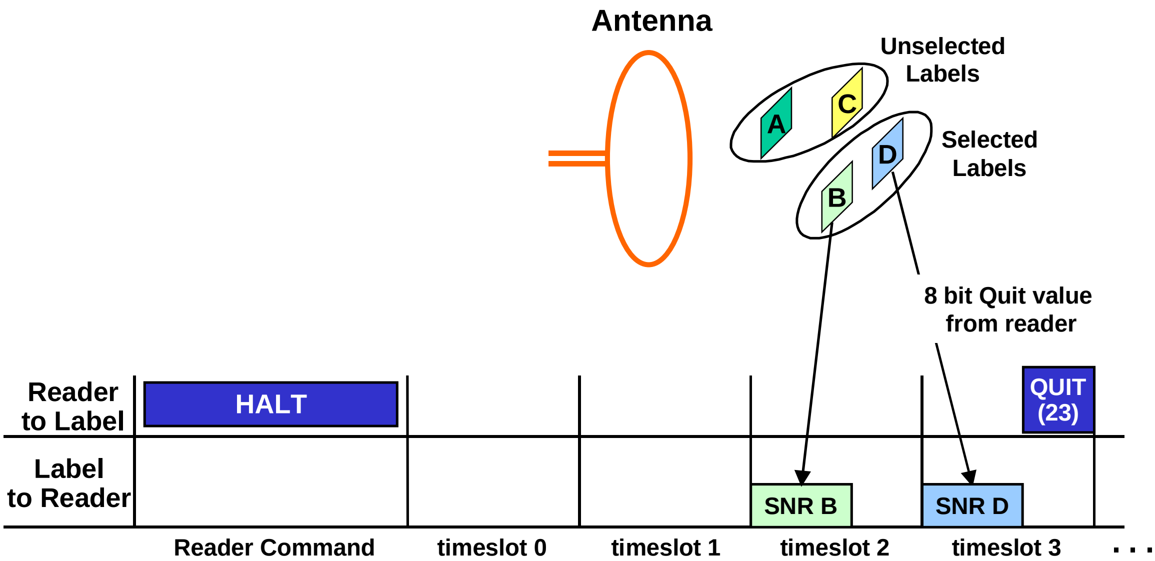

Figure 4-7: HALT command timing

	Label A	Label B	Label C	Label D
SNR (lower 32 bit)	EB 1E 99 00	55 1B 99 <u>00</u>	F2 14 99 00	A4 14 99 <u>00</u>
Response in timeslot	not selected	02	not selected	03
QUIT value calculation: CRC input for hashvaue+8=24	not selected	00	not selected	00
CRC preset value	not selected	FF	not selected	FF
QUIT value = CRC result	not selected	no Quit	not selected	23

5 SYSTEM INTEGRATION

5.1 Timeslot Optimisation

The following chapters explain the optimisation for the number of timeslots in order to achieve a minimum command execution time. The optimisation is based on the simulation of mean number of commands which are necessary to read or select all labels. With this mean number of commands, the mean command execution time can be calculated as function of the number of labels in the field and the number of timeslots.

The minimum of the mean command execution time gives the optimum number of timeslots.

A constant number of timeslots can be used for a constant number of labels in the field or if the variation of the number of labels in the field is low. In the other case, the number of timeslots should be dynamically adapted.

5.1.1 Mean number of commands

The mean number of commands is calculated separately for the two relevant commands UNSELECTED READ and ANTICOLLISION/SELECT. The mean number of commands depends on the number of labels and the number of timeslots. This dependency has been simulated for both commands.

UNSELECTED READ:

The number of commands necessary to completely read a set of labels for a given number of timeslots is simulated. The timeslot position is calculated with the same probability for each timeslot. The mean number of the commands N_{com} is given as the average of 20000 values. The figure below shows the simulation results with the number of timeslots as parameter.

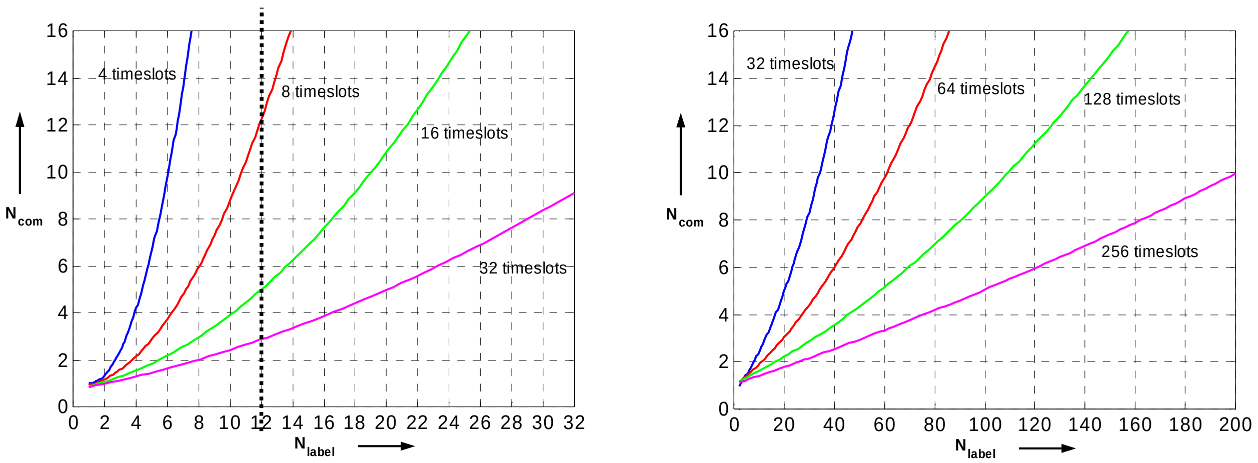

Figure 5-1: Mean number of UNSELECTED READ as function of the number of labels

Example:

Let's assume that 12 labels are in the field. Then the reader needs about:

3.0 reader commands with 32 timeslots -> complete: 3*32=96 timeslots

5.0 reader commands with 16 timeslots -> complete: 5*16=80 timeslots

12.0 reader commands with 8 timeslots -> complete: 12*8=96 timeslots

5 reader commands with 16 timeslots gives the minimum value.

ANTICOLLISION/SELECT:

The number of commands necessary to completely select a set of labels for a given number of timeslots is simulated. The timeslot position is calculated using the same probability for each timeslot. The mean number command N_{com} is given as the average of 20000 values.

The figure below shows the simulation results with the number of timeslots as parameter.

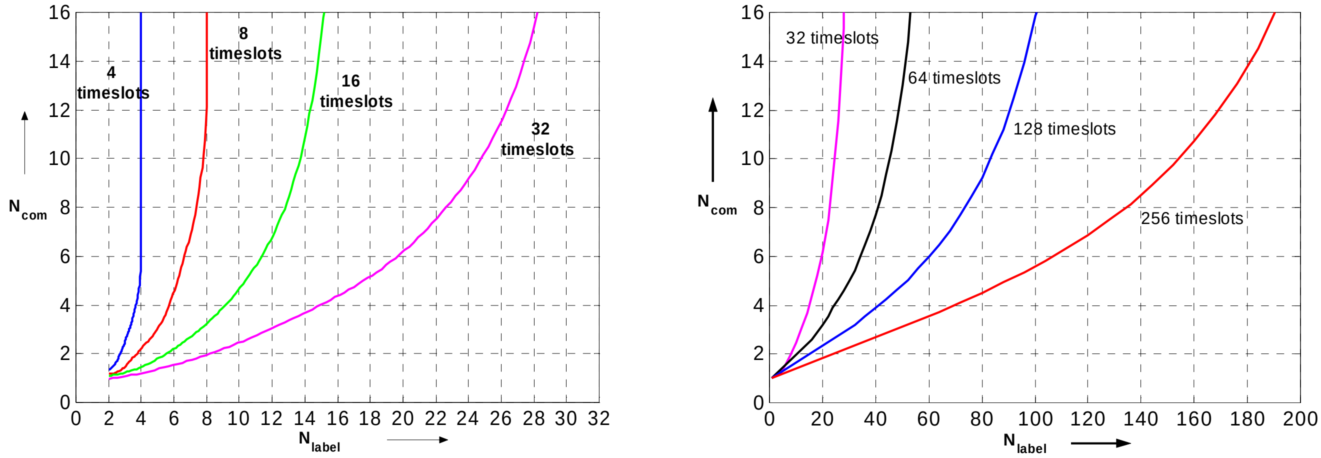

Figure 5-2: Mean number of ANTICOLLSION/SELECT as function of the number of labels

The simulation has a singularity when the number of labels is greater then the number of timeslots. Therefore, the number of timeslots shall always be greater than the number of the labels.

Example:

Let's assume that 6 labels are in the field. Then the reader needs about:

1.5 reader commands with 32 timeslots -> complete: 1.5*32= 48.0 timeslots

2.3 reader commands with 16 timeslots -> complete: 2.3*16= 36.8 timeslots

4.5 reader commands with 8 timeslots -> complete: 4.5* 8= 36.0 timeslots

4.5 reader commands with 8 timeslots gives the minimum value.

5.1.2 Command execution time for a constant number of labels

The complete command execution time is given by:

$$t_{com} = t_{overhead} + t_{slot} \cdot N_{slot}$$

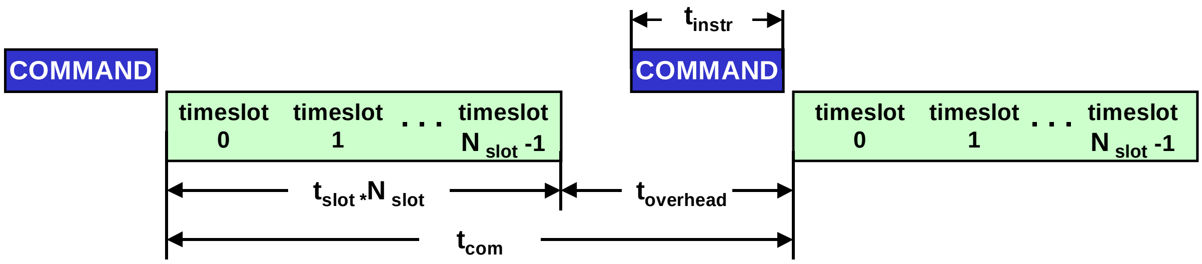

Figure 5-3: Complete command time

The mean access time per label t_{mean} is then given by:

$$t_{mean} = \frac{N_{com} \cdot t_{com}}{N_{label}}$$
$$= N_{com} \cdot \frac{t_{overhead} + t_{slot} \cdot N_{slot}}{N_{label}}$$

The timeslot duration time and the command overhead time depend on the command and data transmission mode (standard mode and fast mode).

	t_{slot} (standard mode)	t_{slot} (fast mode)
UNSELECTED READ	1.2 ms * n_{read} + 0.9 ms	1.2 ms * n_{read} + 0.9 ms
ANTICOLLISION/SELECT	8.46 ms	3.93 ms

Note : n_{read} denotes the number of block to be read.

The command overhead time $t_{overhead}$ is always greater than the instruction time t_{instr} (see Figure 5-3). The instruction time t_{instr} is 39 ms in standard mode and 2.8 ms in fast mode. The following mean access time calculation assumes that the overhead time is slightly greater then the instruction time:

$$t_{overhead} \approx 40\text{ms} \quad (\text{standard mode})$$
$$t_{overhead} \approx 3\text{ms} \quad (\text{fast mode})$$

The diagrams in Figure 5-4 to Figure 5-7 show the mean access time per label based on the simulation results of mean number of commands N_{com} (see Figure 5-1 and Figure 5-2).

The UNSELECTED READ diagrams are arranged by the number of blocks (n_{read} = 1 ,4 and 16) from top to bottom. The diagrams on the left side show the mean access time for 4, 8,16 and 32 timeslots. The diagrams on the right side show the curves for 32, 64, 128 and 256 timeslots. The optimum number of timeslot is given if by the least mean access time.

Example: Optimum number of timeslots (UNSELECTED READ in standard mode, $t_{overhead}$=40 ms)

The number of labels in the field shall be N_{label}=10. If n_{read} = 1, then 32 timeslots yields in a minimum mean access time of 25 ms. If n_{read} = 4 or 16, then an optimum is given for 16 timeslots and the mean access time per label is t_{mean} = 52ms or 140 ms.

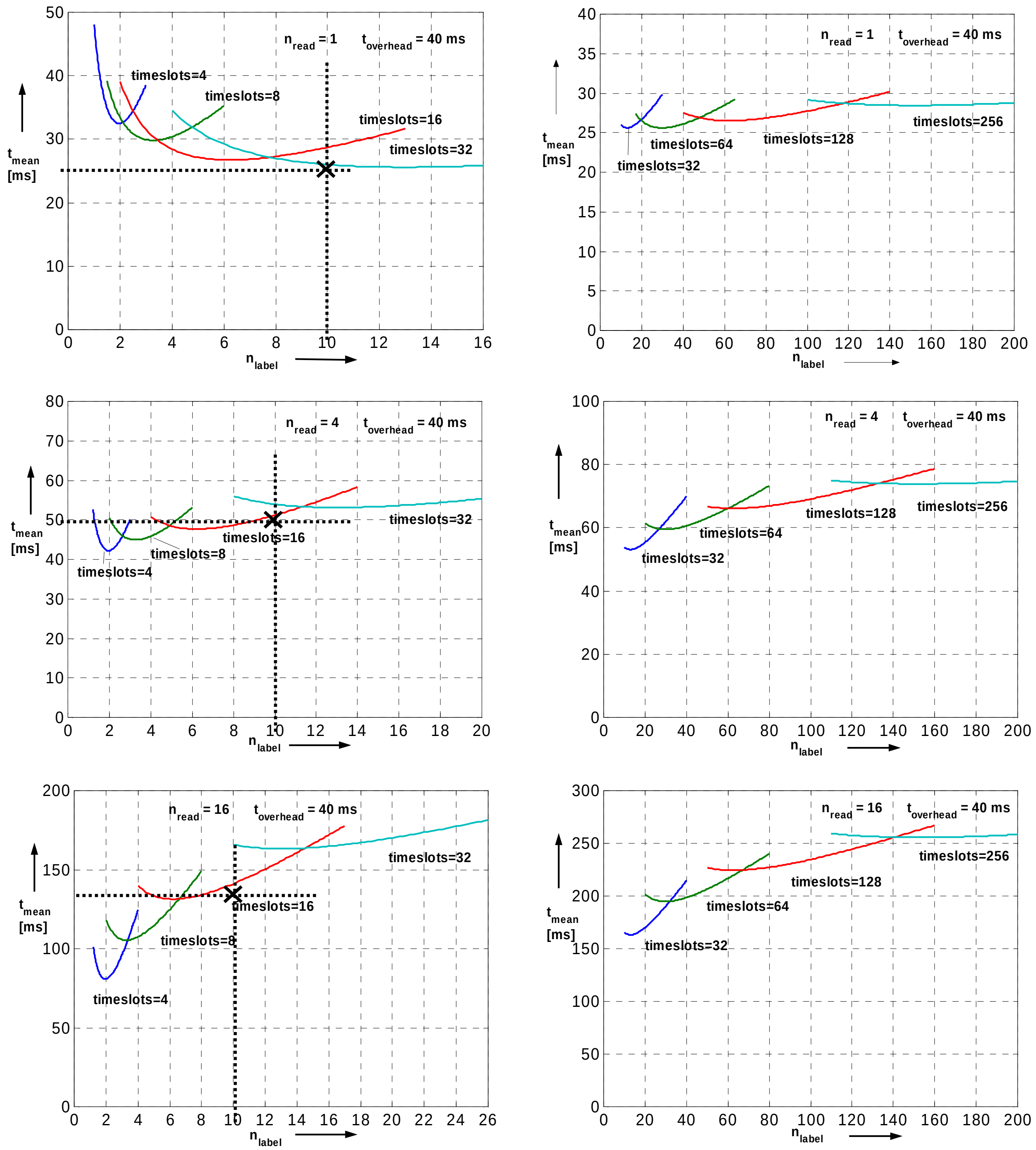

Figure 5-4: Mean access time for the UNSELECTED READ command with t_{com} = 40ms

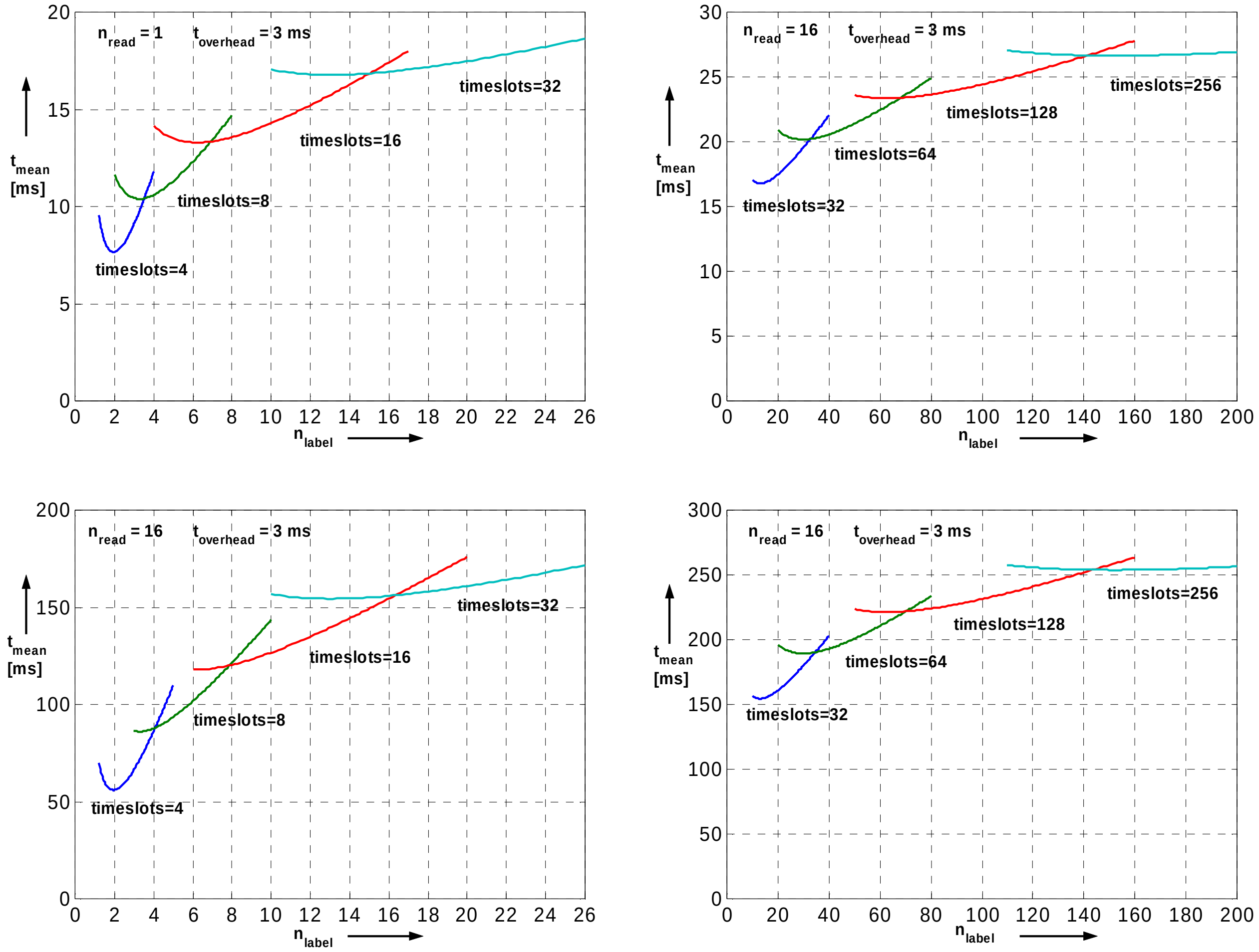

Figure 5-5: Mean access time for the UNSELECTED READ command with t_{com} = 3ms

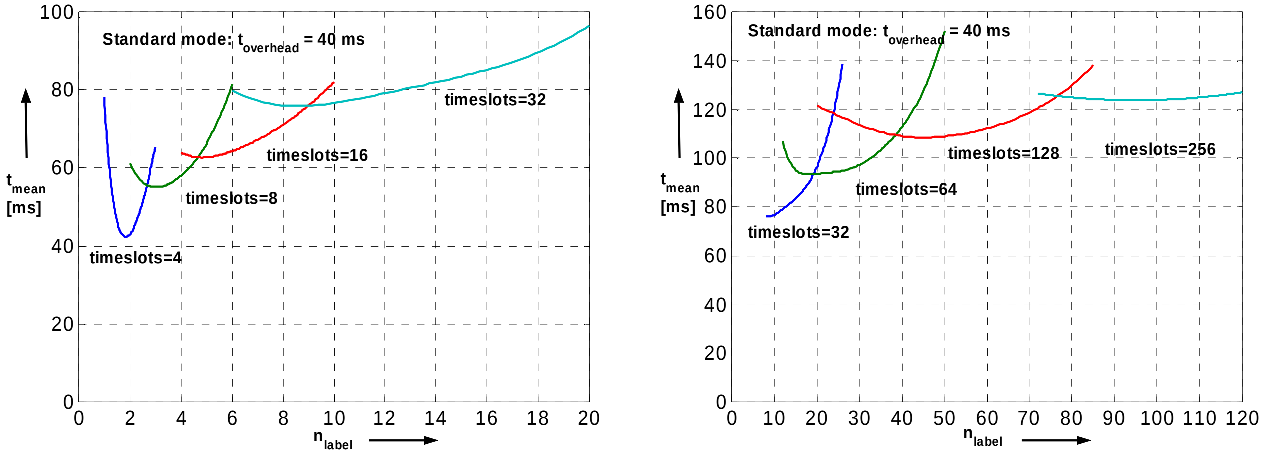

Figure 5-6: Mean access time for the ANTICOLLSION/SELECT command with t_{com} = 40ms

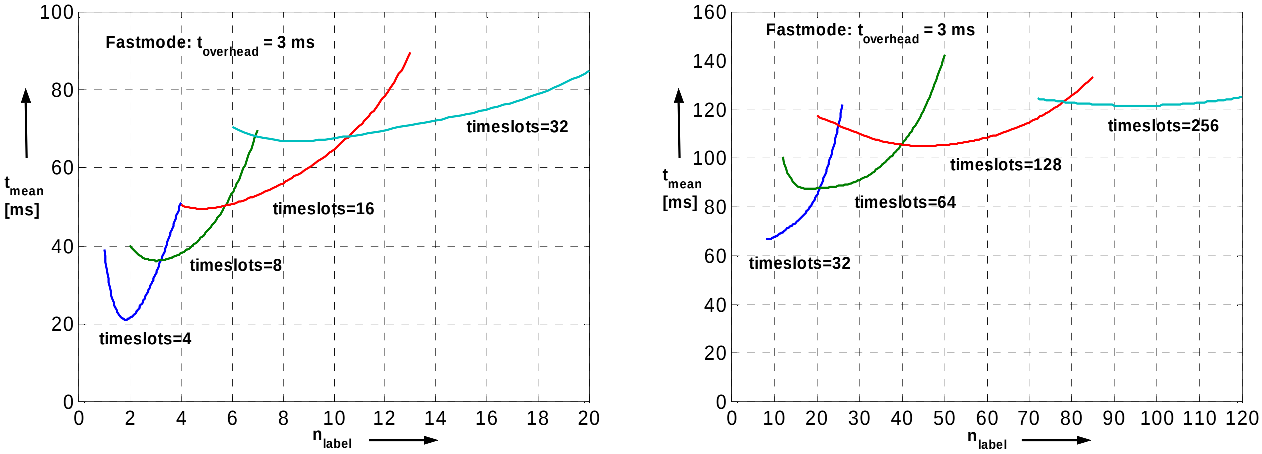

Figure 5-7: Mean access time for the ANTICOLLSION/SELECT command with t_{com} = 3ms

5.1.3 Command execution time for similar number of labels

In general, the number of labels is not constant. Often the variation of the number of labels is small. Then it is sufficient to take the mean number of labels to calculate the mean access time.

Note: For ANTICOLLISION/SELECT, the number of timeslots shall always be greater then the actual number of labels.

A more exact optimization is given when the distribution of the number of labels is known. The probability p_n that n labels are in the field has to be multiplied with the corresponding mean number of commands N_{com}. The mean access time is given by the sum of products multiplied with command access time.

$$t_{mean,all} = t_{com} \cdot \quad p_n \cdot N_{com}$$

<u>**Example:**</u>

Let's assume that 4, 5 or 6 labels are in the field at the same time. The reader send an UNSELECTED READ command with n_{read}=4 and $t_{overhead}$=40ms. The distribution of the number of labels should be:

p_4=0.2 for n=4 labels (20% probability of occurrence)
p_5=0.5 for n=5 labels (50% probability of occurrence)
p_6=0.3 for n=6 labels (30% probability of occurrence)

A first indication is given using the result for 5 label shown in Figure 5-4. It shows that the optimum should be 8 or 16 timeslots. The corresponding command time t_{com} is

timeslots	8	16
t_{com}	85.6ms	131ms

<u>Calculation for 8 timeslots</u>

The mean access number of commands N_{com} is (see Figure 5-1):

	n=4 labels	n=5 labels	n=6 labels
N_{com}	2.2	3.0	3.7
p_n	0.2	0.5	0.3
N_{com}* p_n	0.44	1.50	1.11

The complete mean access time is:

$$\begin{aligned} t_{mean,all} &= t_{com} \cdot \quad p_n \cdot N_{com} \\ &= 85.6\,ms \cdot (0.44 + 1.5 + 1.11) \\ &= 261\,ms \end{aligned}$$

<u>Calculation for 16 timeslots</u>

The mean access number of commands N_{com} is (see Figure 5-1):

	n=4 labels	n=5 labels	n=6 labels
N_{com}	1.6	1.8	2.2
p_n	0.2	0.5	0.3
N_{com}* p_n	0.32	0.90	0.66

The complete mean access time is:

$$
\begin{aligned}
t_{mean,all} &= t_{com} \cdot \quad p_n \cdot N_{com} \\
&= 131ms \cdot (0.32 + 0.9 + 0.66) \\
&= 246\,ms
\end{aligned}
$$

The UNSELECTED READ command with 16 timeslot is around 6 % faster then an UNSELECTED READ command with 8 timeslots.

5.1.4 Dynamic Adaptation of the number of timeslots

Some applications have a wide range of the number of labels in the field at the same time. For this kind of applications, the reader should be adapted to the number of timeslots. The reader needs a criterion to change the number of timeslots. This criterion could be the number of empty timeslots in relation to total number of timeslots N_{slot}. The mean number of empty timeslots N_0 as function of the number of label N_{label} can be calculated using the statistical theory:

$$
N_0 = \left(1 - \frac{1}{N_{slot}}\right)^{N_{label}} \cdot N_{slot}
$$

The relative number of empty timeslots N_0/N_{slot} as function of N_{label}/N_{slot} is shown in Figure 5-8. The superposition of the curves for the 8 possible numbers of timeslots depicts only a small difference for the relative number of empty timeslots.

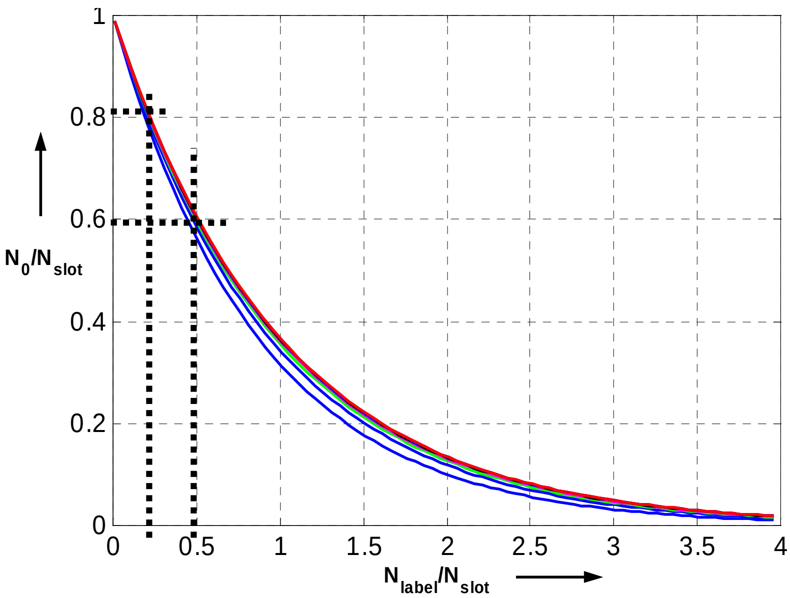

Figure 5-8: Number of empty timeslots

Thus, the relative number of empty timeslots can be used to estimate the number of labels that are currently in the field. E.g. if 60% of the timeslots are empty (N_0/N_{slot}=0.6), it can be assumed that the number of labels is 50% of the number of timeslots (N_{label} =0.5 * N_{slots}).

Example:

A simple rule for an optimisation is:

$N_{slot} > 2 * N_{label}$ -> $N_{label}/N_{slot} < 0.5$

Now, the upper threshold to increase the number of timeslots shall be (see Figure 5-8):

$N_0/N_{slot} = 0.6$

The next smaller number of timeslots is always half of the currently used number of timeslots. If

$N_{label}/N_{slot} < 0.25$

then the number of timeslot can be divide by 2 ($N_{slot,new} = N_{slot}/2$) because

$N_{label}/N_{slot,new} < 0.5$

fulfils the optimisation rule. Therewith, the lower threshold to decrease the number of timeslots is given by:

$N_0/N_{slot} = 0.8$

The number of timeslot can be adapted:

if $N_0/N_{slot} < 0.6$ increase the number of timeslots

if $N_0/N_{slot} > 0.8$ decrease the number of timeslots

5.1.5 Hashvalue

The timeslot calculation of each label is based on a pseudo random calculation with 8 bit initial value. The initial value is a section of the serial number (block0). The start bit address of the section is controlled by the command parameter *hashvalue.* Two labels with the same content of the serial number section respond always in the same timeslots. Thus the reader should changes the *hashvalue* to use different sections of the unique serial number. The *hashvalue* shall be changed on UNSELECTED READ and ANTICOLLSION/SELECT instruction The *hashvalue* starts with zero and follows the series:

0 8 16 24 4 12 20 28 2 10 18 26 6 14 22 30 1 9 17 25 5 13 21 29

3 11 19 27 7 15 23 31

and again with

0 8 16 24 …

This *hashvalue* adaptation can be used for the relevant commands UNSELECTED READ and ANTICOLLISION/SELECT.

5.2 Reader Module

5.2.1 Block diagram

The Figure 1-1 below shows the block diagram of the I•CODE1 reader module SL RM 900 (see [3],[4]). The microcontroller gets the instructions from a host computer via the serial interface. The controller is connected to an analogue interface. An optical coupling separates the DC voltages. The analogue interface contains a modulator including a 50 Ohm output driver and a demodulator unit. The microcontroller has digital outputs to generate the modulation pulses. The pulse width is adjustable. The output power and the modulation index can be adjusted by EEPROM controlled resistances. The absolute value is unknown. For measurement of the actual output voltage, a peak detector at the antenna output is connected to ADC input of the microcontroller. Hence, the reader is able to measure the output power and the modulation index. Due to tolerances of the absolute voltages, the output power measurement using the ADC has to be calibrated by a reference measurement. The relative modulation index does not need a calibration.

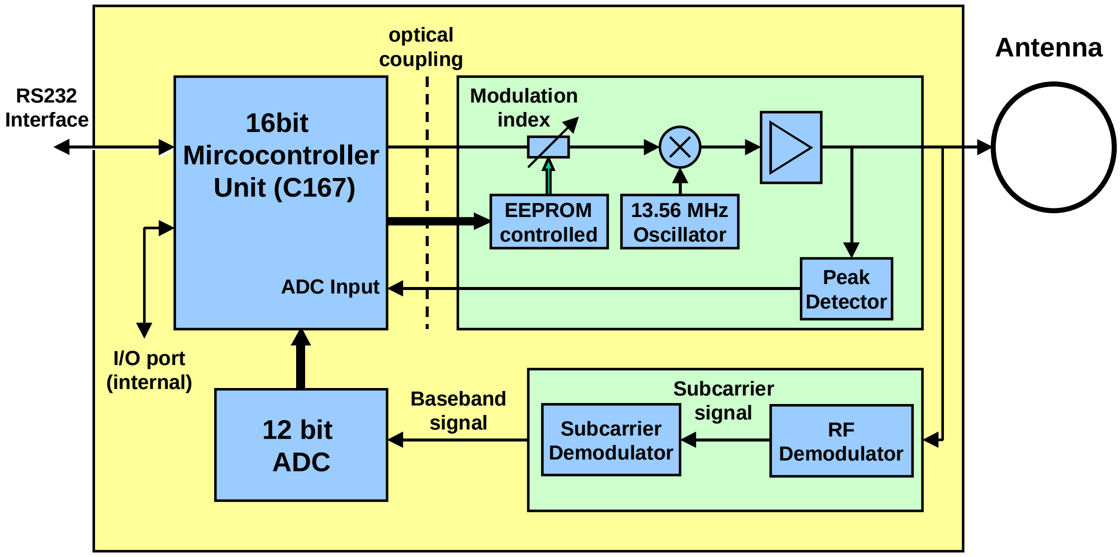

Figure 5-9: Reader module block diagram

The demodulation is made in two steps. First, a bandpass filter separates the upper side band of the antenna voltage and a posted demodulator delivers the modulated subcarrier signal. Second, this subcarrier signal is converted to the baseband signal. The 12 bit ADC converts the baseband signal to a digital signal with a sample rate of 211.9 kHz (8 sample per data bit). The microcontroller evaluates the samples using digital signal processing algorithms.

5.2.2 Weak Collision

The next figures show the principle of the collision detection. When two labels respond on a reader command in the same timeslot, the data modulation of both labels is superposed. A data bit "0" produces a modulation of eight subcarrier periods during the first half date bit frame. A data bit "1" produces a modulation of eight subcarrier periods during the second half date bit frame. The reader is able to detect the data bits only if the bits of both labels are equal. Otherwise the reader decodes a subcarrier signal in the complete data bit frame. This case is called as "bit collision". Thus, a collision can be detected only if the data from the labels are different. The transmission of their unique serial numbers (ANTICOLLISION/SELECT and UNSELECTED READ of block 0) guarantees at least one different data bit and therefore a detection of a collision.

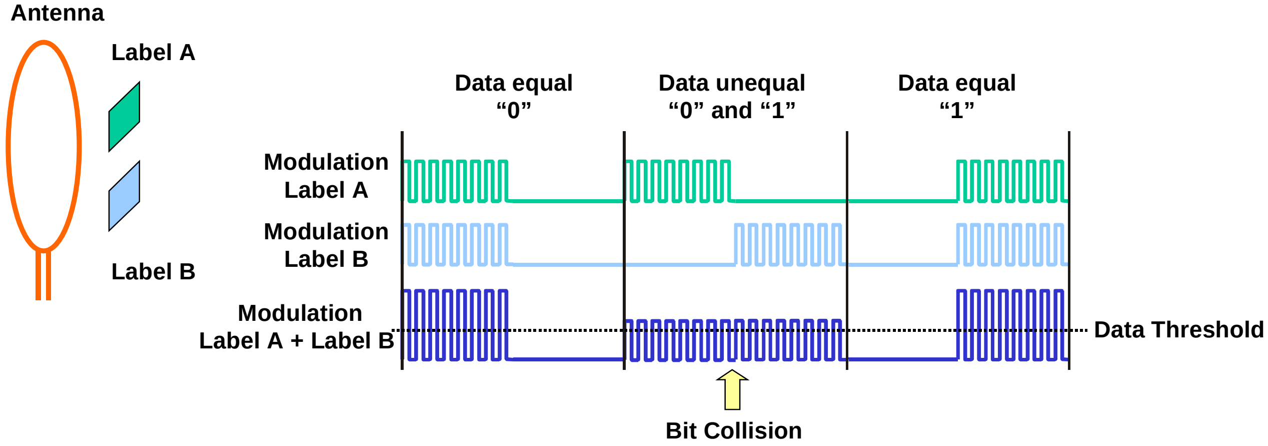

Figure 5-10: Detection of Collisions

This is particularly necessary for the ANTICOLLISION/SELECT command to avoid a selection of one or more labels in the same timeslot. The Figure 5-10 depicts a "strong" collision when the labels have the same distance to the reader antenna. A week collision is given in case that one label is much closer to the reader antenna. The received modulation depth is different (see Figure 5-11). With a Data Threshold in the middle of the data signal, the reader is able to decode the data from label A. The reader is also able to detect a weak collision using a lower weak collision threshold. The next chapter contains a detailed description of the weak collision including noise.

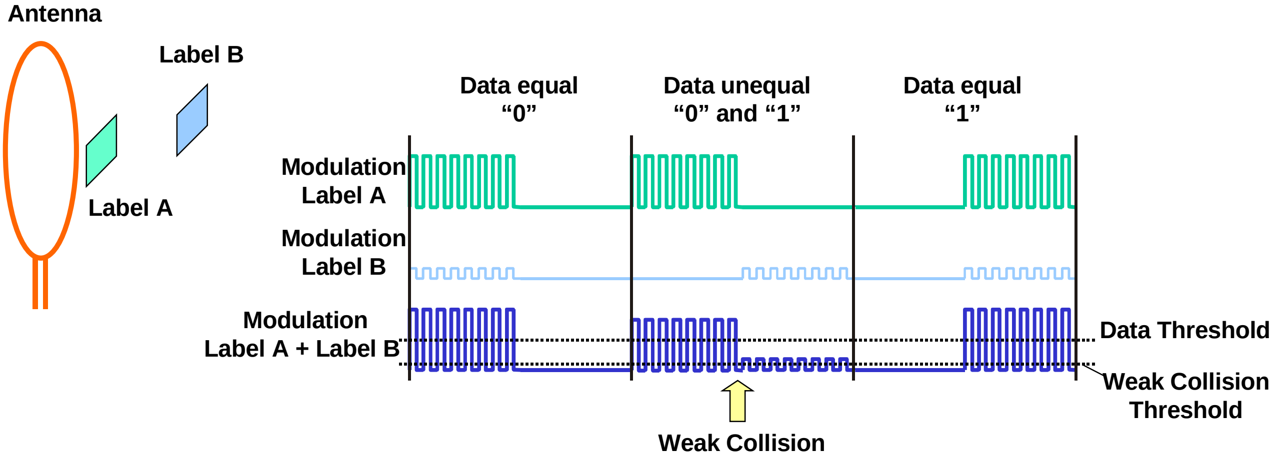

Figure 5-11: Detection of Weak Collisions

5.2.3 Data decoding

The upper diagram in Figure 5-12 displays the modulation signal of one single bit. It is superposed by additional noise. The lower diagram shows the corresponding baseband signals (analogue demodulator output). The baseband noise signal can be described by 3 parameter: The average, maximum and minimum noise levels. These noise levels can be measured when no data signal is present. The reader module SL RM 900 is able to measure the noise levels controlled by the host computer or automatically before each command transmission.

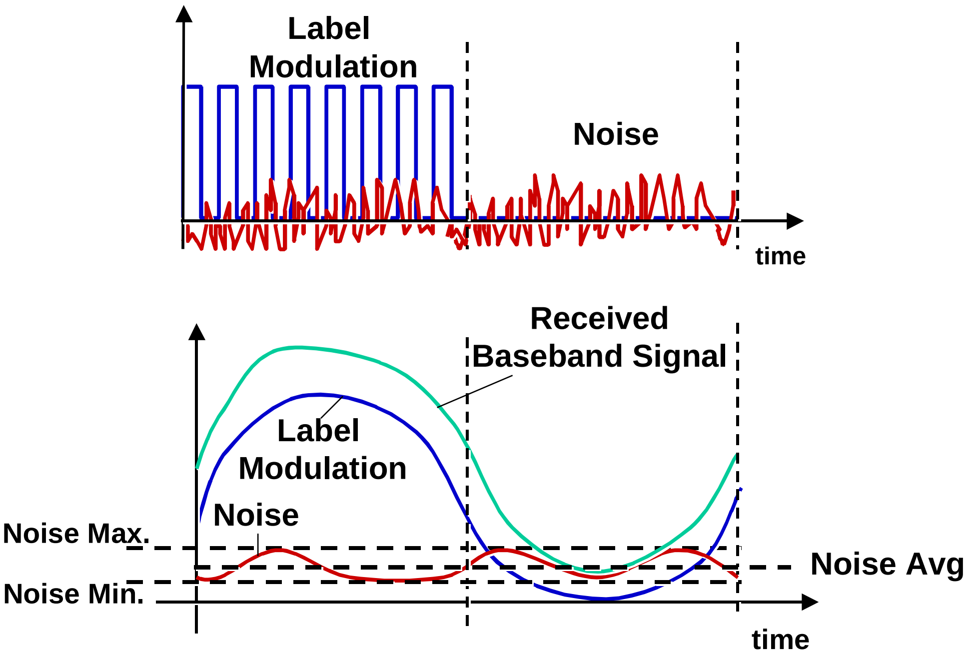

Figure 5-12: Baseband Noise Levels

These noise levels are used to determine the Bit Thresholds, the Noise Threshold and the Collision Thresholds. The Figure 5-13 shows the principle of the data recognition. The baseband signal is sampled 8 times per data bit. The symbol d_1 denotes the average value of the first four samples. The symbol d_2 denotes the average value of the second half bit. The vertical bars in Figure 1-1 indicate these average values.

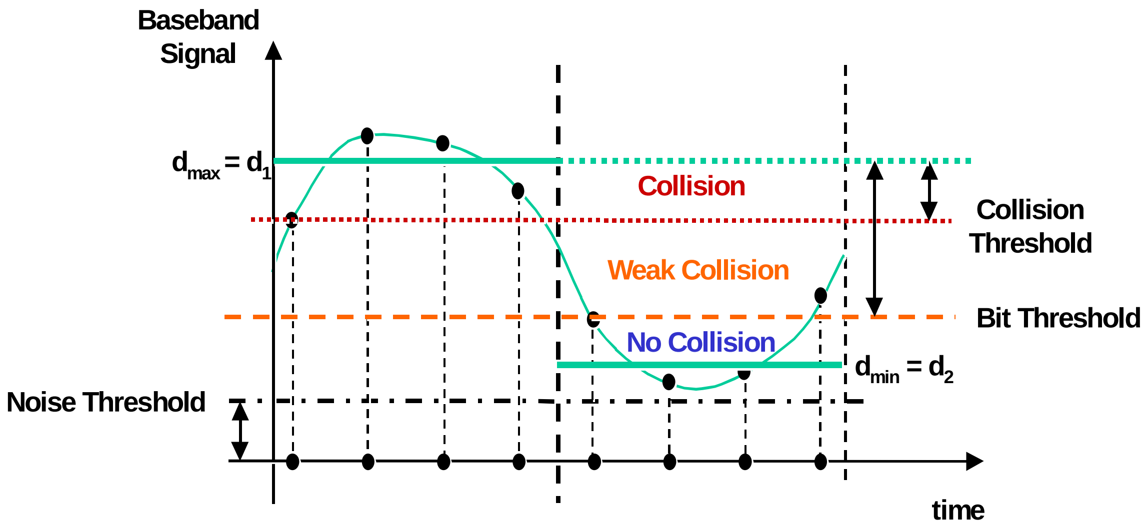

Figure 5-13: Data recognition

The reader signals “no label” if d_1 and d_2 below the Noise Threshold. A collision is detected if the difference $|d_1\text{-}d_2|$ is less than Collision Threshold. If the difference $|d_1\text{-}d_2|$ is greater than Collision Threshold the data bit can be recognised:

data bit = “1”   if $d_1 > d_2$

data bit = “0”   if $d_2 > d_1$

The reader signals a “weak collision” if the difference $|d_1\text{-}d_2|$ is less than the Bit Threshold and greater than Collision Threshold.

The reader module SL RM 900 has automatic calculation of the Thresholds. The Noise Threshold is slightly set above maximum noise level. On one hand, this Collision Threshold should be as low as possible to get high demodulator sensitivity. One the other hand, the data signal has to be distinguished from noise signal. The reader module SL RM 900 uses the noise level difference to adapt the Collision Threshold and also the Weak Collision Threshold. The greater the noise level difference is the greater the Collision Thresholds are set.

The reader module SL RM 900 allows continuos noise measurement. The adaptation of collision threshold gives the optimum demodulator sensitivity (please refer to [3]).

5.2.4 Baseband signal for Weak Collision and Noise

The reader calculates a "Bit Threshold" as a function of the noise levels. Assuming that only label A modulates a data bit "1". The corresponding baseband signal has a high level in the first half of the data bit frame. The level in the second half touches the zero line. Additional noise shifts the curve by the noise level. But the level in the second half drops below the bit threshold. A second label B should produce a data bit "0" modulation with a lower amplitude. The sum of the label A and label B baseband signal and the noise result in a baseband signal, which is always above the "Bit Threshold". Even the reader is able to detect the data of label A (stronger modulation).

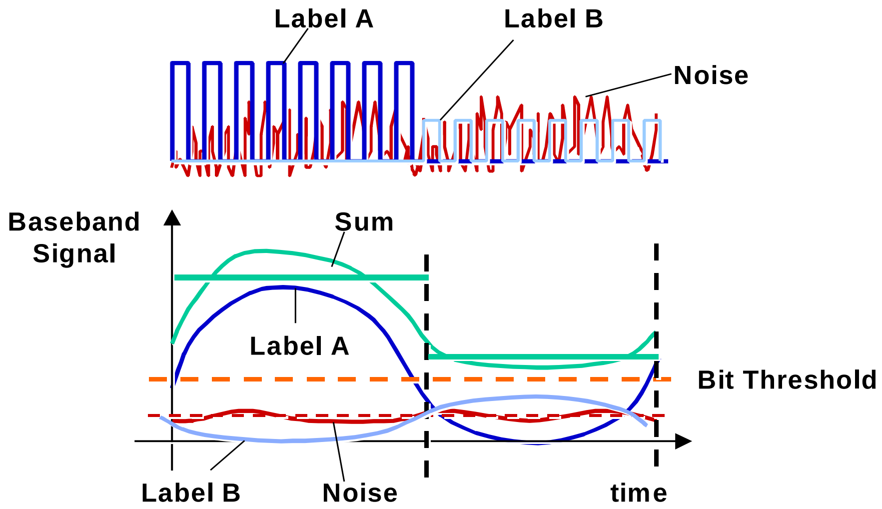

Figure 5-14: "Bit Threshold" and Weak collision

The Figure 5-15 shows a special case. The modulation of label B produces a baseband signal, which is below the noise level. Then the resulting baseband signal drops below the "Bit Threshold". The reader can not detect a weak collision although two labels respond in the same timeslots.

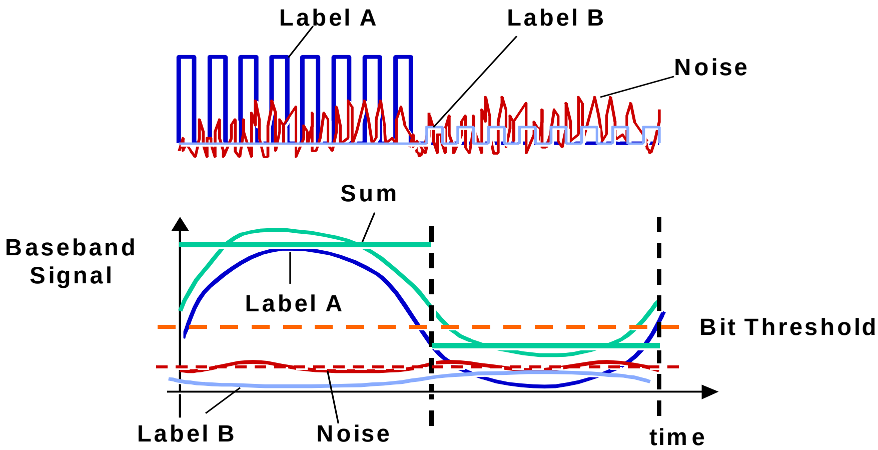

Figure 5-15: No detection of weak collision

This is critical for an ANTICOLLSION/SELECT in combination with WRITE BLOCK command. The reader selects both labels in the same timeslot when both labels expect the same QUIT value. If the QUIT for a further WRITE BLOCK is identical, the reader writes data in both labels. The reader is able to write data into label B but the reader is not able to read data from label B. This undesired behaviour can be avoided if the reader is adjusted so that the read distance is greater than the write distance (e.g. by power reduction, antenna coil shape…). In the case that it is impossible to design a reader with greater read distance the probability that undesired writing of data into a "unreadable" label can be minimised by using different hashvalues for ANTICOLLSION/SELECT and WRITE BLOCK.

5.2.5 Demodulator saturation influence

When a label is very close to the antenna, the demodulation amplifier operates in the non-linear saturation range. The Figure 5-16 shows a typical saturation influence. The baseband signal gets a virtual offset. The lower average value d_2 moves above the "Bit Threshold". The reader indicates always a weak collision although only one label responds in this timeslot. For the UNSELECTED READ, the reader signals a weak collision but data can be read.

Usually, it is not allowed to select the label on weak collision. The selection of the label is only allowed if the user really knows that the weak collision is caused by the saturation effect. The reader module SL RM 900 is able to ignore the weak collision for the ANTICOLLSION/SELECT.

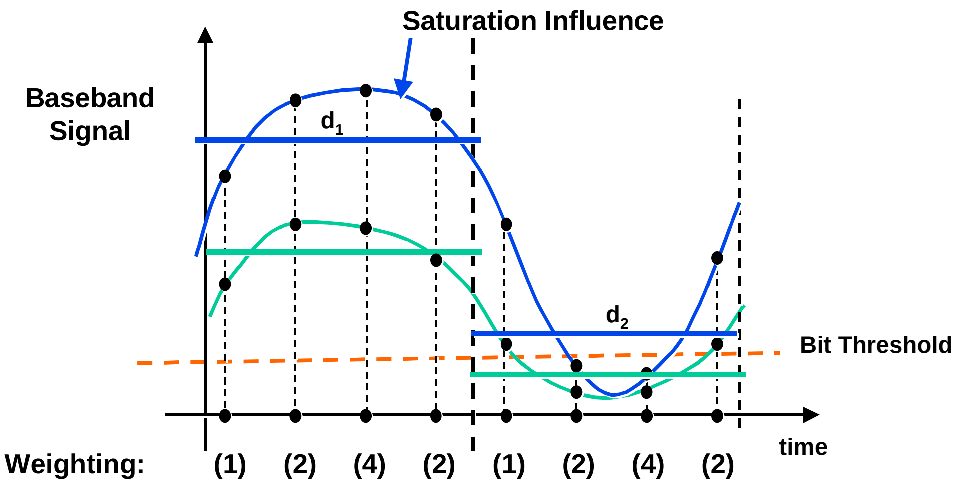

Figure 5-16: Demodulator saturation

5.2.6 Noise Level Measurement, Spurious spikes

The reader demodulator sensitivity is depends on the Noise Threshold. On each noise level measurement, the Noise Threshold is slightly set above maximum noise level (see chapter 5.2.2). If spurious spikes superpose the noise, the reader measures higher noise levels and the Noise Threshold is set to a higher value. This reduces the receiver sensitivity.

The Figure 5-17 shows that the pure noise yields a noise average level approximately in the middle between the maximum and minimum levels. With spurious spikes the noise average value is much closerto the minimum noise level. Thus spurious spikes can be detected on significant asymmetrical noise levels (see Figure 5-17).

To avoid, that spurious spikes reduce the receiver sensitivity, the noise level measurement shall be repeated until the noise levels are approximately symmetrical.

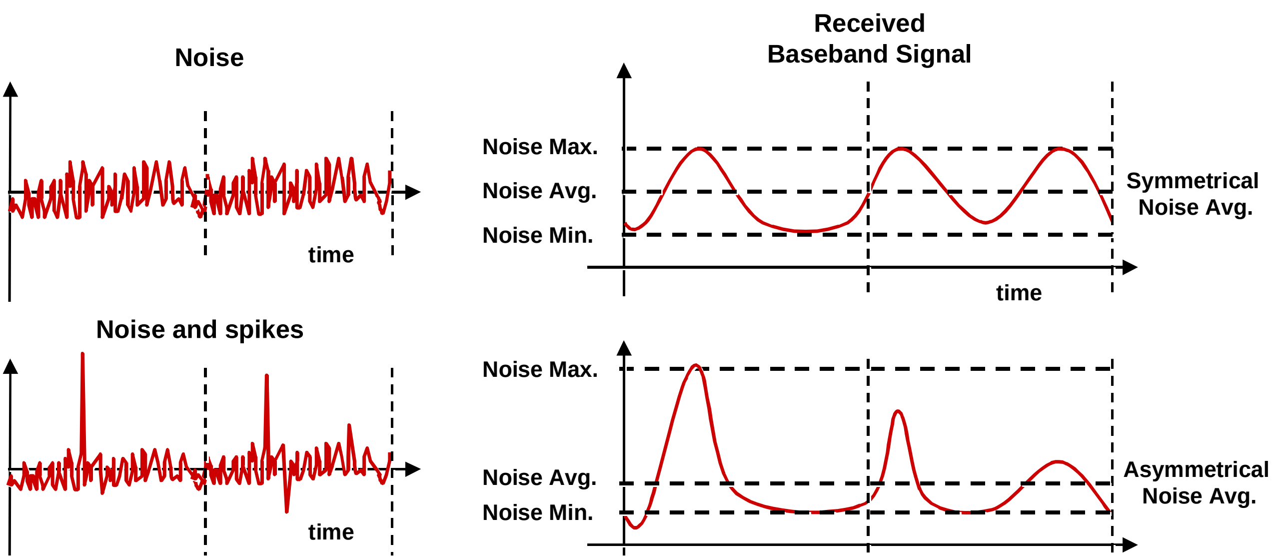

Figure 5-17: Spurious spikes and baseband signal

5.3 System Command Sequence

5.3.1 Classification

General guidelines for system implementations can be given on the following classification.

Classification depending on the number of labels:

a) Single label applications (e.g. handheld reader):
Only one label is in the field. The reader uses only one timeslot. The hash value has no effect. Collisions and weak collisions are not possible. The weak collision caused by the demodulator saturation can be ignored.

b) Multi label applications (gate antenna):
Several labels are in the field. The reader defines the number of timeslots. A simple rule: The number of timeslots should be twice the expected number of labels. An optimisation of the number of timeslots is described in chapter 5.1. The hash value should be changed with each reader command (see chapter 5.1.5). When using the WRITE BLOCK command, the “ignore weak collision” reader configuration is not allowed.

Another functional classification is the separation into “read only” and “read/write” applications:

a) “Read Only EAS”:
The EAS function is a read only command. All labels respond synchronously with the same EAS pattern without any data collision. It is not required to distinguish the labels. The reader gives an EAS alarm if a EAS pattern is detected.

b) “Read Only”:
Usually a “read only” system uses only the UNSELECTED READ. The identification of the labels requires that all labels can be distinguished on their response, e.g. if the unique serial number is read from block 0.

c) “Read / Write”:
Before performing the write command, the labels have to be selected. The reader repeats the ANTICOLLSION/SELECT until a proper number of the labels have been selected. Then WRITE BLOCK writes a complete data block into the label. A SELECTED READ can be use to verify the written data. If all data are written, the reader forces the selected labels into the halt mode. Now the next group of labels can be selected. A typical command sequence is given in the example below.

5.3.2 “Read/Write” command sequence example

The figure below shows the timing of this command sequence with 7 labels and 8 timeslots.

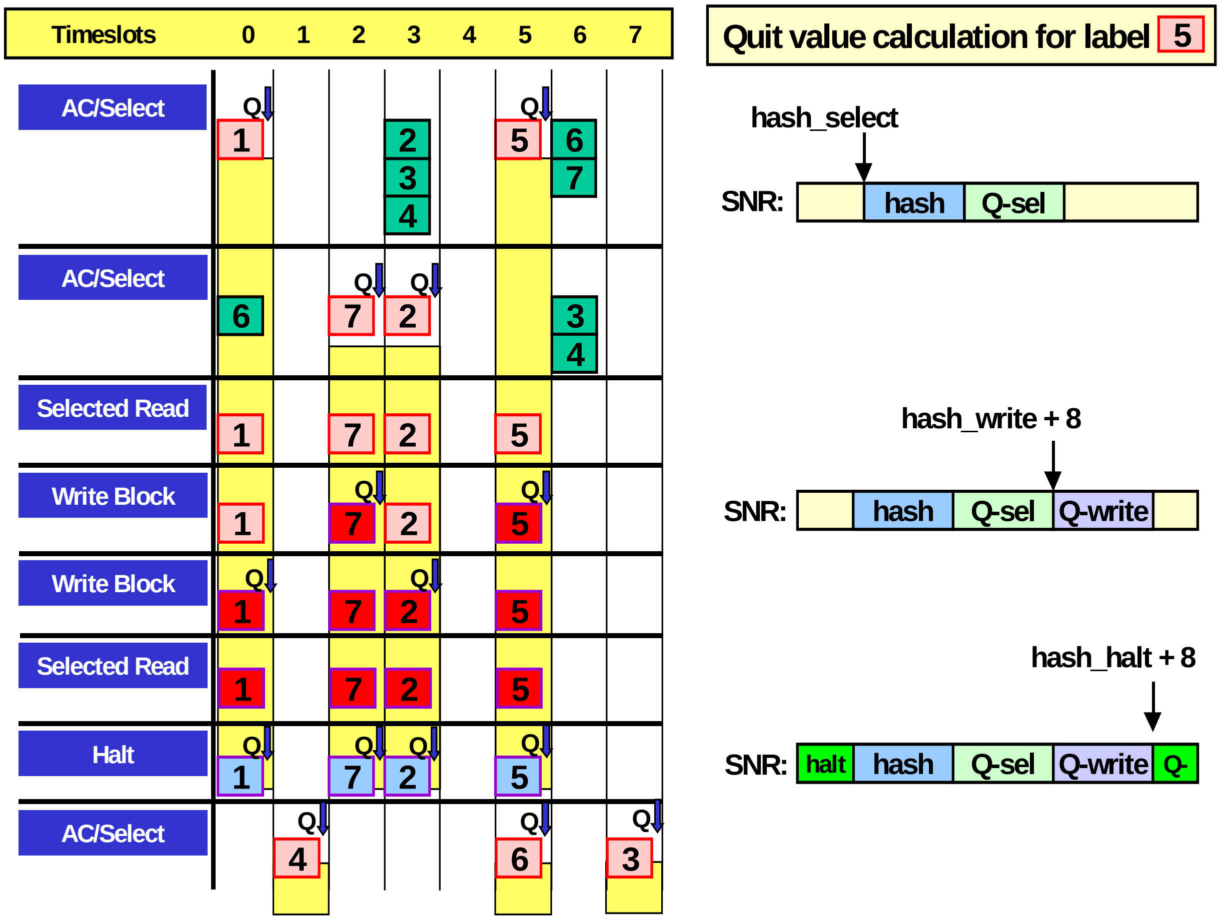

Figure 5-18: Command Sequence and Quit value influence

1. ANTICOLLSION/SELECT:
   The reader sends an ANTICOLLSION/SELECT and the labels respond with their serial number in the timeslots 0 to 7. The hash value is set to 6. Thus the timeslot position of label 5 depends on the serial number bit 6 to bit 13 (hash). The reader receives the serial number of label 2 in timeslots 0 and label 5 in timeslots 5. The reader sends a QUIT value immediately after the serial number. For label 5, the QUIT value is given by serial number bit 14 to 21 (Q-sel). The timeslots 0 and 5 are allocated to label 1 and label 5. The timeslots 1, 2, 4 and 7 are empty. In timeslots 3 and 6 the reader detects a collision. The reader detects 50% empty timeslots and decides to send another ANTICOLLSION/SELECT command.

2. ANTICOLLSION/SELECT:
   Only the unselected labels 2, 3, 4, 6, 7 respond to the second ANTICOLLSION/SELECT. The hash value is changed (see chapter 5.1.5). The reader reads the serial number of label 6, 7 and 2 in timeslots 0, 2 and 3. The labels 7 and 2 can be selected in timeslot 2 and 3. The label 6 is not selected because timeslots 0 is already allocated by label 1. The three timeslots 1, 4 and 7 are empty. Now the empty rate is lower the 50% and the reader decides to perform the write operations with the Label 1 in timeslot 0, label 7 in timeslot 2, label 2 in timeslot 4 and label 5 in timeslots 5.

3. SELECTED READ:
   The reader reads the data of the selected label. The label responds in the allocated timeslots.

4. WRITE BLOCK:
   The reader sends the WRITE BLOCK instruction with a hash value of 14 and all selected labels respond their serial number in the allocated timeslots. The data block is written into the memory of label 7 and 5 by sending the QUIT immediately after the serial number. The serial number bit 22 to 29 (Q-write) is used to calculate the QUIT value. 24 bits of the unique serial number are involved up to the write instruction.

   Note: In the previous chapter 5.2.4 was explained that is possible to have a label far from the antenna. The label is able to receive the reader instruction, but the data transmission to reader is below the noise level. The reader doesn't recognise this label. If a label near to the antenna has the same 24 bit of the serial number, then the label, which is far from the antenna, follows the exactly commands to the label, which is near to antenna. The same data are written in both labels. This undesired writing has a probability less than 1: 16 Million ($1:2^{24}$).

5. WRITE BLOCK:
   Another data block is written into label 1 and 2.

6. HALT:
   The reader sends a HALT command with a hash value 22. All selected labels are set into the Halt mode because the reader sends the Quit value to all selected labels. The bit 30 to bit 5 of the serial number (Q-halt) is used to calculate the individual QUIT value.

7. ANTICOLLSION/SELECT:
   The label 1, 2, 5 and 7 are in the "Hold" mode. Thus only label 3, 4, and 6 are involved in further communications. Now the reader repeats the complete sequence to write the data into the remaining labels.

6 REFERENCE LIST

[1] Data Sheet: SL1 ICS30 01 - I•CODE1 Label IC
Chip Specification

[2] Data Sheet: SL1 ICS30 01 - I•CODE1 Label IC
Protocol Air Interface

[3] Data Sheet: SL RM900 - I•CODE1 Long Range Reader Module
Protocol Reader to Host

[4] Data Sheet: SL RM900 - I•CODE1 Long Range Reader Module
Hardware

[5] Application Note: I•CODE Label IC
Coil Design Guide

[6] Application Note: I•CODE
Design of Read/Write Antennas

A. APPENDIX: QUIT VALUE CALCULATION

The table below contains all possible QUIT values in hexadecimal notation. SNR8 is the part of the serial number (8 bit).

SNR8	Quit	SNR8	Quit	SNR8	Quit	SNR8	Quit	SNR8	Quit	SNR8	Quit	SNR8	Quit	SNR8	Quit
00	23	20	0D	40	7F	60	51	80	9B	A0	B5	C0	C7	E0	C7
01	47	21	69	41	1B	61	35	81	FF	A1	D1	C1	A3	E1	A3
02	EB	22	C5	42	B7	62	99	82	53	A2	7D	C2	0F	E2	0F
03	8F	23	A1	43	D3	63	FD	83	37	A3	19	C3	6B	E3	6B
04	C2	24	EC	44	9E	64	B0	84	7A	A4	54	C4	26	E4	26
05	A6	25	88	45	FA	65	D4	85	1E	A5	30	C5	42	E5	42
06	0A	26	24	46	56	66	78	86	B2	A6	9C	C6	EE	E6	EE
07	6E	27	40	47	32	67	1C	87	D6	A7	F8	C7	8A	E7	8A
08	90	28	BE	48	CC	68	E2	88	28	A8	06	C8	74	E8	74
09	F4	29	DA	49	A8	69	86	89	4C	A9	62	C9	10	E9	10
0A	58	2A	76	4A	04	6A	2A	8A	E0	AA	CE	CA	BC	EA	BC
0B	3C	2B	12	4B	60	6B	4E	8B	84	AB	AA	CB	D8	EB	D8
0C	71	2C	5F	4C	2D	6C	03	8C	C9	AC	E7	CC	95	EC	95
0D	15	2D	3B	4D	49	6D	67	8D	AD	AD	83	CD	F1	ED	F1
0E	B9	2E	97	4E	E5	6E	CB	8E	01	AE	2F	CE	5D	EE	5D
0F	DD	2F	F3	4F	81	6F	AF	8F	65	AF	4B	CF	39	EF	39
10	34	30	1A	50	68	70	46	90	8C	B0	A2	D0	D0	F0	D0
11	50	31	7E	51	0C	71	22	91	E8	B1	C6	D1	B4	F1	B4
12	FC	32	D2	52	A0	72	8E	92	44	B2	6A	D2	18	F2	18
13	98	33	B6	53	C4	73	EA	93	20	B3	0E	D3	7C	F3	7C
14	D5	34	FB	54	89	74	A7	94	6D	B4	43	D4	31	F4	31
15	B1	35	9F	55	ED	75	C3	95	09	B5	27	D5	55	F5	55
16	1D	36	33	56	41	76	6F	96	A5	B6	8B	D6	F9	F6	F9
17	79	37	57	57	25	77	0B	97	C1	B7	EF	D7	9D	F7	9D
18	87	38	A9	58	DB	78	F5	98	3F	B8	11	D8	63	F8	63
19	E3	39	CD	59	BF	79	91	99	5B	B9	75	D9	07	F9	07
1A	4F	3A	61	5A	13	7A	3D	9A	F7	BA	D9	DA	AB	FA	AB
1B	2B	3B	05	5B	77	7B	59	9B	93	BB	BD	DB	CF	FB	CF
1C	66	3C	48	5C	3A	7C	14	9C	DE	BC	F0	DC	82	FC	82
1D	02	3D	2C	5D	5E	7D	70	9D	BA	BD	94	DD	E6	FD	E6
1E	AE	3E	80	5E	F2	7E	DC	9E	16	BE	38	DE	4A	FE	4A
1F	CA	3F	E4	5F	96	7F	B8	9F	72	BF	5C	DF	2E	FF	2E

QUIT value calculation C – Program

```
#include <stdio.h>

/**********************************************************/
/*****  FUNCTION CRC8fun                         *********/
/**********************************************************/
/*****  INPUT:  in      8 bit crc8  input        *********/
/*****          preset  8 bit crc8  preset       *********/
/**********************************************************/
/*****  RETURN: 8 bit crc8 calculation with      *********/
/*****          a generator polynom B8 (hex)     *********/
/**********************************************************/

unsigned char crc8fun(unsigned char in,unsigned char preset)
{
  int loop;
  unsigned char out;
  const unsigned char crc_pol=0xb8; /* generator polynom   */

  out=in^preset;                            /* preset xor */

  for(loop=0; loop<8; loop++)      /* crc8 calulation loop */
  {
    if (out&0x0001) { out = (out>>1) ^ crc_pol;}
    else            { out = (out>>1);}
  }

  return out;
}

/**********************************************************/
/***** Main Program I-CODE QUIT value calculation *********/
/**********************************************************/

void main(void)
{
  int snr_8;                /* 8 bit serial number section */
  unsigned char crc_res;
  const unsigned char quit_preset=0xff;     /* QUIT preset */

  printf("\n\n|------|------|\n");         /* table header */
  printf(    "|  SNR | QUIT |\n");
  printf(    "|------|------|\n");

  for(snr_8=0; snr_8 < 256; snr_8++)
  {
     crc_res=crc8fun((unsigned char)snr_8,quit_preset);
     printf("|  %02X  |  %02X  |       \n",snr_8,crc_res);
     printf("press <ESC> to quit\r");    /* keyboard input */
     if (getch()==0x1b) break;           /* continue/abort */
  }
}
```

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