RFID Technology

Matthias Handy
Institute of Applied Microelectronics & CS
University of Rostock

RFID-Workshop, 30.9./1.10.04, Berlin

Latest News

Agenda

- Introduction
- Characteristics
- Operating Principles
- Applications & Standards
- Summary

Radio Frequency Identification

RFID: **Automatic identification** technology where information is carried by **radio waves**.

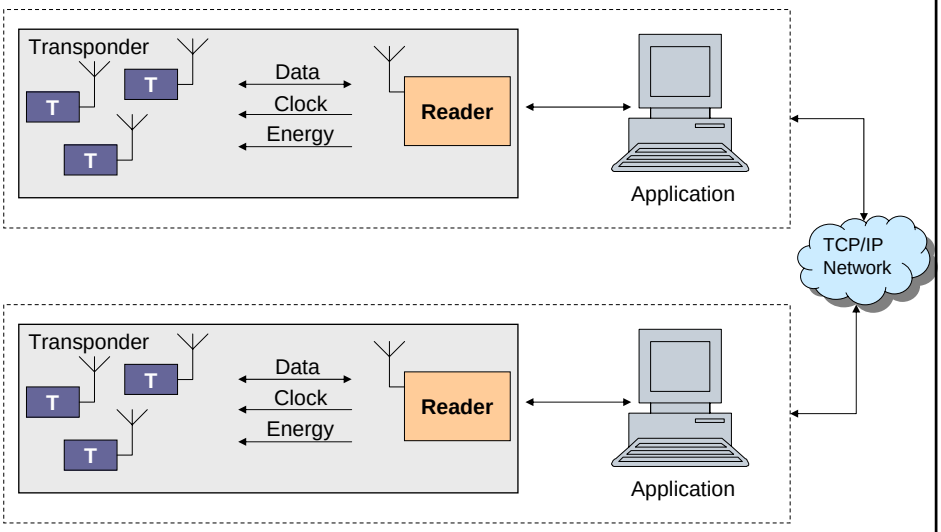
Other Auto-ID-Technologies:

- Bar Code
- Smart Cards
- Biometrics (e.g. fingerprint)

Special Characteristics of Radio Communication:

- No physical contact
- No line-of-sight
- Imperceptible

Elements of an RFID-System

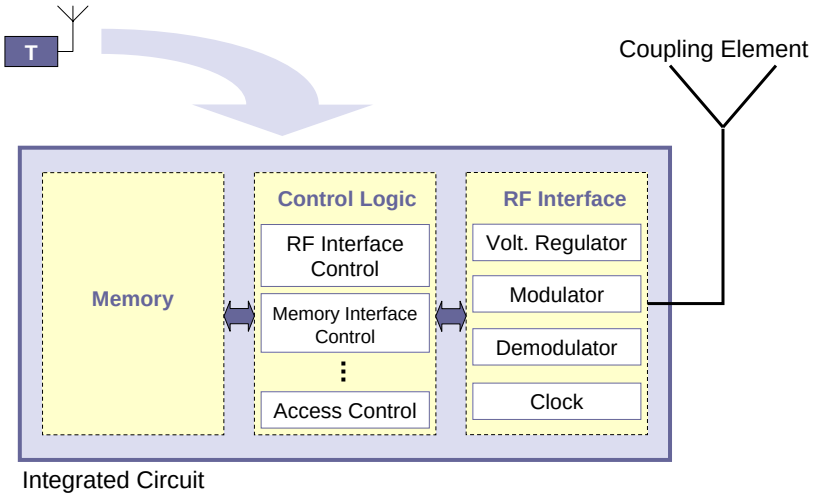


Transponder Power Supply

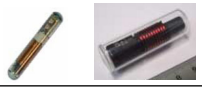
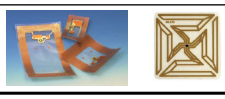
- **Active (battery-assisted) Transponders**
  - own energy source (e.g. battery)
  - transponder transmits radio signal
  - higher read range
  - finite lifetime

- **Passive Transponders**
  - no power supply "on board"
  - transponder reflects/modulates radio signal from reader
  - shorter read range
  - lifetime not limited by energy source

Passive Transponders – What's inside?

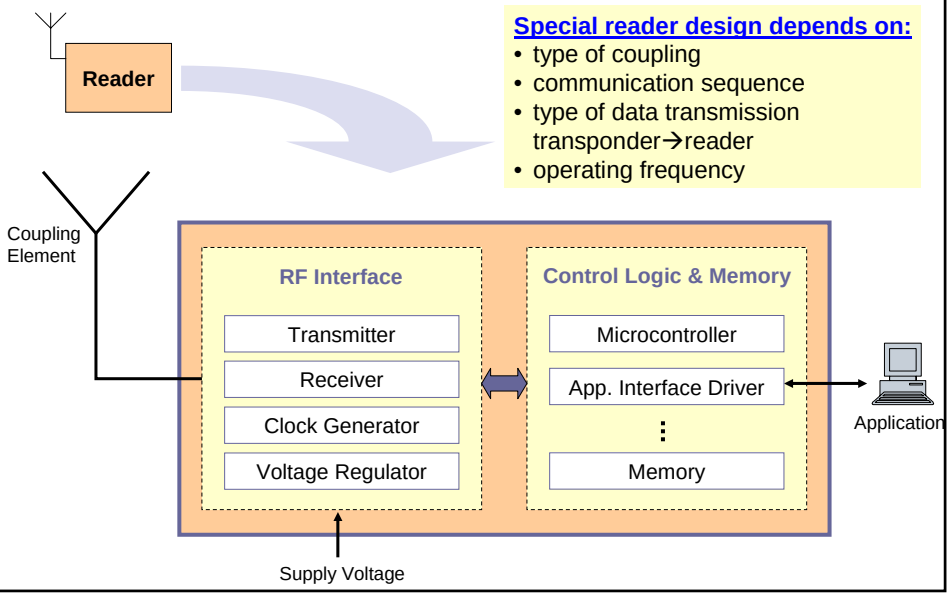


Transponder Construction Formats (Examples)

Disks	
Cylinders	
Cards	
Key Fobs /Rings	
Glass	
Smart Labels	

Pictures: Texas Instruments, Matrics, Philips

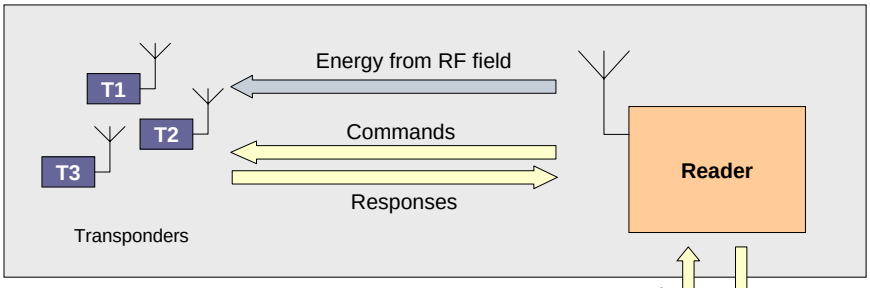
Readers – What's inside?

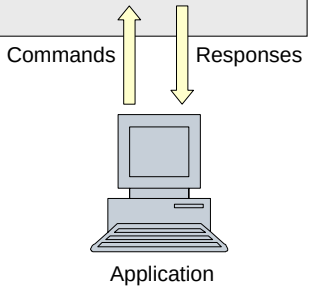


Special reader design depends on:

- type of coupling
- communication sequence
- type of data transmission transponder→reader
- operating frequency

Communication Model (Passive)





Communication Example:

- Application → Reader:
  - "Show me IDs of all tags in range!"
- Reader → Tags:
  - "Deliver your ID!"
- Tags → Reader:
  - "T1", "T2", "T3"
- Reader → Application:
  - "IDs of tags in range: T1, T2, T3"

Agenda

- Introduction
- Characteristics
- Operating Principles
- Applications & Standards
- Summary

Overview of RFID System Characteristics

- Operating Frequency
- Method of Coupling
- Transmission Range
- Data Storage Capacity
- Power Supply (Active, Passive)
- Read Only / Read-Write
- Transmission Types (HDX, FDX, SEQ)

Selected Operating Frequencies (1)

- **< 135 kHz (LF)**
  - Short range
  - Low data (read-) rates
  - Penetrate non-metallic materials (e.g. water)
  - Do not penetrate / transmit around metals
  - E.g. for animal identification
- **13,56 MHz (HF)**
  - ISM Band
  - Higher data rates and range (than <135 kHz-systems)
  - Penetrate non-metallic materials (e.g. water)
  - Do not penetrate / transmit around metals
  - E.g. for contactless smart cards

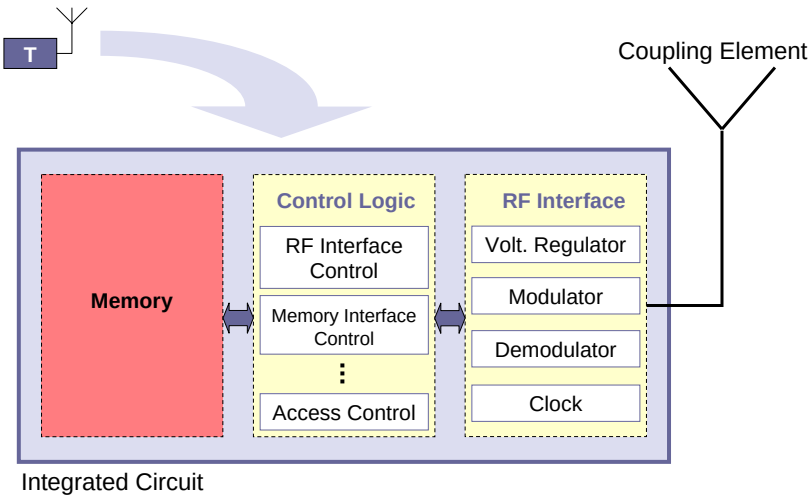
Selected Operating Frequencies (2)

- **860-930 MHz (UHF)**
  - High data rate / long range
  - Effective around metals
  - Do not penetrate water
  - Differences in frequency (Europe, USA, Japan)
  - E.g. for logistics
- **2,45 GHz (UHF)**
  - ISM Band (same as Bluetooth, WLAN)
  - High data rate, long range
  - Effective around metals
  - Do not penetrate water
  - E.g. for logistics

System Ranges - Classification

- **Close Coupling Systems**
  - Range: < 1cm
  - Frequencies: DC ... 30 MHz
  - Based on *inductive* or *capacitive coupling*
  - E.g. for door locking systems
- **Remote Coupling Systems**
  - Range: < 1m
  - Frequencies: 135 kHz or 13,56 MHz
  - Mostly based on *inductive coupling*
  - E.g. for contactless smart cards
- **Long Range Systems**
  - Range: > 1m
  - Also known as *backscatter systems*
  - Frequencies: 860-930 MHz or 2,45 GHz
  - E.g. for logistics

RFID Tag as Data Storage Device

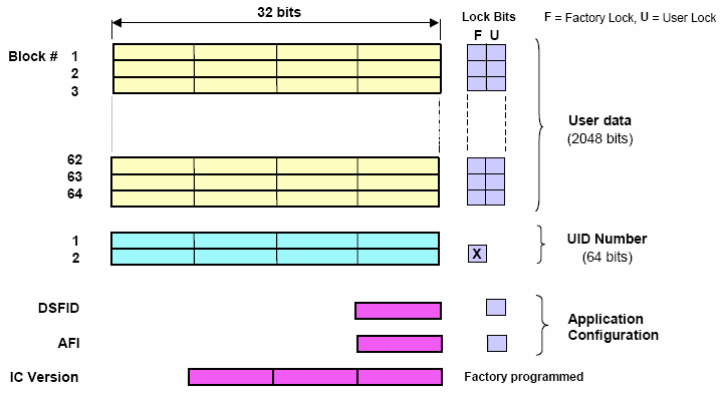


RFID Tag as Data Storage Device

- Most RFID-Tags store (U)ID – **Unique IDentifier**
  - Mostly read only
  - Factory programmed
- Some tags can store **user data**
  - Mostly read/write
  - EPC, Product information
- Memory Technologies:
  - EEPROM, RAM, ROM, FRAM

RFID-Tag Memory (Example)

Texas Instr. Tag-It HF-I (passive smart label; 13,56 MHz)



Example Storage Capacities

Manufacturer	Tag Name	Type	Frequency	Memory (user data)
Philips	U-CODE	passive smart label	2,45 GHz	2048 bit
Philips	I-CODE	passive smart label	13,56 MHz	up to 1024 bit
Alien Technologies	ALB-2482	batt. assisted (8cm x 2.5cm x 1.5cm)	2,45 GHz	4 kByte RAM
Matrics	I2010-LBL	passive smart label	860-960MHz	256 bit
Texas Instruments	RI-TH1-CB1A	passive smart card	13,56 MHz	2048 bit

Agenda

- Introduction
- Characteristics
- Operating Principles
- Applications & Standards
- Summary

Coupling Overview

- **Close Coupling Systems**
  - Range: < 1cm
  - Frequencies: DC ... 30 MHz
  - Based on *inductive* or *capacitive coupling*
  - E.g. for door locking systems
- **Remote Coupling Systems**
  - Range: < 1m
  - Frequencies: 135 kHz or 13,56 MHz
  - Mostly based on *inductive coupling*
  - E.g. for contactless smart cards
- **Long Range Systems**
  - Range: > 1m
  - Also known as *backscatter systems*
  - Frequencies: 860-930 MHz or 2,45 GHz
  - E.g. for logistics

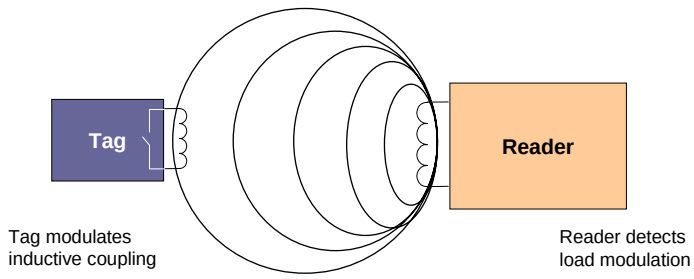
Inductive Coupling (close coupling & remote coupling systems)

Transponder's power supply:

1. Reader generates magnetic alternating field.
2. This field induces a voltage in tag's antenna coil → power supply

Data transfer from transponder → reader:

1. Resonant transponder draws energy from magnetic alternating field.
2. This can be detected in reader's antenna (voltage drop)
3. Switching a load resistor on and off at the *transponder* → amplitude modulation of voltage at the *reader* antenna (load modulation)



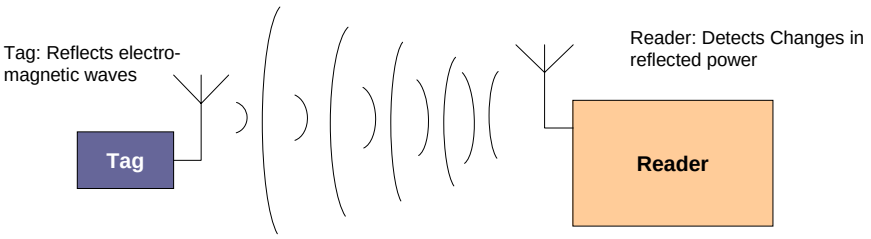
Electromagn. Backscatter Coupling (long range)

Transponder's power supply:

- Tag draws energy from electromagnetic field of the reader.
- Tag may be battery-assisted.

Data transfer from transponder → reader:

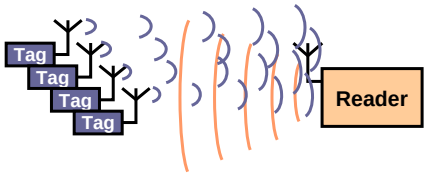
- Similar to radar technology
- Incoming power at the tag antenna is reflected partially.
- Reflection characteristics depend on load connected to the antenna.
- Load resistor in parallel with the antenna can modulate the amplitude of the reflected power (modulated backscatter).



Anticollision

The Problem:

A reader is only able to communicate with one single tag at a time!



The Solution:

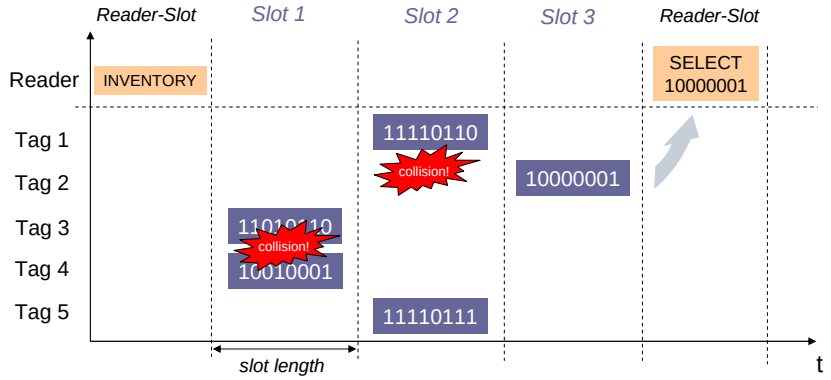
Use anticollision (singulation) protocols!

Common anticollision techniques:

- (Slotted) ALOHA
- Binary Search

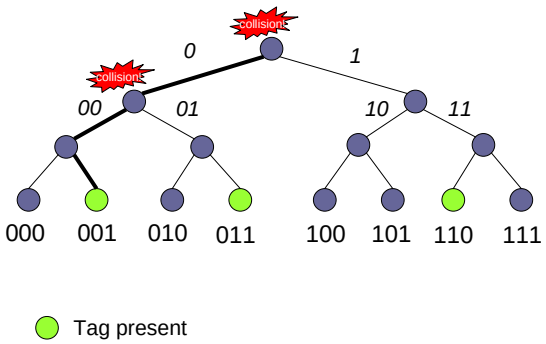
Anticollision: Slotted ALOHA

- Tags only transmit packets at pre-defined points in time (slots)
- Synchronized by reader
- Example: 1 Reader, 5 Tags, 8-bit ID



Anticollision: Binary Search

- "Tree Walking"
- Recursive depth-first search
- Requirement: Reader is able to detect bit position of a collision
- Example: 1 Reader, 3 Transponder, 3-bit ID

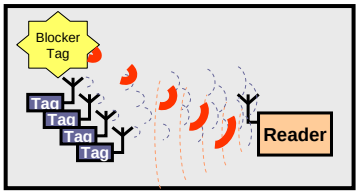


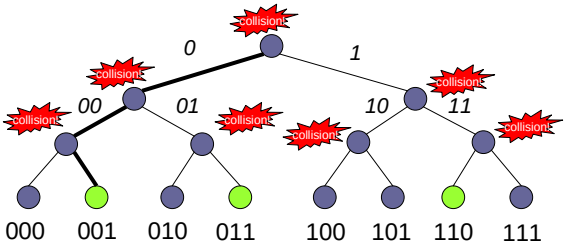
Received data at reader

Bit number	2	1	0
1st iteration	X	X	X
2nd iteration	0	X	1
3rd iteration	0	0	1

Anticollision: Blocker Tag

- A. Juels, R. Rivest, M. Szydlo; 2003
- (Selective) Blocking of RFID tags
- Only works with binary search anticollision
- Simulates the full set of 2^k possible RFID-tag serial numbers
- Reader cannot tell which tags are really present
- Example: 48 bit ID, Reader reads 1000 tags/s: > 8000 years reading all tags





Anticollision protocol recursively asks:

"What is your next bit?"

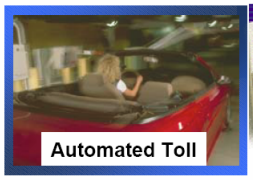
Blocker tag always answers:

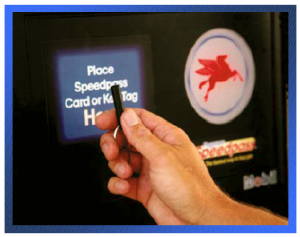
"Both 1 and 0!"

Agenda

- Introduction
- Characteristics
- Operating Principles
- Applications & Standards
- Summary

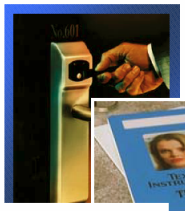
Applications

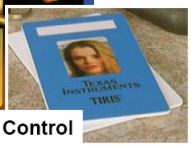




Mobil *Speedpass*™
Freedom Pay™

Smart Cards





Access Control

RFID Standards

- Standards for logistics applications
  - ISO/IEC 18000
  - ISO/IEC 15961-15963
  - ISO/IEC 15418
- Standards for automatic livestock identification
  - ISO 11784
  - ISO 11785
  - ISO 14223
- Standards for vicinity coupling cards
  - ISO/IEC 10373
  - ISO/IEC 10536
  - ISO/IEC 14443
  - ISO/IEC 15693
- Supply Chain Management
  - EPC (under development)

Summary

- There's no typical RFID-System
- Main differentiation characteristics
  - Tag's power supply
  - Frequency
  - Type of Coupling
  - Data storage capacity

  } Range!
- Operating Principles
  - Inductive coupling
  - Electromagnetic Backscatter coupling
- Anticollision techniques
  - Slotted ALOHA
  - Binary Search

References

- **K. Finkenzeller**; *RFID-Handbook*; John Wiley & Sons, 2003.
- **M. Reynolds**; *Physics of RFID,* MIT RFID Privacy Workshop, Cambridge, MA, November 2003.
- **C.K. Harmon**; *Basics of RFID Technology,* MIT RFID Privacy Workshop, Cambridge, MA, November 2003.
- **R. Bridgelall**; RADAR Technology for Commodity Goods; 2004.
- **A. Juels, R.L. Rivest, M. Szydlo**, *The Blocker Tag: Selective Blocking of RFID Tags for Consumer Privacy*, ACM Press, 2003.
- **A. Juels**; *RFID Tags: Privacy and Security without Cryptography*; MIT RFID Privacy Workshop, Cambridge, MA, November 2003.
- Texas Instruments; Tag-it HF-I Transponder Inlays Reference Guide.

Contact Information

Matthias Handy

Institute of Applied Microelectronics
& Computer Science
University of Rostock

matthias.handy@uni-rostock.de