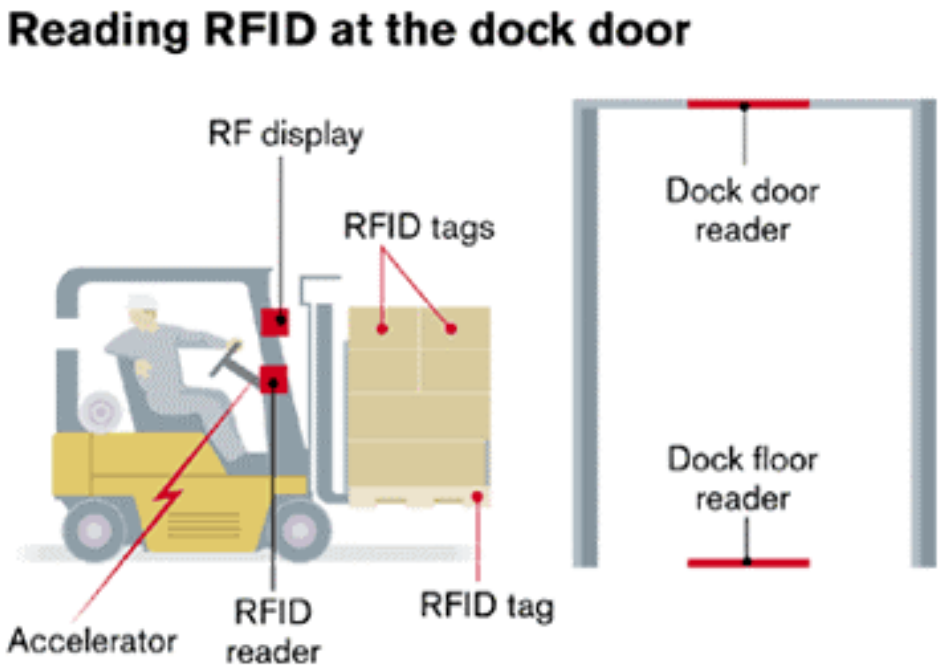
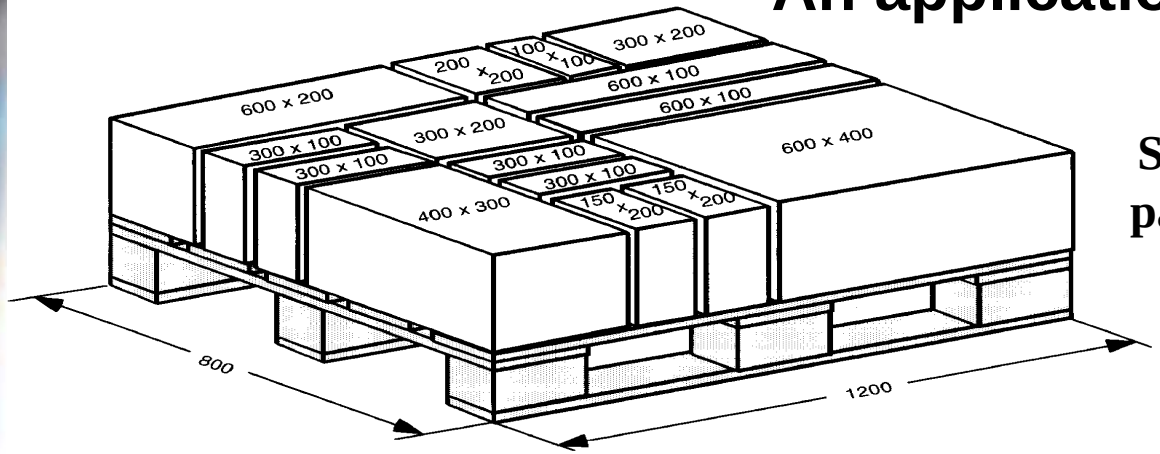
UHF RFID protocols-



Targeting increased application requirements

Speaker: Ulrich Friedrich, Atmel

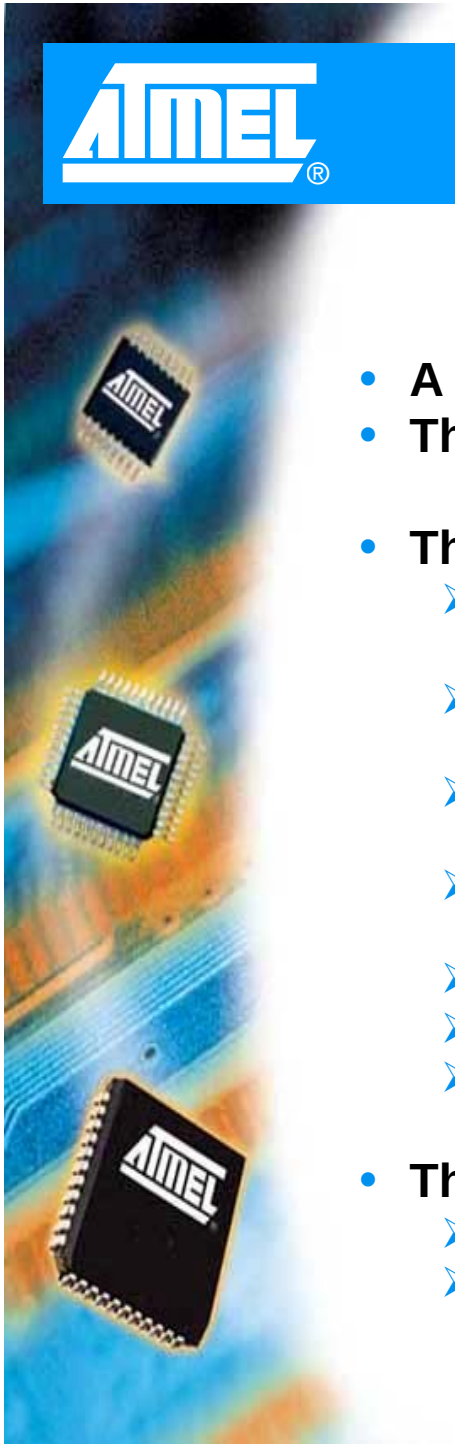
An application scenario



Summary of different packaging sizes related to pallets

- **A collection of tags containing an ID is moving on a pallet**
  - **There are for example *2 pallet tags, up to 500 case tags, up to 2000 inner pack tags and up to 12000 item* tags on a full pallet (one of the EPC scenarios)**
  - **The pallet is moving with up to 20 km/h through a dock door**
  - **There are many dock doors close together**
    - ***The fork lift is driving from door to door***
    - **It is cold -20 degree Celsius**
- **The communication shall be wireless**
- **Time is money**

What is required by (basic?) application(s)?



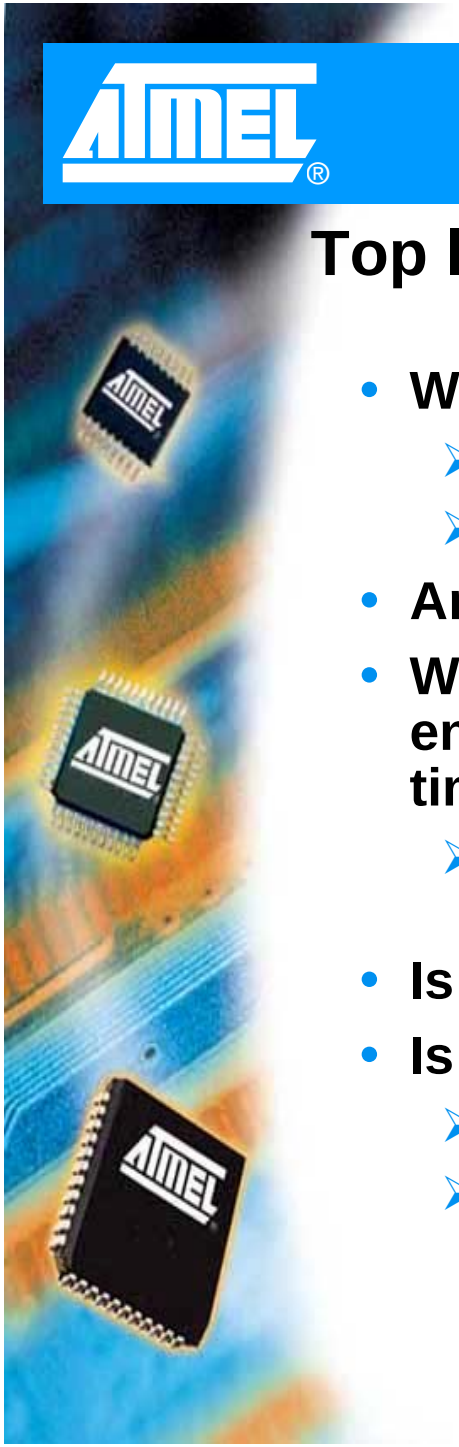
- A protocol shall enable cheap solutions
- The implementation shall enable an added value

- The protocol implementation shall work 100% ☹
  - every time and anywhere (it is a wish!!!)

  - Read of an information (ID number,.,..) stored on a tag
    - placed on a pallet, ….
  - Program of an information on the chip
    - over a long distance?
  - Basic encryption possibility NEW
    - To hide forward transmitted information
  - Interrupt level(s) within singulation procedures NEW
  - Hide function for tags (access) (required for drugs,…) NEW
  - Kill (it was defined in such a way) NEW

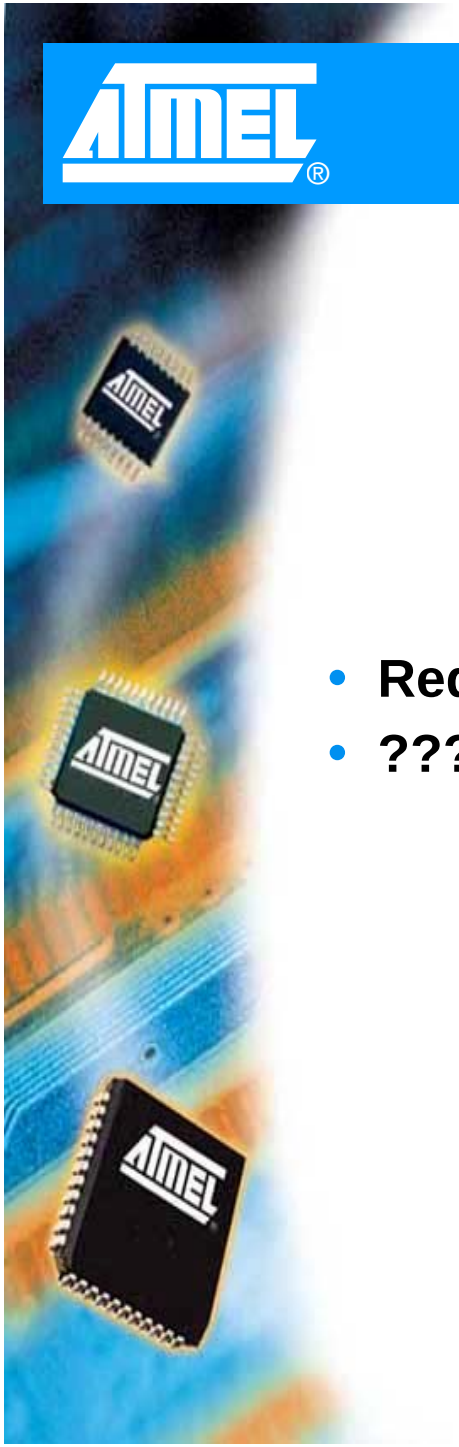
- The protocol shall be public
  - Open standard like a de facto standard (EAN/UCC, …)
  - ISO registered standard

Top level questions related to the needed protocol

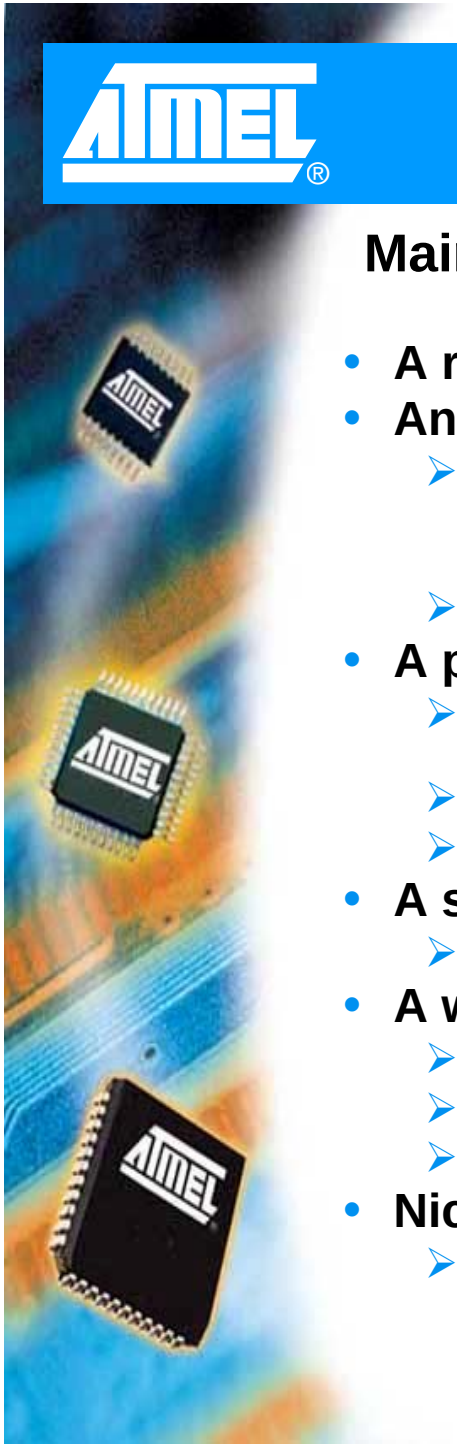


- Which kind of tags shall be identified ?
  - Is it so important to get all tags?
  - Priority: pallet -> case -> inner pack cases -> items
- Are there any limitations given by RF regulations? *(A4)*
- What is the required TX power for the reader which enables a 100 % possibility to power a tag for a certain time frame? *(A4)*
  - The system shall be able to address the last tag in the middle of the pallet !!!!
- Is the allowed RFID system able to do this job?
- Is the protocol usable also in other countries?
  - Because I want to send this pallet to ....
  - They have to check the pallet, too.

Questions to the audience



- **Required effective data rate?????**
- **????????**



Main properties for a protocol targeting such applications ?

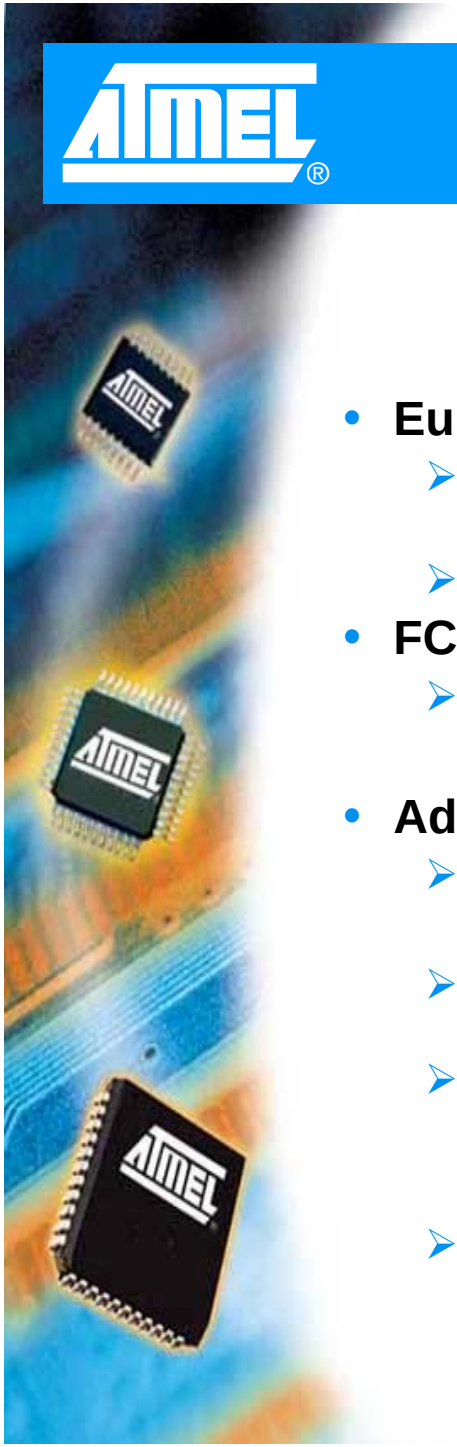
- A really world wide accepted protocol NEW
- An open and public standard which defines the basics
  - Open:
    - Anyone can use it
    - Enabling diversification to upper levels
  - Public industrial standard
- A possibility to address a single tag out of several
  - An arbitration which is able to detect “any” number of tags in a short time
  - Interrupt level(s) NEW
  - A function enabling a multi dock door scenario NEW
- A select mechanism to select the package level
  - dynamic priority during arbitration
- A write and a read possibility for an ID or other data
  - Which kind of ID?
  - Programmable length of the ID
  - Truncated read NEW
- Nice to have:
  - A possibility to write several tags at once (same data portion)
    - Parts of the ID, like ID length, AFI, DSFID, manufacturer ID, ….

Requirement for an air interface description considering power effects *(A6, A7)*

- Due to power gaps moving tags are sometimes not powered by the field
  - Therefore, a tag shall be able to hold the select status over a defined time to skip power gaps.
- This status info is stored as a persistent node on chip
- The information storage over time depends on
  - Temperature (leakage current, 9 degree rule)
- Protocol solutions
  - Not specified (ISO 18000-6) ☹
  - Between 500 ms @ 60 C and 2 sec @ - 40 C (Class1Gen2) ☺

Protocol requirements and solutions to address different RF regulations *(A8, A9, A10)*

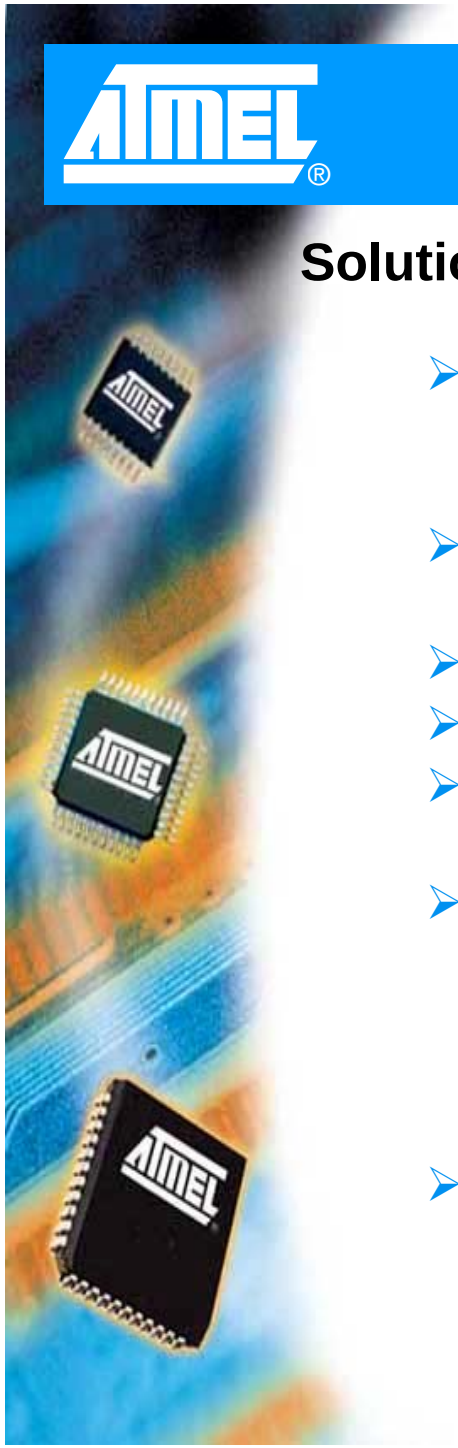
- **Requirement**
  - **Possibility to tune the spectrum**
- **Solutions**
  - **Traditional AM modulation (DSB-ASK)(ISO 18000-6 and class0, class0)**
    - **Reduction of the modulation index ☹**
      - **The feasibility of the tag to distinguish between noise and real signal decrease**
      - **Power of the side band decrease ☺ and power to the tag ok ☺**
    - **Modulation index = 1**
      - **Power transport is worst case ☹**
      - **Robustness against other services: top ☺**
  - **Other types of AM modulation**
    - **DSBM (Palomar) = DSB-SC = PR-ASK (Class1Gen2) ☺ ☺**
      - **Best power transport combined with m = 1**
      - **Half of bandwidth relative to traditional AM**
    - **“SSB” (Class1Gen2)**
      - **Advantage in bandwidth ☺**



Influence of the RF regulations and challenges for the backscatter stream (A11, A12,)

- **Europe: In band is required**
  - **Necessary bandwidth rule ☹**
    - **Not related to a power mask level**
  - **In channel also required in Europe ☹**
- **FCC**
  - **“no” limitation as long as it is below the power mask**

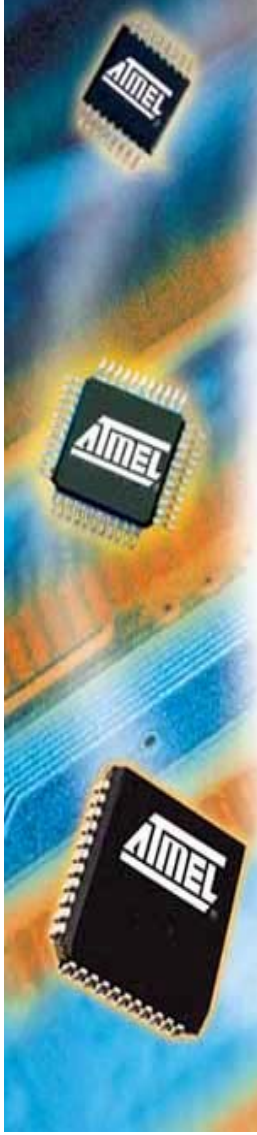
- **Additional challenge**
  - **long range means also low RX power on reader side**
    - **100 dB is a real challenge ☹**
  - **Monitors, neon light, electronic controlled neon light; they are backscattering a modulated carrier, too. ☹ ☹**
  - **Other noise sources (cell phone, etc.) ☹ ☹**
    - **Allowed spurious emissions in Europe -54 dBm (SRD’s)**
    - **-36 dBm (phones) ☹ ☹**
  - **The power of the receivable backscatter stream can be less**



Solution for the backscatter link within Class1Gen2 *(A13, A14)*

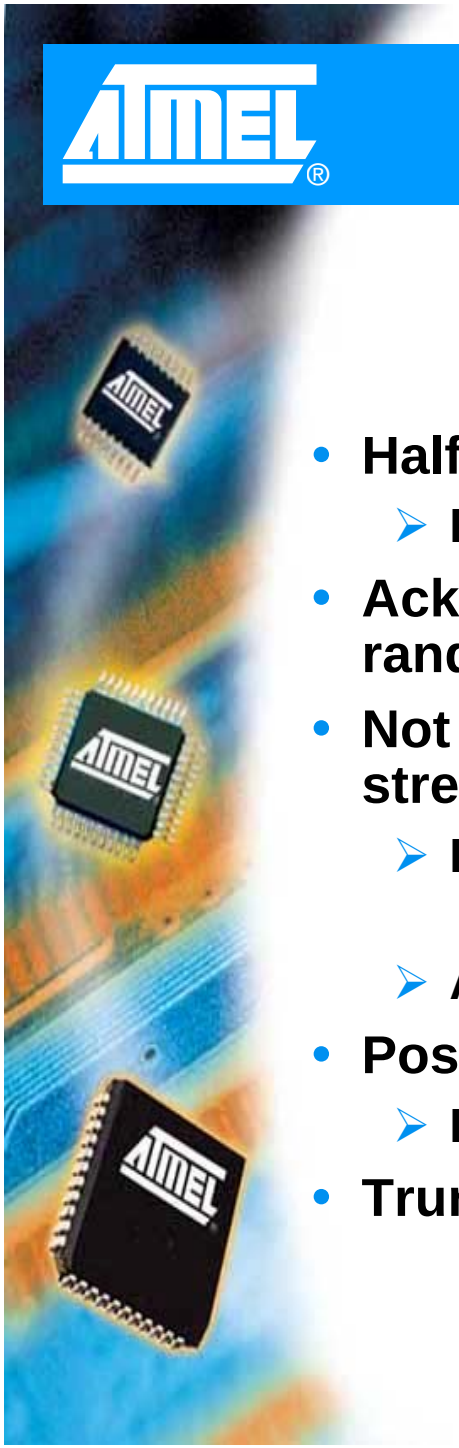
- Data rate 20 kbit/s to 640 kbit/s
  - Enabling spectrum management (similar to Palomar)
  - Former ISO and Auto-ID solutions around 40 kbit/s
- ASK or PSK ☺
  - Former only ASK
- Asynchronous backscatter link
- Half duplex communication is default communication style
- Base band encoding (FM0) (Europe)
  - Close to the carrier (max 640 kHz) ☹
- Class1Gen2: Miller encoded sub carrier ☺
  - The primitive contains 2 to 8 modulation swings per bit
  - FFT ?
  - Linear prediction method for detection is possible
  - Close to the carrier (max 640 kHz) ☹
- long and short preamble
  - To enable different reader implementations ☺
  - If the environment is very noisy (synchronization) ☺ ☺

Master slave arbitration types *(A15)*



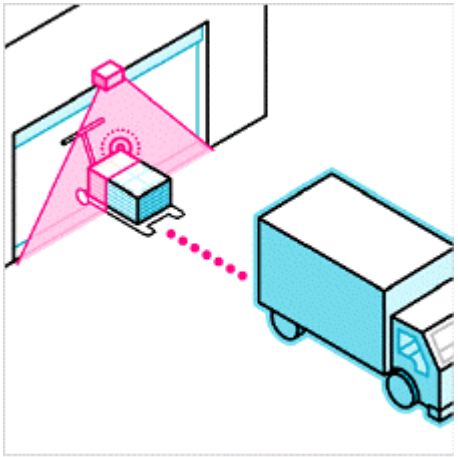
- **General**
  - Old: no restriction
  - New: the ID shall never be transmitted by the reader ☺
    - Security (drugs, military goods)
- **Aloha**
  - Time controlled
  - Slot controlled (ISO 18000-6 A)
  - Throughput: statistical maximum is 1/3 ☹☹
  - Speed depends mainly on feasibility to detect a collision or a free slot ☹
- **Deterministic types**
  - Throughput: 100% ☺ ☺
  - Enables dynamic hierarchy management (package level) ☺
  - To be very fast, full duplex is required, which is not standard yet ☹
  - Blind time of the RX path of the reader must be considered ☹
  - Current deterministic solutions (ISO 18000-6 B, Class0, Palomar)

Arbitration within Class1Gen2



- Half duplex arbitration
  - RSSI is disabled during return link ☹
- Acknowledge mechanism after Query based on a 16 bit random value ☺
- Not acknowledge (NAK) if the reader has seen an invalid ID stream
  - ID length is programmable ☺ ☺
    - 18000-6A+B; fixed Tag ID (/= item ID) length
  - Arbitration timing is a function of the ID length ☹
- Positive ACK of received ID was skipped
  - It is possible to get more than one ID at once
- Truncated read is enabled (advantage in time) ☺

The moving problem



- The pallet is scanned by a reader
- Each tag sets the select flag if it was recognized
  - Acknowledged by receiving the backscattered random value
- What will happen if the pallet was scanned some seconds before, too?
  - The reader can send a reset command
    - Look at the picture!!!
    - This will not work if the tags are moving ☹ ☹
  - Also a pre-selection for arbitration must be done several times

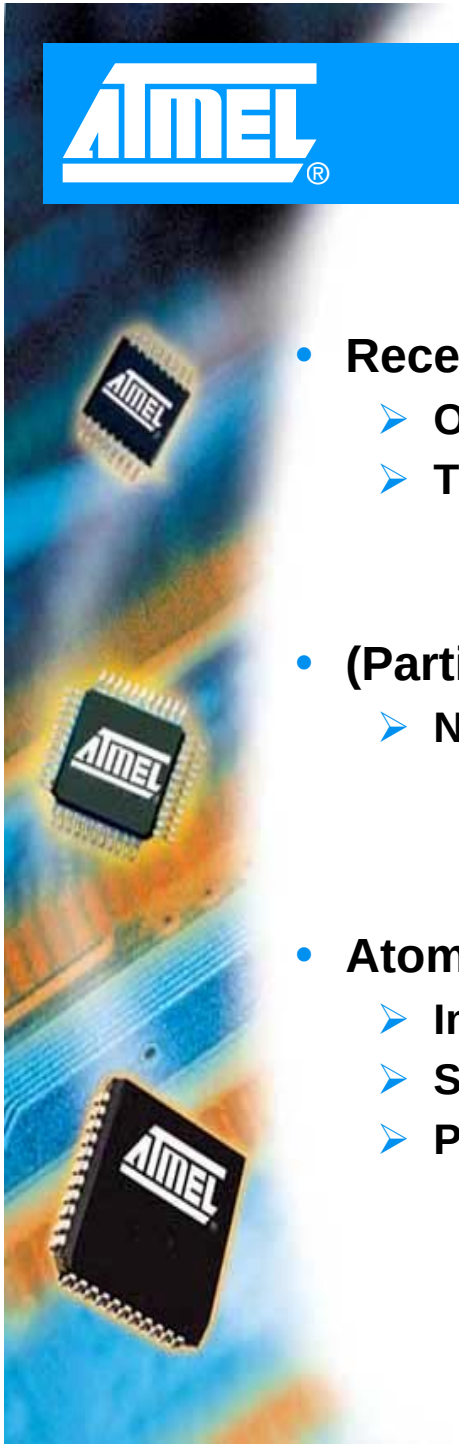
Solution for the shown moving problem

- Former solution for arbitration
  - tag is selected -> set a persistent node flag
  - Reset over time or by a reset command
  - Such a reset command will not be received by all tags ☹ ☹
- Solution: A / B symmetry
  - If a tag is selected then it is A or B
  - The select marker can be reset over time or by a command
  - If a tag has been previously selected as A, it will shift to B or if it has been previously selected as B it will shift to A ☺ ☺
    - A command controlled reset is not necessary ☺

The portal challenge

- There are several portals close to each other
  - The tag shall be able to distinguish between the readers
- Solution
  - Old: physical techniques (metal shields)
  - New: physical techniques and/or addressing techniques
    - The arbitration is controlled by a session parameter ☺
    - 4 sessions are supported ☺
  - This allows also an interrupt solution ☺
    - Portal reader, different hand held readers
  - Dense reader mode (not practical/usable) in Europe!?
    - Reader interferes with reader and tag with tags

How to program data to the tag



- **Receipt mechanism**
  - Ok signaling only
  - Tag backscatters the content of the memory as a receipt
    - Normal read mechanism
    - Margin read, telling something about quality of programming
- **(Partial) global programming within class1Gen2**
  - Not implemented in Class1Gen2 ☹
    - Requires error signaling and margin read possibility
    - Partial global programming therefore also excluded from standard ☹
- **Atomic programming**
  - Implemented in all RDWR systems
  - Simple 16 bit word encryption is implemented in Class1Gen2 ☺
  - Partial group programming not possible within Class1Gen2 ☹

Which properties are addressable by Class1gen2?

- A really world wide accepted protocol ✓
- An open and public standard which defines the basics
  - Open:
    - Enabling diversification to upper levels ✓
  - Public industrial standard
- A possibility to address a single tag out of several
  - An arbitration which is able to detect “any” number of tags in a short time
  - Interrupt level(s) ✓
  - A function enabling dock door scenarios ✓
- A select mechanism to select the package level ✓
  - A dynamic priority solution during arbitration no ☹
  - *loop1*(x select query ack *loop2:* (query_rep ack)) ☹
- A write and a read possibility for an ID or other data
  - Which kind of ID? ✓
  - Length of the ID? Up to 512 bit ✓
  - Truncated read ✓
- Nice to have:
  - A possibility to write several tags at once (same data portion) no ☹
    - Parts of the ID, like ID length, AFI, DSFID, manufacturer ID, ….

Thanks for your attention

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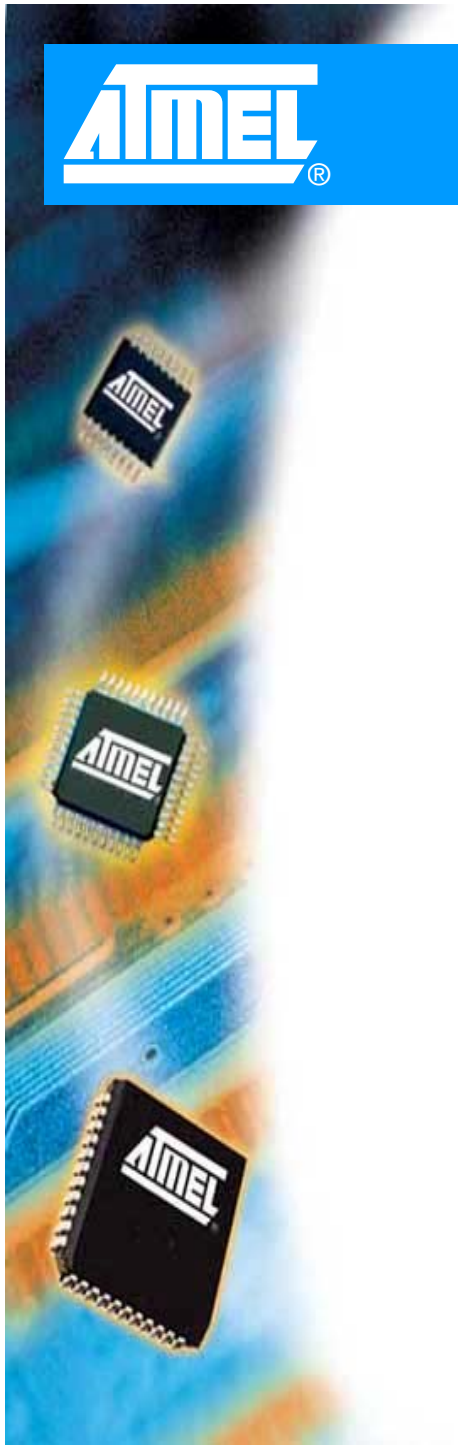
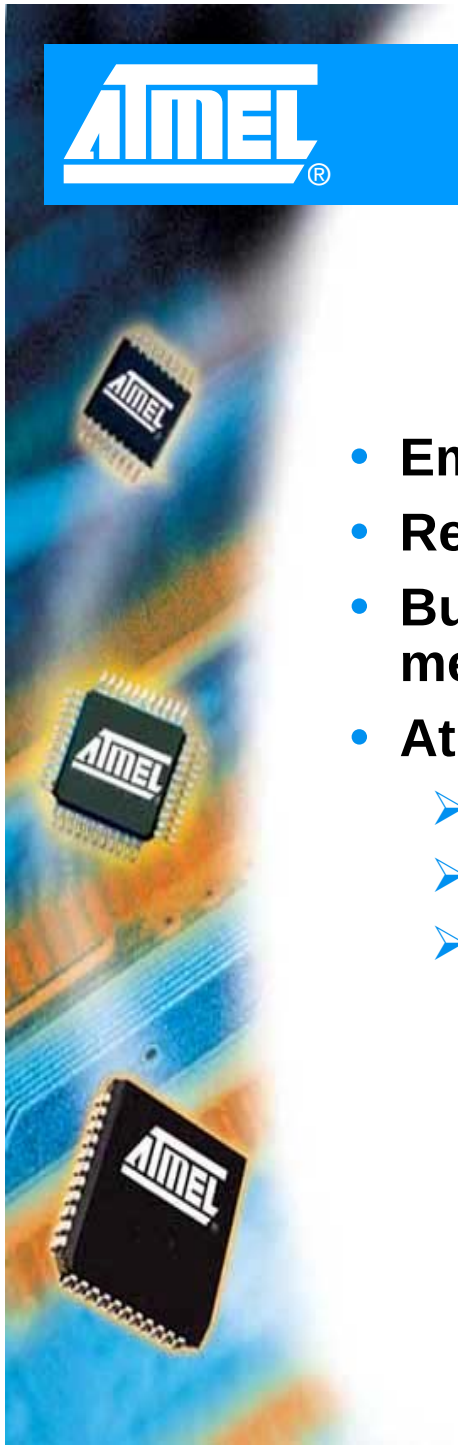
Date: February 2005



Appendix



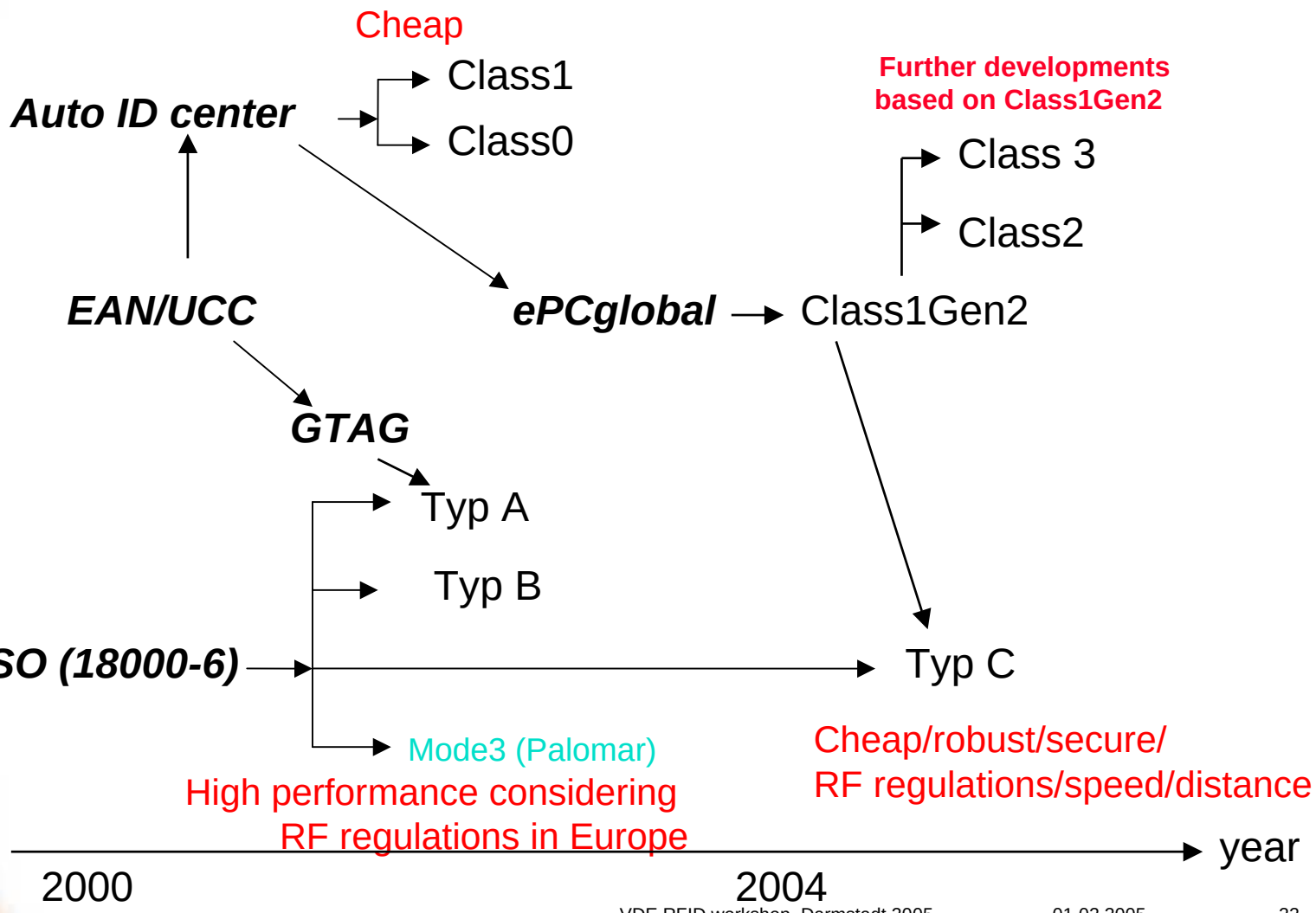
A0: Atmel

- **Employees: 8700**
- **Revenue: 1.6 B$**
- **Business area: Advanced logic, mixed signal, non-volatile memory and RF semiconductors.**
- **Atmel Germany GmbH: Subsidiary of Atmel Corporation**
  - **Previously known as: TELEFUNKEN and TEMIC**
  - **Location: Headquarter in Heilbronn, Germany**
  - **One business segment: Development of RFID ICs**
    - **LF (125 kHz) : e5530, e555x series, e556x series, U2270**
    - **UHF: Palomar, ATA5590**
    - **One of the pioneers in RFID (since 1987)**

A1: The link definition

- An RFID communication system is a master slave system
- An RFID protocol describes a wireless communication method
- A UHF RFID protocol shall
  - Describe the synchronization method
  - Define how the parameters for the forward and backscatter link are to be set
  - Define which kind of encryption is supported (if needed)
  - Define the supported commands
  - Define how robustness can be achieved and error detection shall work
  - Define what shall happened if a error occurs
  - Define the MAC layer
- As long as the applications needs are changing we have to develop / upgrade protocols *(A2, A3, A4)*

A2: What has happened since 2000



A3: Standards

- **Standard protocols are driven and/ or controlled by**
  - **Needs of applications**
    - **The application itself**
    - **The environment conditions**
    - **Pressure of the market and the added value behind**
  - **RF regulations**
    - **Europe, US, Asia (Japan, Korea, China, …), Australia**
  - **Politics ☹**
  - **Dinner sessions ☹**
- **Standards are under development, every time ☺ ☹**
- **Standards are not offering the best technical solution**
  - **They are based on compromises ☹**
  - **They are describing a common ground for diversification strategies ☺ ☺ ☹**

A4: Some basics of UHF RFID

$$d > \frac{\lambda}{2\pi} \qquad Q = \frac{1}{R} \cdot \sqrt{\frac{L}{C}} \qquad s(t) = \cos(2 \cdot \pi \cdot f_{carrier} \cdot t) \cdot \cos(2 \cdot \pi \cdot f_{\mathrm{mod}} \cdot t)$$

$$\mathrm{distance}_{\max} = \left(\frac{\lambda}{4 \cdot \pi}\right) \sqrt[n]{\eta \cdot G_{reader} \cdot G_{transponder} \cdot \frac{P_{reader}}{P_{transponder}}}$$

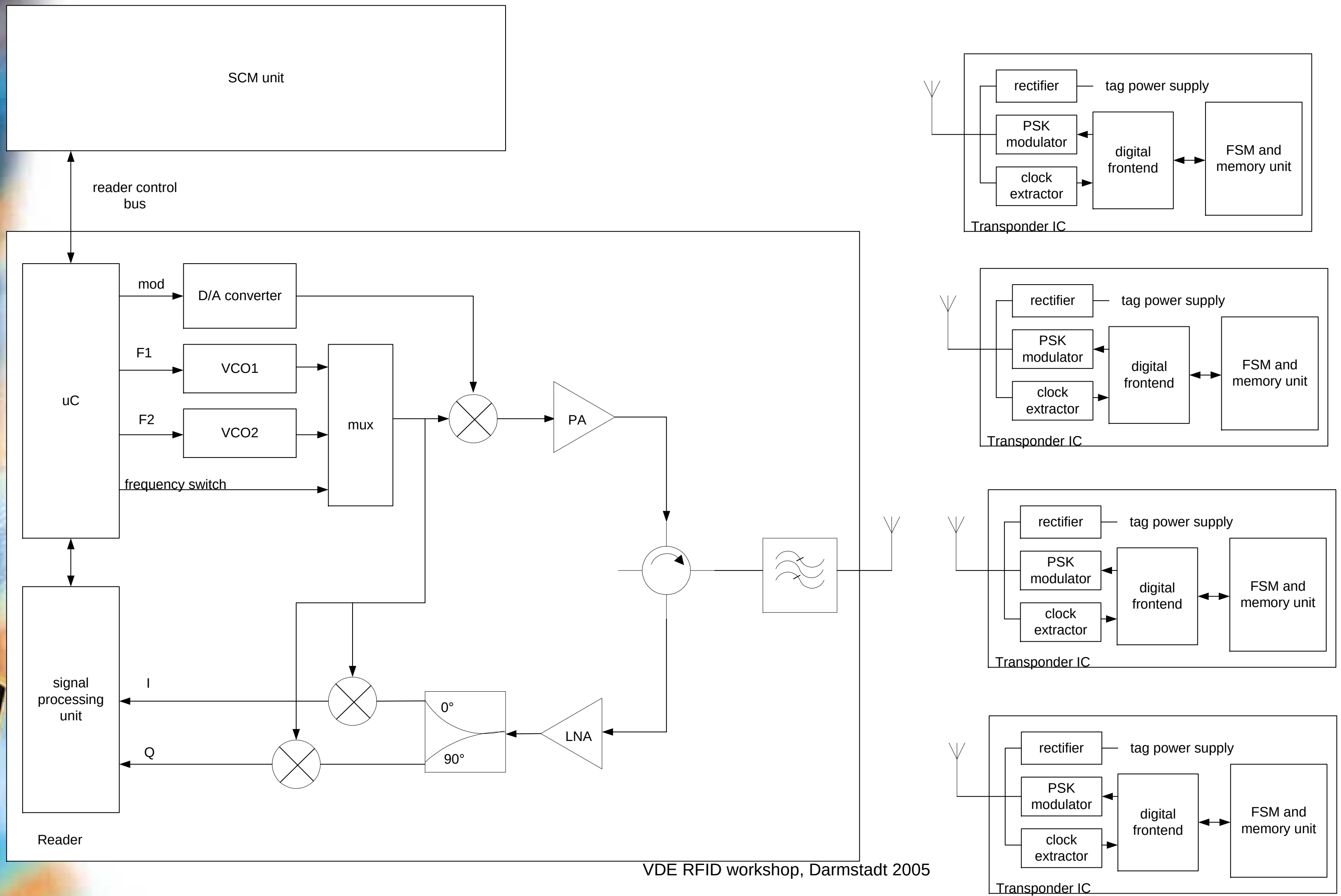
$$\Delta RCS = \left(\frac{\lambda^2 \cdot G_{tag\_antenna}^2 \cdot \Delta Z_{tag\_IC}}{4 \cdot \pi \cdot R_{tag\_ic}}\right)$$

$$\Delta phase\_angle = 2 \cdot \arctan\left(\frac{\Delta \mathrm{Im}_{transponder-IC}}{4 \cdot \mathrm{Re}_{transponder-IC}}\right)$$

$$P_{tag\_IC} = P_{reader} \cdot G_{tag} \cdot G_{reader} \cdot \left(\frac{\lambda}{4 \cdot \pi \cdot \mathrm{distance}}\right)^2$$

$$P_{tag} = P_{reader} + 20 \log\left(10, Abs\left(\sum_{N=0}^{N} \frac{\lambda \cdot e^{\frac{-j \cdot 2\pi \cdot (x + 2n(l_1 + l_2))}{\lambda}}}{4\pi(x + 2n(l_1 + l_2))} + \sum_{N=0}^{N} \frac{\lambda \cdot e^{\frac{-j \cdot 2\pi (2l_1 - x + 2n(l_1 + l_2))}{\lambda}}}{4\pi(2l_1 - x + 2n(l_1 + l_2))}\right)\right)$$

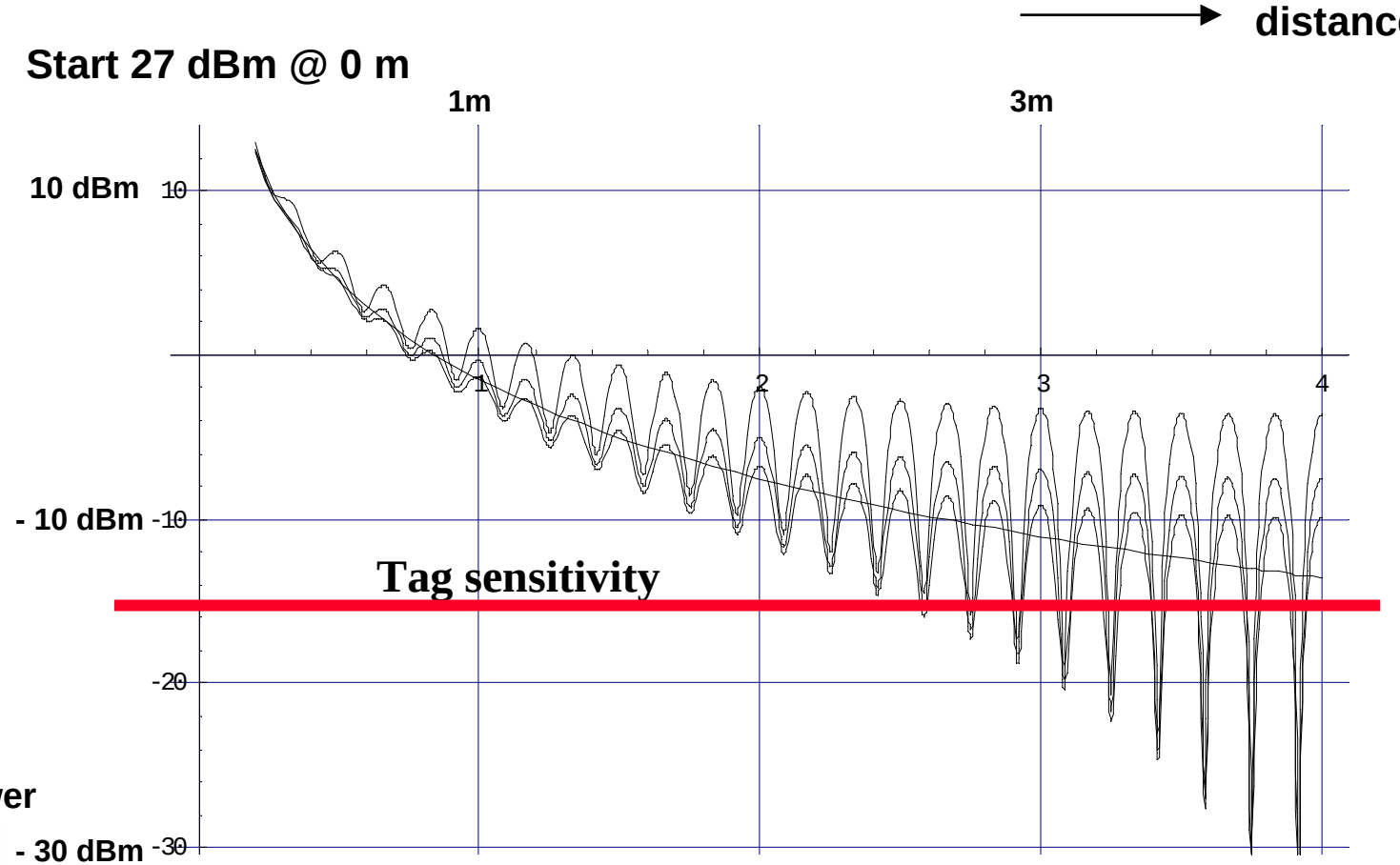
A5: A simplified UHF RFID system



A6: Physics of UHF RFID

- **Why UHF?**
  - **Communication distance for inductive coupled systems is limited to** $d < \frac{\lambda}{2\pi}$
  - **Practical limitations for sizing and by RF regulations**
  - **Increased data rates relative to LF**
- **The field strength is influenced by reflections**
  - **Constructive and destructive interference of the carrier signal ☹**
- **Losses**
  - **Free space attenuation**
    - **86 dB free space attenuation @ 868 MHz and a distance of 4 m (reader (TX) -> tag -> reader (RX)**
    - **In practice 100 dB and more between TX and RX is a real challenge**
  - **Tag attenuation because the tag needs also power for operation**
  - **Attenuation given by the goods**

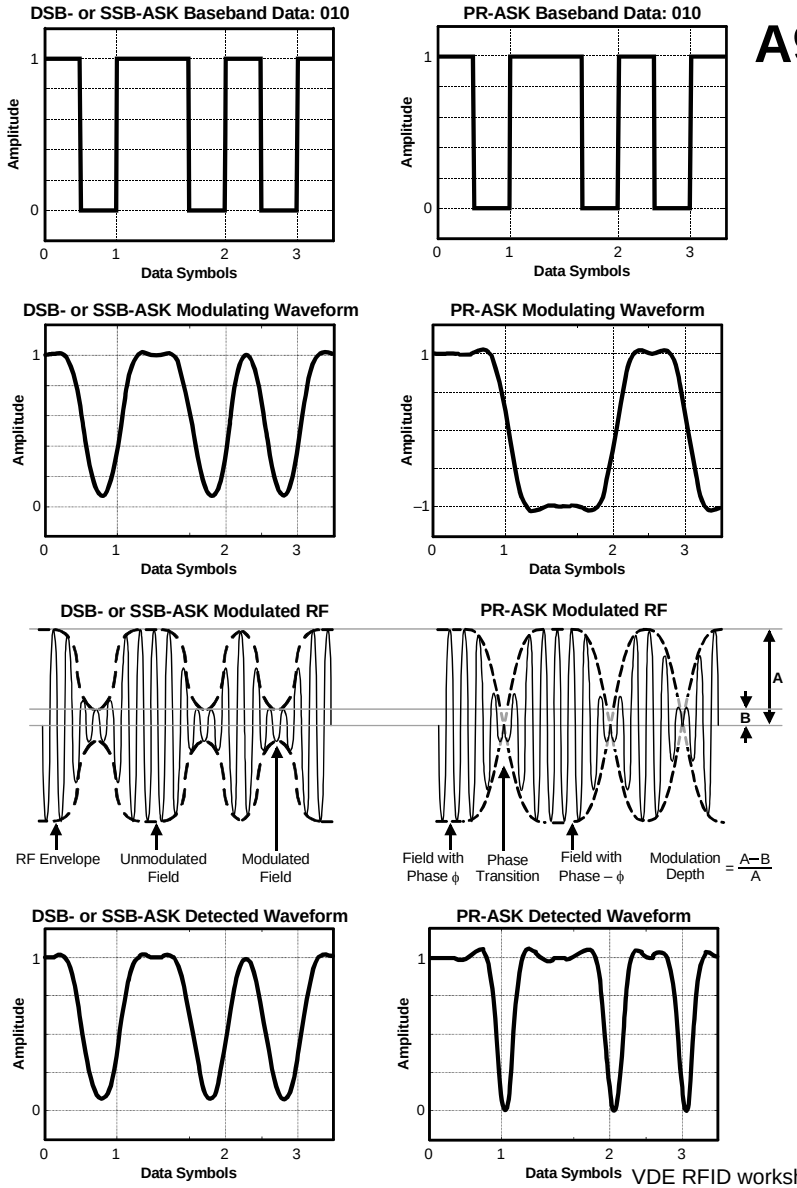
A7: Example for the receivable power (Tag) as a function of distance and reflections



A8: RF Regulations for UHF based SRD's

- America
  - Frequency: 902…928 MHz (915 MHz band)
  - Transmitted power: 37 dBm EIRP (4 W)
  - Up to 50 channels; channel bandwidth: up to 1 MHz
- Europe
  - Old and new
    - Frequency: 869.4 - 869.65 MHz
    - Transmitted power: 27 dBm ERP (500 mW)
    - One channel; channel bandwidth: 250 kHz
    - Or up to 10 channels; channel bandwidth: min 25 kHz
  - New
    - Frequency: 865 ... 868 MHz
    - Transmitted power: 34 dBm ERP (2 W) (listen before talk)
    - 15 channels; channel bandwidth: 200 kHz ☹
- Asia (Japan/Korea/China under development)
  - In ISO they have voted against each UHF based RFID system in 2002
  - Frequency (Japan) close to 950 MHz

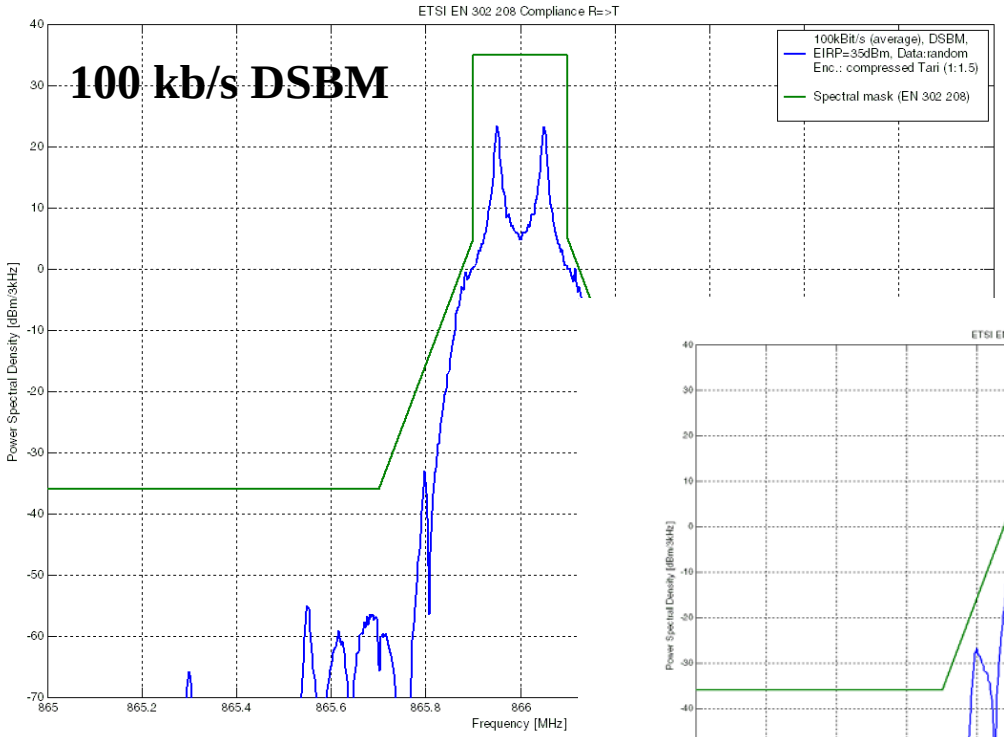
A9: AM modulation types

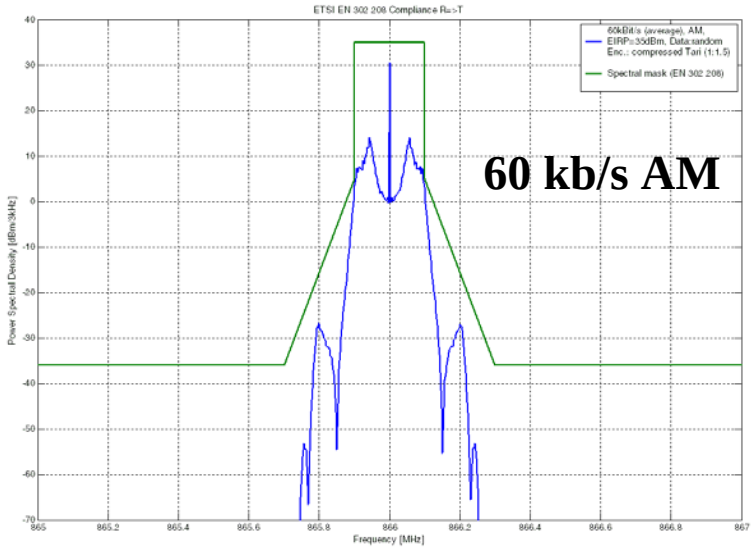


DSB-ASK requires more bandwidth than
- **ASK-SSB or**
- **PR-ASK (DSBM)**

Power transport is optimized by using PR-ASK (DSBM)

A10: Spectrum challenges (Europe, EN 302 208)

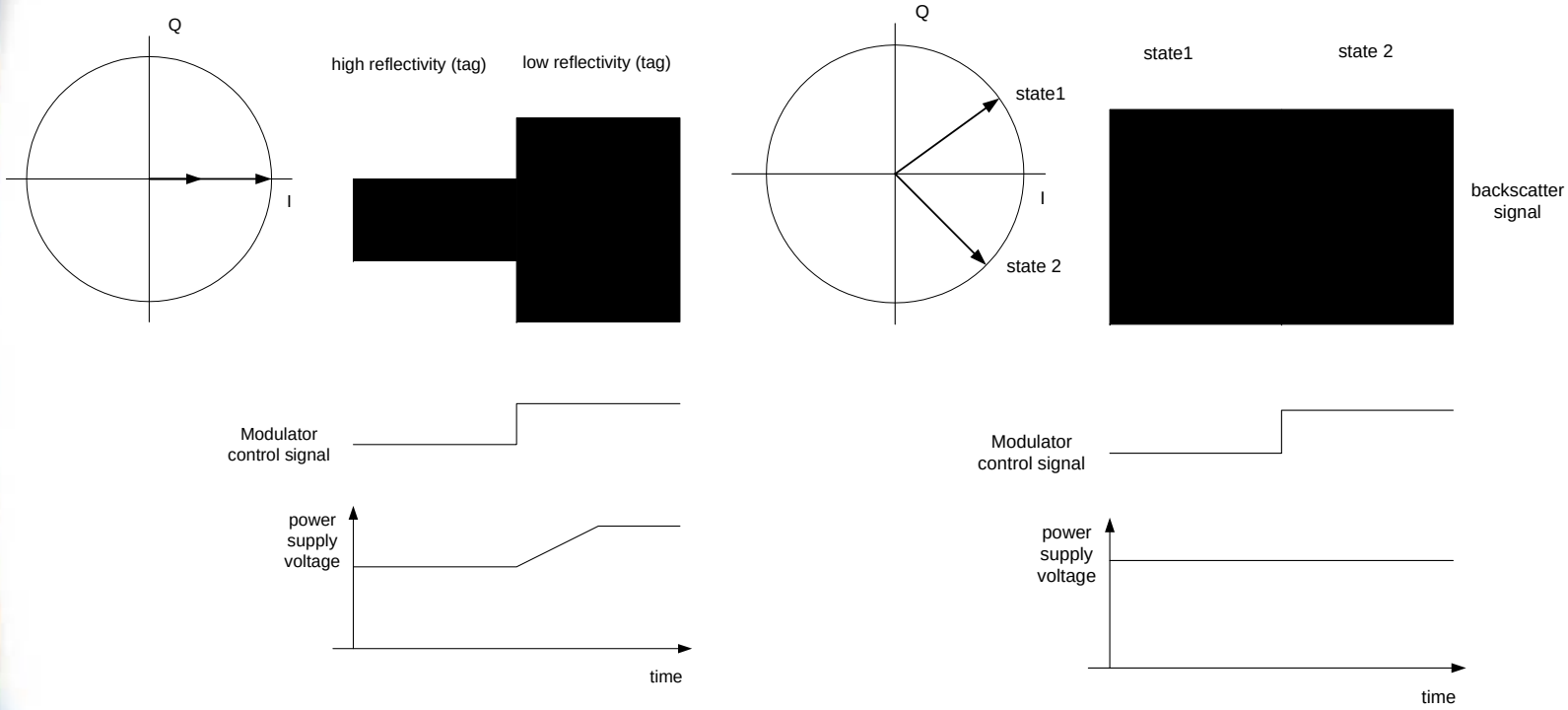




A11: Possible solutions for the backscatter link

- Half duplex or full duplex communication
  - FD to enable higher robustness in forward link
  - FD requires that the RSSI is not disabled
- ASK or (real) PSK modulation
  - ASK is the traditional solution (class0, class1, ISO 18000)
  - PSK offers higher sensitivity, “no” power supply ripple
  - PSK enables full duplex
- Spectrum management
  - Enables better SNR; a shift around noise is possible
  - Similar to Palomar
- Synchronous and / or asynchronous backscatter link
  - Synchronous link has the highest SNR
  - Synchronous requires full duplex if the timing is variable
  - Asynchronous link is ISO 18000 conform

A12: Differences ASK vs. PSK

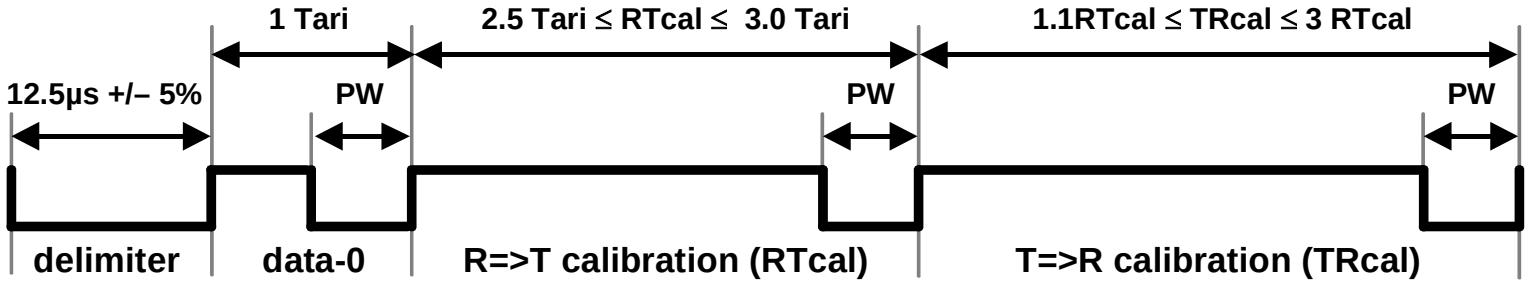


A13: Timing and spectrum adjustment within Class1Gen2

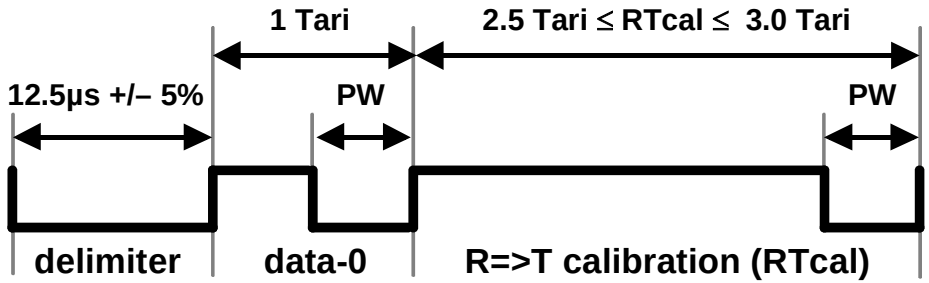
Forward threshold is defined by this timing reference

Primitive timing for backscatter symbols is encoded by a timing reference

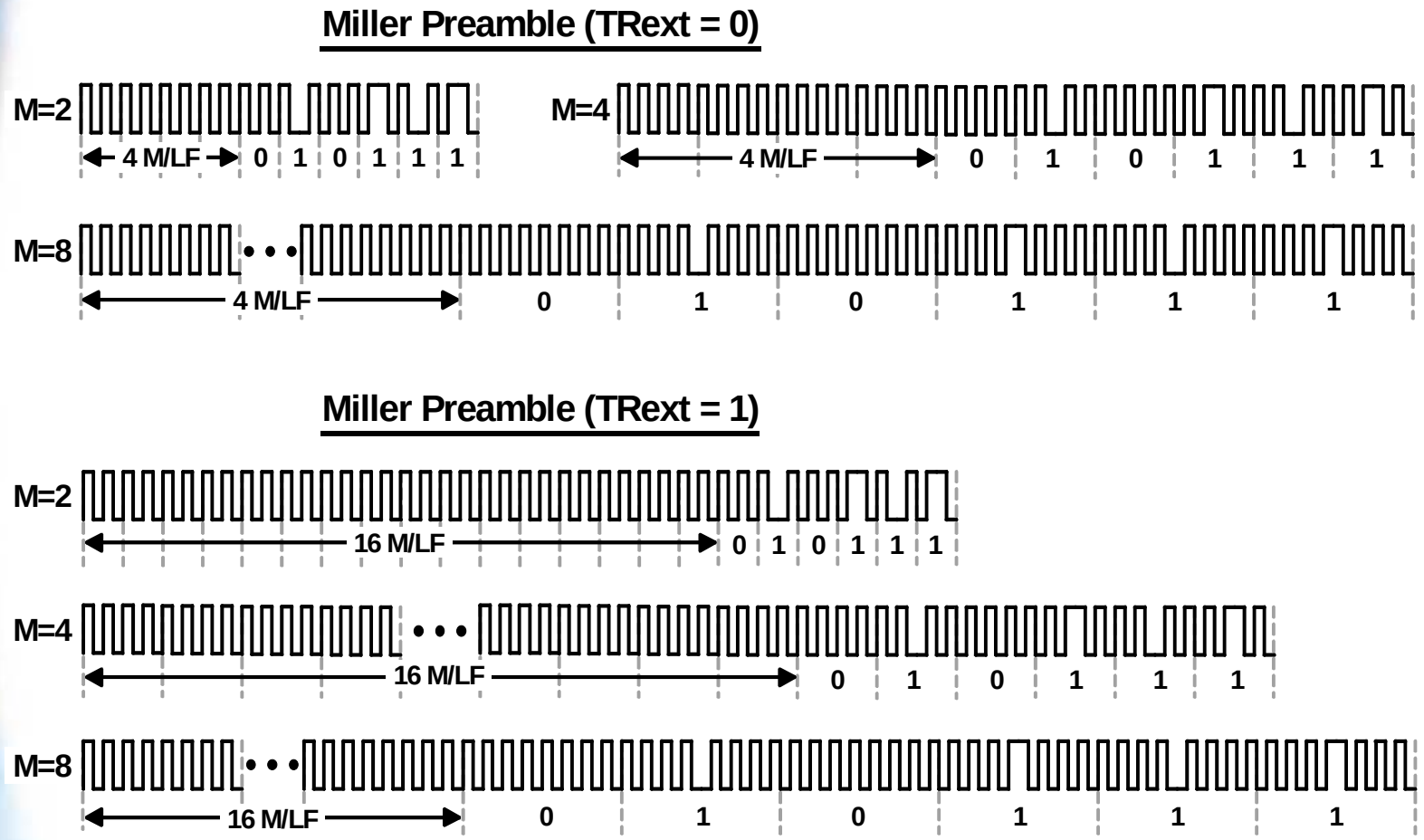
R=>T Preamble



R=>T Frame-Sync



A14: Sub carrier encoding within Class1Gen2



A15: Questions regarding current solutions for arbitration

- **Deterministic**
  - Depends on the data stream for arbitration (ID, other data fields, random value)
    - Over ID is now forbidden
    - Arbitration has to be made over an n-bit random stream
- **Aloha**
  - Is it possible to detect hidden tags (different distances!)?
  - Is there a receipt mechanism based on a random value?
- **Aloha implemented in ISO 18000-6 A**
  - Next slot mechanism is based on a 4 bit signature
    - Tag backscatters the whole Tag ID (not the Item ID)
    - No interrupt possibility if there is a collision (half duplex!)
    - 4 bit signature is *not always* a random number
      - But in praxis a 4 bit is a nice joke, birthday phenomenon !!!
  - Truncated read not implemented

A16: The implementation of the arbitration within Class1Gen2