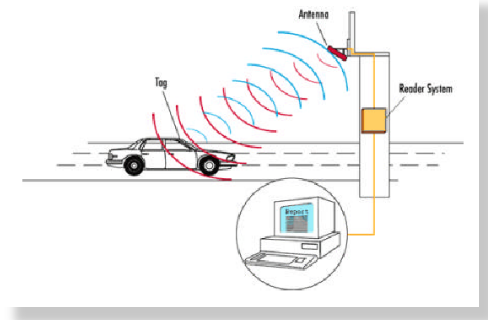
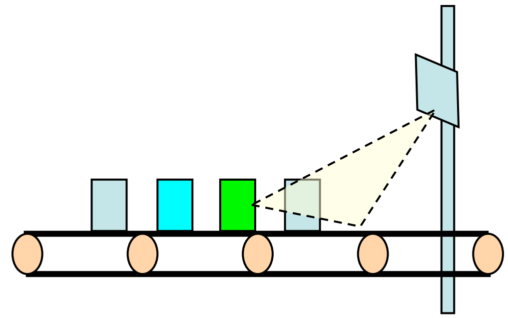
Final Project
Introduction to RFID
(Radio Frequency IDentification)

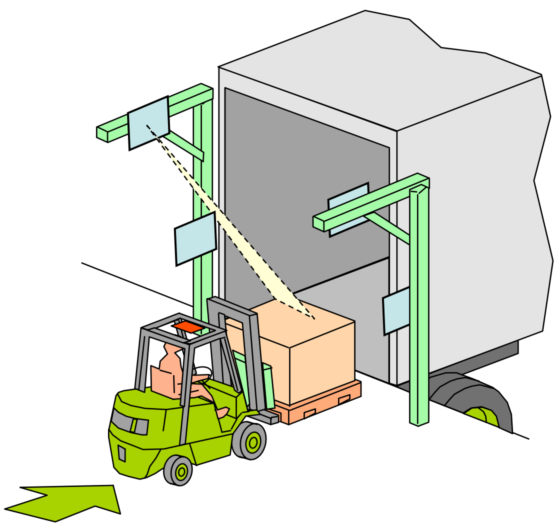
Andreas G. Andreou

Radio Frequency IDentification

- **Tag wirelessly sends bits of data when it is triggered by a reader**
- **Power source not required for passive tags… a defining benefit**
- **Superior capabilities to barcode:**
  - **Non Line of Sight**
  - **Hi-speed, multiple reads**
  - **Can read *and* write to tags**
  - **Unit specific ID**







Four main frequencies:

	Frequency	Distance	Example Application
LF	125khz	Few cm	Auto-Immobilizer
HF	13.56Mhz	1m	Building Access
UHF	900Mhz	~7m	Supply Chain
μwave	2.4Ghz	10m	Traffic Toll

Lecture Objectives:

- Explain technical principles behind RFID
- Provide overview of RFID technology
- Discuss architecture for RFID chips

Outline

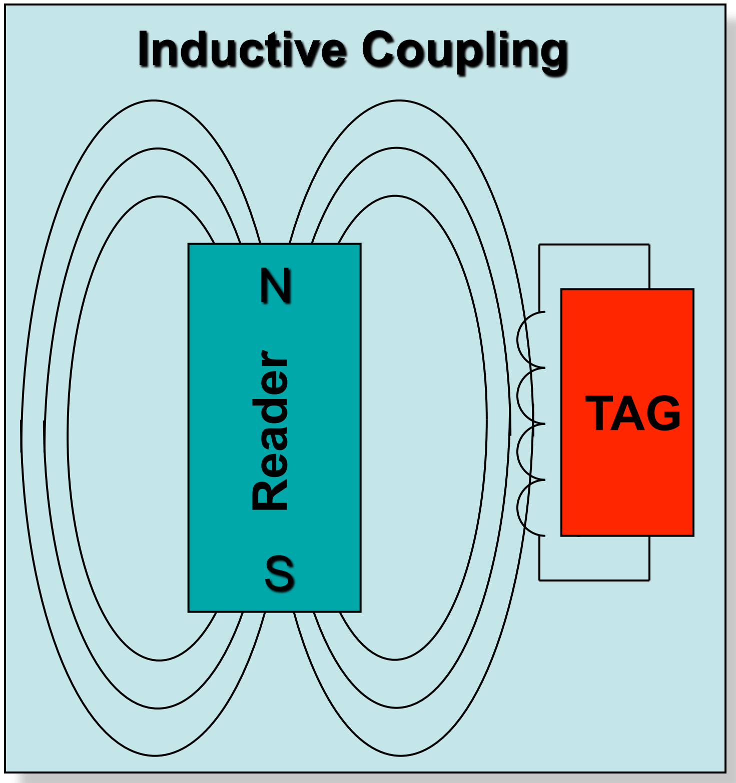
- RFID history
- Technical principles
- Tag overview
- Reader overview
- Adoption challenges
- The UHF market
- The future??

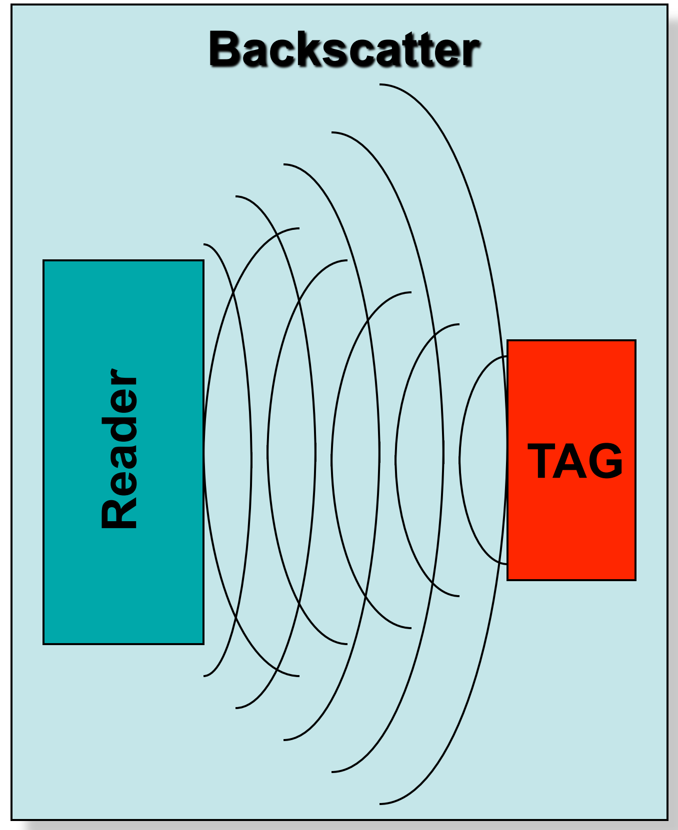
RFID History

- First Bar code patents – 1930s
- First use of RFID device – 2nd world war – Brittan used RFID-like technology for Identify- Friend or Foe
- Harry Stockman October 1948 Paper – Communication by means of reflected power (The proceedings of the Institute of Radio Engineers)
- First RFID Patent - 1973
- Auto-ID center founded at MIT – 1999
  - Standardization effort taken over by EPC Global (Electronic Product Code)
- Current thrust primarily driven by Wal-Mart and DoD
  - Automate Distribution:
    - Reduce cost (man power, shipping mistakes)
    - Increase sales (keep shelves full)
    - DoD Total Asset Visibility Initiative

Source of data: EDN – October 2004 - "Reading Between the Lines" Brian Dipert

Basic Tag Operational Principles

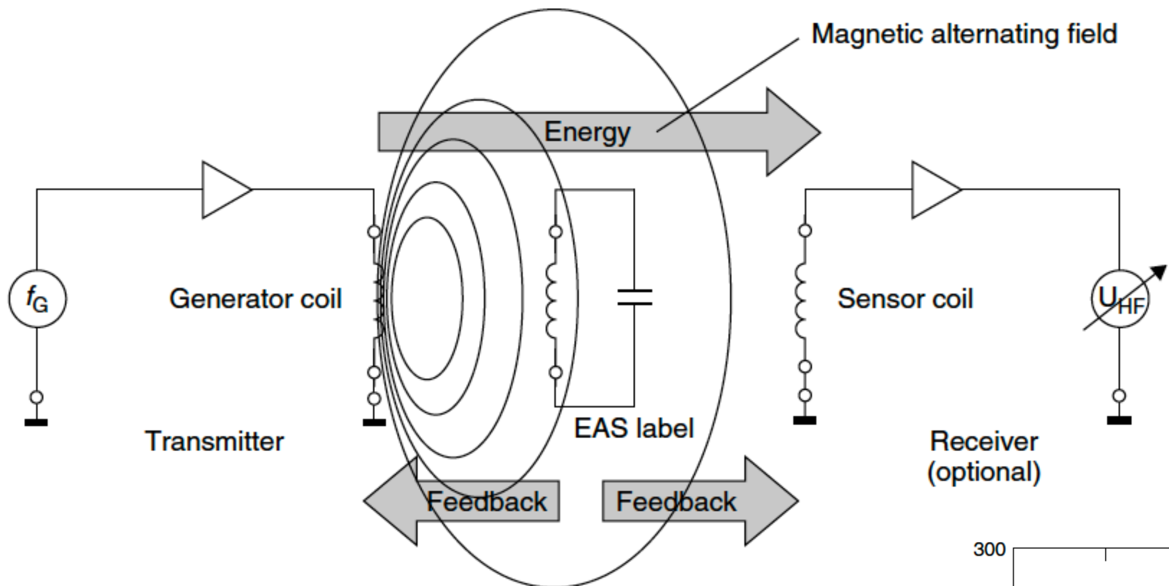


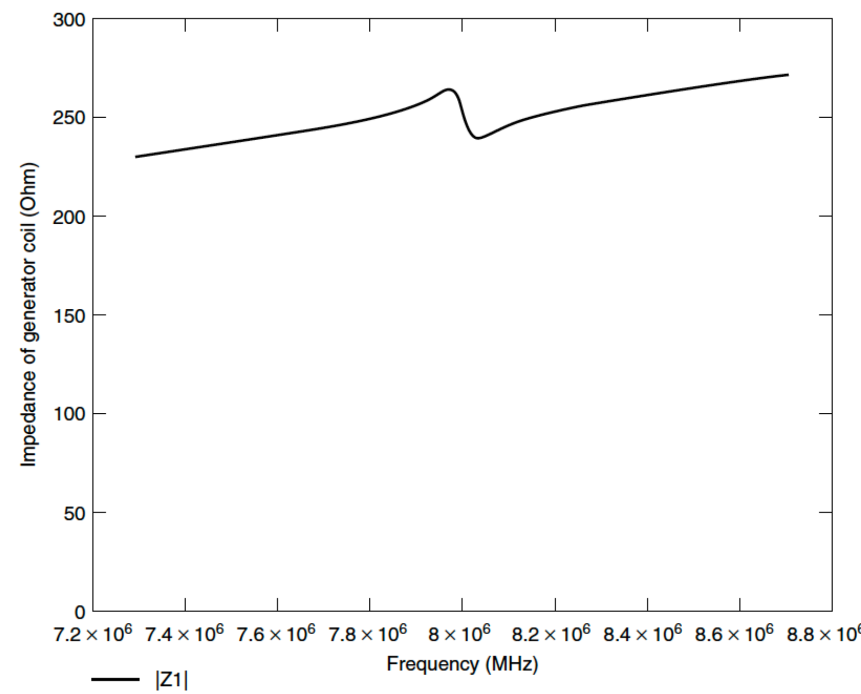


- Near field (LF, HF): inductive coupling of tag to magnetic field circulating around antenna (like a transformer)
  - Varying magnetic flux induces current in tag. Modulate tag load to communicate with reader
  - field energy decreases proportionally to $1/R^3$ (to first order)
- Far field (UHF, microwave): backscatter.
  - Modulate back scatter by changing antenna impedance
  - Field energy decreases proportionally to 1/R
- Boundry between near and far field: R = wavelength/2 pi so, once have reached far field, lower frequencies will have lost significantly more energy than high frequencies
- Absorption by non-conductive materials significant problem for microwave frequencies

Source of data: "Introduction to RFID" CAENRFID an IIT Corporation

Basic Principle





Traditional RFID Market Segments

Auto Immobilizers

Automated Vehicle Id

- *Isolated systems*
- *Simple reads*
- *Slow growth*

Access Control

Animal Tracking

The New Mkt Segment
Consumer Pkg Goods Supply Chain

Wal-Mart

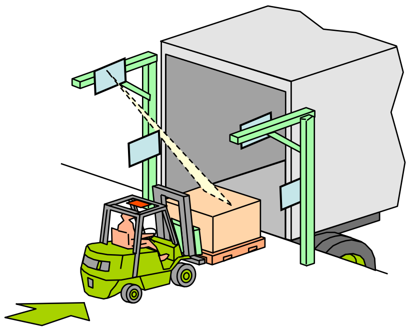
- **June ’03 announcement**
- **Pallet/Case tagging**
  - **-Top 100 suppliers Jan ’05**
  - **-Other 30K by end of ’06**
- **4 Billion tags/year**
- **300k direct readers**
- **18 Million indirect readers**

+

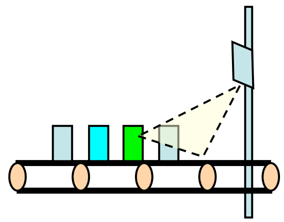
- ***End to end systems***
- ***Complex reads***
- ***Emerging market***

Usage Models

Container, Pallet, Munitions



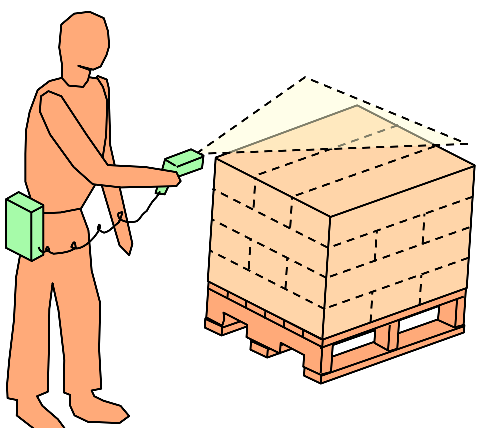
Dock Door



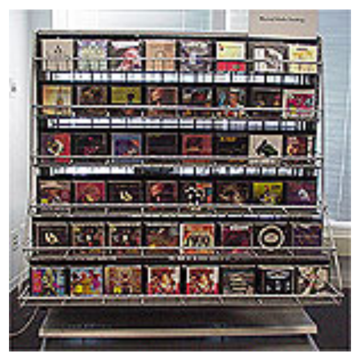
Conveyor Belt

Forklift

Printers



Handheld



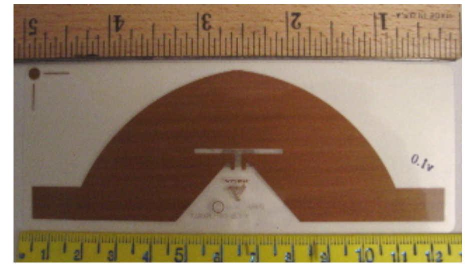
Smart Shelves

Point of Sale

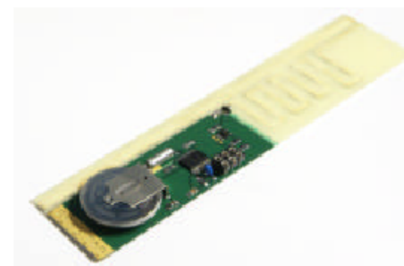
Tags

Types of Tags

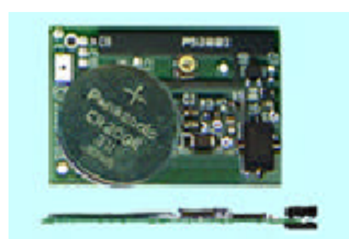
– **Passive**
  - Operational power scavenged from reader radiated power



– **Semi-passive**
  - Operational power provided by battery

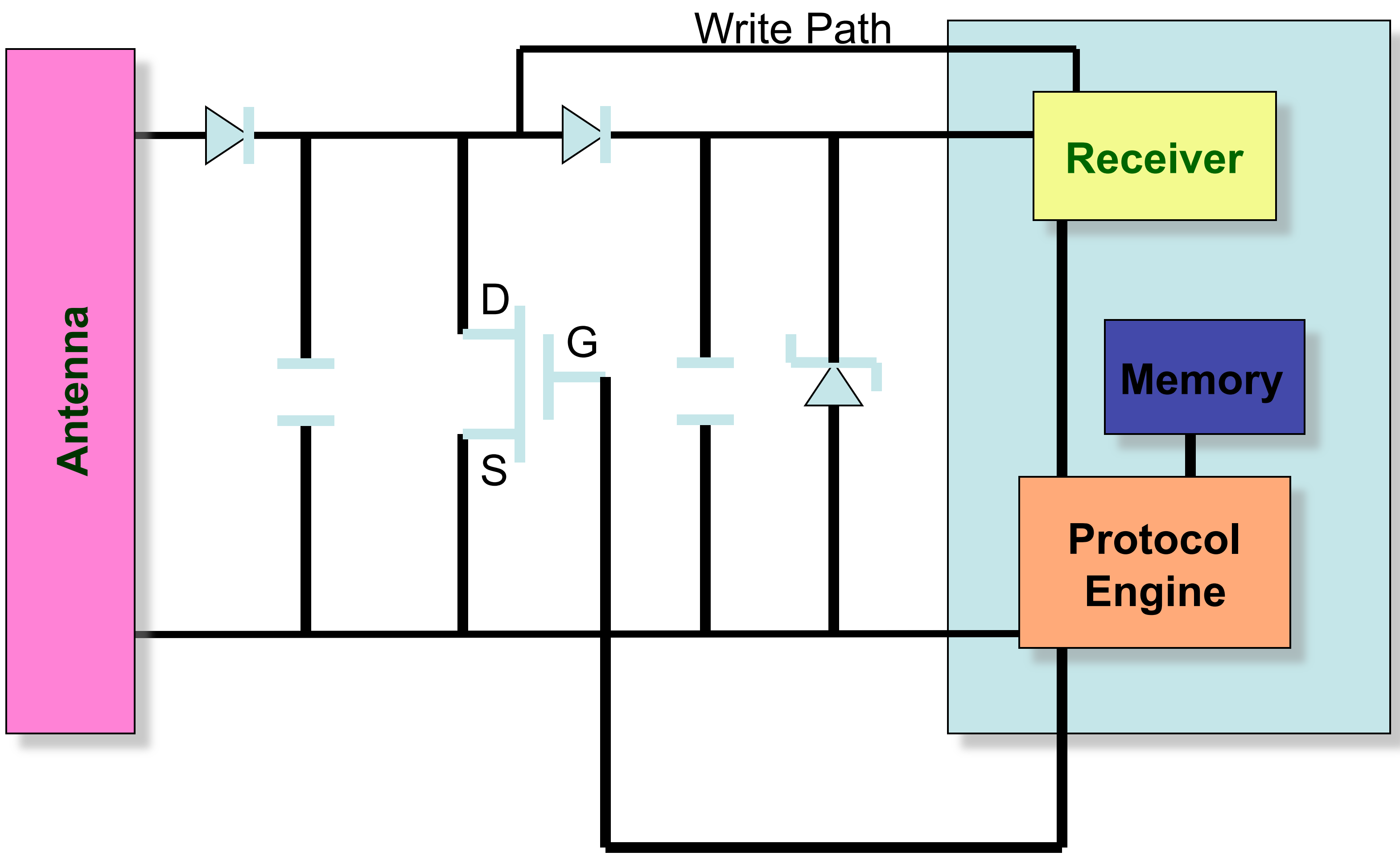


– **Active**
  - Operational power provided by battery - transmitter built into tag

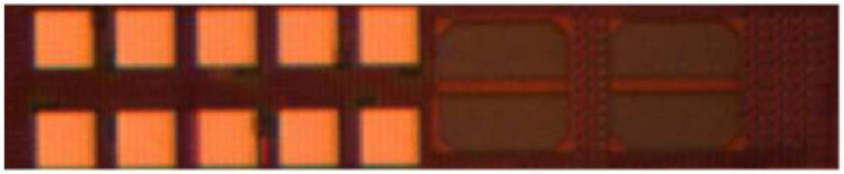


Generic Tag Architecture

(Highly Simplified)



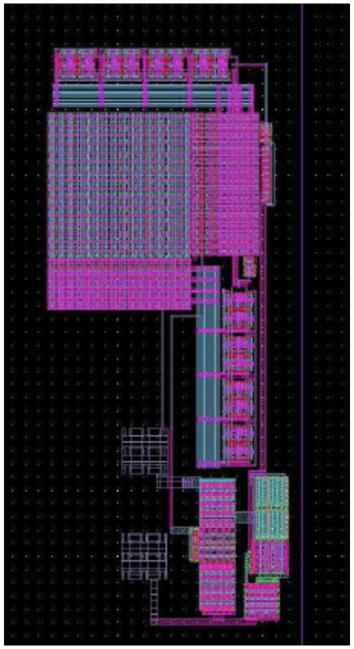
What is on a chip

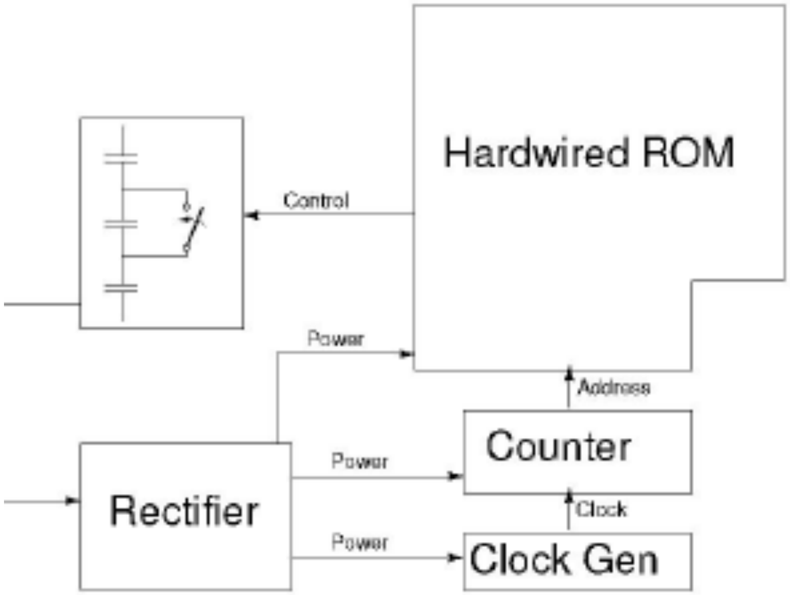


Proceedings of the 41st Annual Conference on Information Sciences and Systems (CISS07), Baltimore, 14-16 March 2007.

Architecture of a μRFID with integrated antenna in 3D SOI-CMOS

Edward Choi* and Andreas Andreou*
*Department of Electrical and Computer Engineering
The Johns Hopkins University, Baltimore, MD
Email: echoi, andreou@jhu.edu



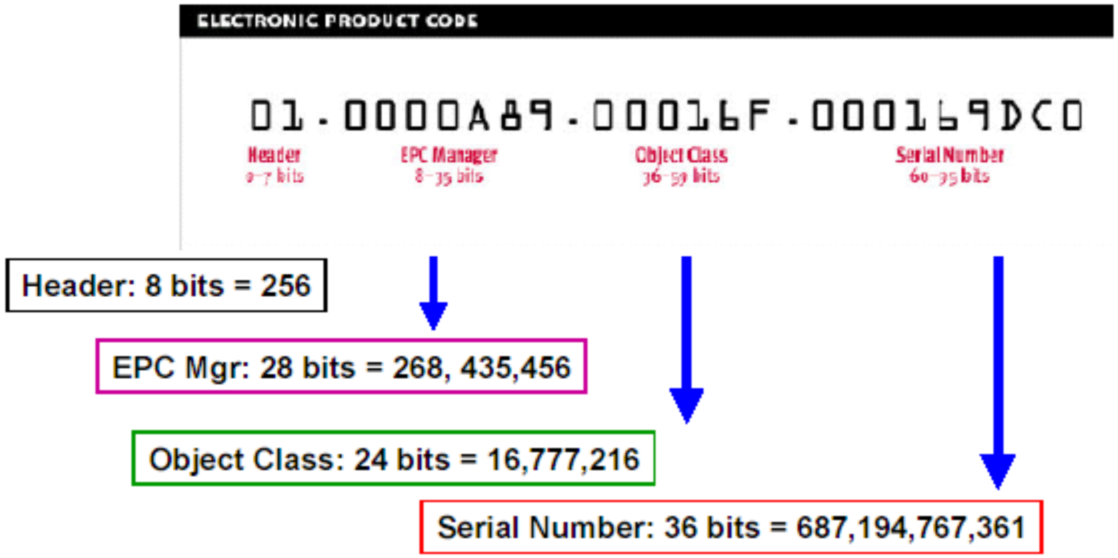


RFID Antennas:

- Gate antennas (orthogonal use)
- Patch antennas
- Circular polarized
- Omni directional antennas
- Stick antennas (directional)
- Di-pole or multi-pole antennas
- Linear polarized
- Adaptive, beam-forming or phased-array element antennas

Electronic Product Code

EPC Data Standard- 96 bit



Header - Tag version number
EPC Manager - Manufacturer ID
Object class - Manufacturer's product ID
Serial Number - Unit ID

With 96 bit code, 268 million companies can each categorize 16 million different products where each product category contains up to 687 billion individual units

Note: 64 bit versions also defined, 256 bit version under definition

Tag Details

	LF	HF	UHF	Microwave
Freq. Range	125 - 134KHz	13.56 MHz	866 - 915MHz	2.45 - 5.8 GHz
Read Range	10 cm	1M	2-7 M	1M
Market share	74%	17%	6%	3%
Coupling	Magnetic	Magnetic	Electro magnetic	Electro magnetic
Existing standards	11784/85, 14223	18000-3.1, 15693,14443 A, B, and C	EPC C0, C1, C1G2, 18000-6	18000-4
Application	Smart Card, Ticketing, animal tagging, Access, Laundry	Small item management, supply chain, Anti-theft, library, transportation	Transportation vehicle ID, Access/Security, large item management, supply chain	Transportation vehicle ID (road toll), Access/ Security, large item management, supply chain

Competing UHF Protocols (EPC only)

	Read Rate	Read or Read/Write	Tag Cost	Privacy	Security	Global Standard
Class 0	NA: 800 reads/sec EU: 200 reads/sec	Read Only	$$	24 bit password	Reader broadcasts OID or Anonymous modes with reduced throughput	No
Class 0+	NA:800 reads/sec EU:200 reads/sec	Read & Write	$$	See above	See above	No
Class 1	NA:200 reads/sec EU: 50 reads/sec	Read & Write	$	8 bit password	Reader broadcasts partial OID	No
Class 1 Gen 2* (UHF Gen2)	NA:1700 reads/sec EU: 600 reads/sec	Read & Write	?	32 bit password and concealed mode	Authentication and Encryption	Yes

*** Class 1 Gen 2 is still in development, expected to close in Q4, 2004**

Class 0 Protocol

Backscatter	North America
Class 0 Tag Backscatter Frequency	3.3 Mhz for data "1" 2.2 Mhz for data "0"
Modulation Format	FSK

Typical data stored in tag:

- 96 bit EPC code
- 24 bit kill code
- 16 bit Cyclic Redundancy Check (CRC)

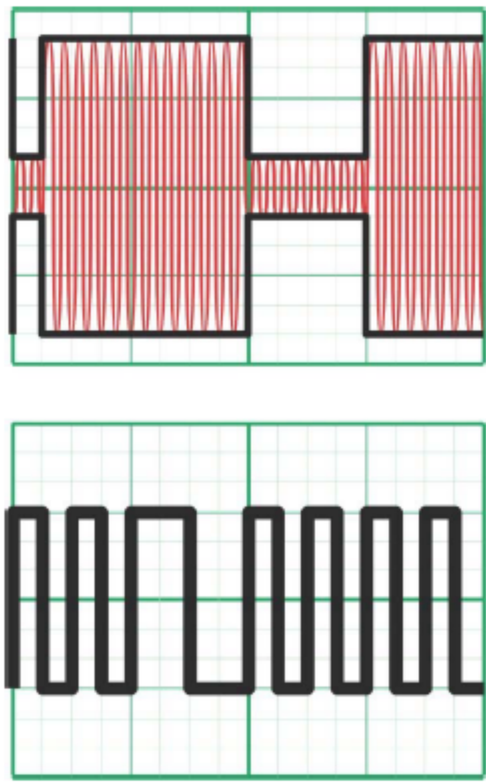
Reader/tag communication modes:

1. Start up signals (power up tags and sync. with them)
2. Tree Traversal (read individual tags)
3. Communication (send commands to tags)

Data rates: fast and slow defined: fast (12.5 micro sec bit period) and slow (62.5 micro second bit period) --- either 20% or 100% modulation depths

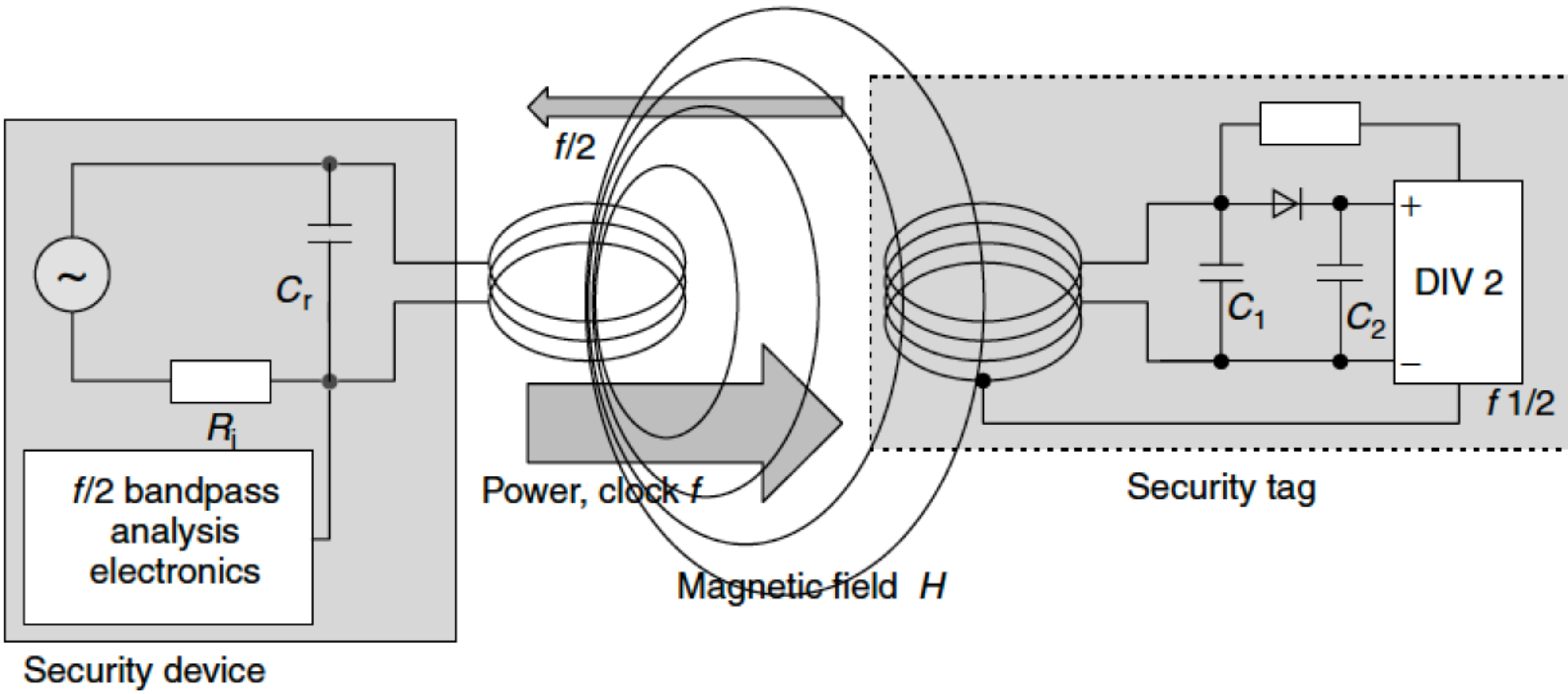
Class 0 Signaling

EPC : Reader-tag Communication



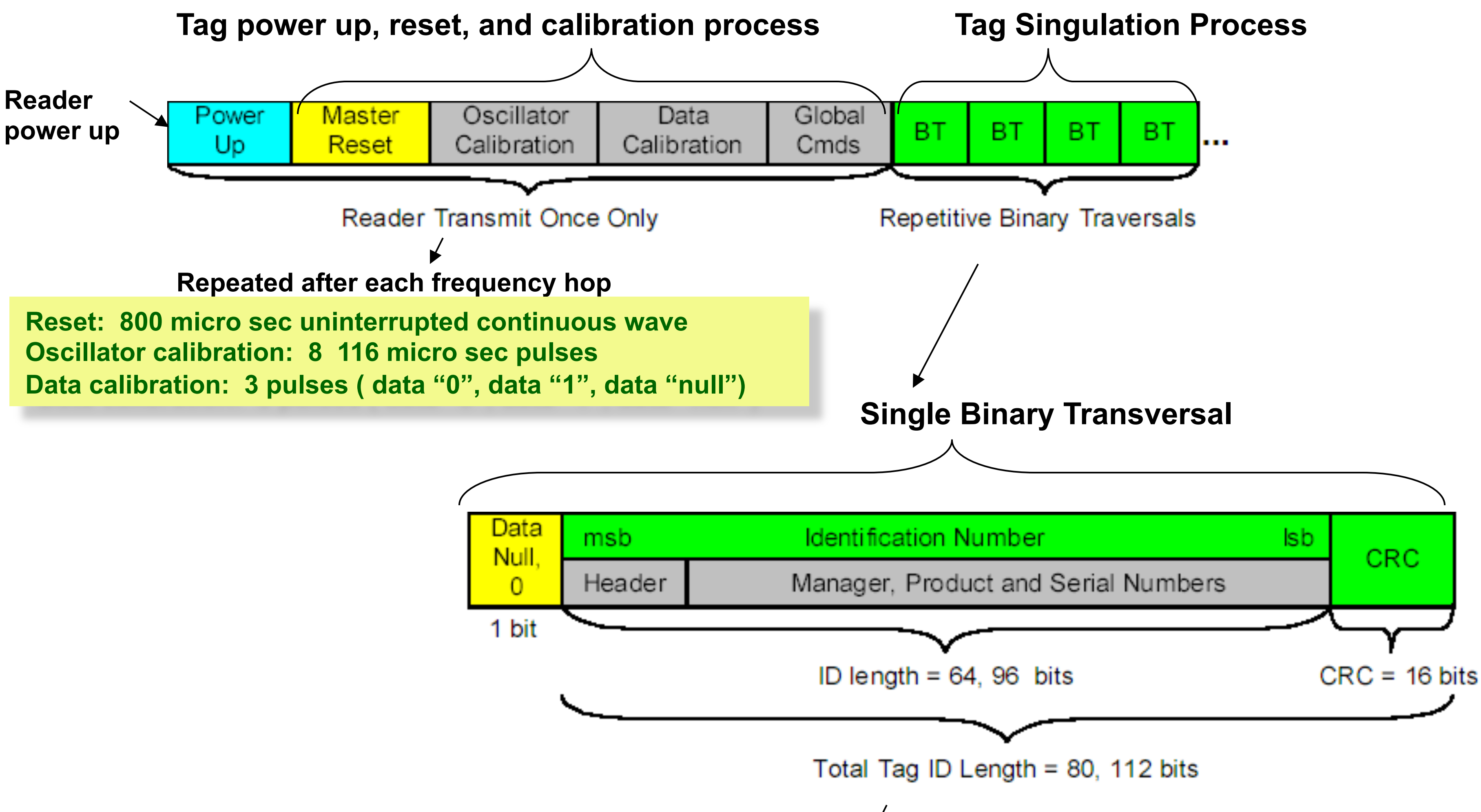
- Reader to tag communication (AM)
  - Output RF power is modulated between full and fractional power
  - 50% duty cycle is binary ‘1’
  - 88% duty cycle is binary ‘0’
    - Picture at left shows ’01’
      Tag to reader communication
- Tag responds by FM
  - 2 cycles of modulation in one data bin is a binary ‘1’
  - 1 cycle of modulation is a binary ‘0’
    - Picture at left shows ‘1011’

Basic Architecture



Frequency	130 kHz
Modulation type:	100% ASK
Modulation frequency/modulation signal:	12.5 Hz or 25 Hz, rectangle 50%

Default Class 0 Reader Communication Sequence



Once tag has been singulated, reader can send commands to it or begin next BT cycle

Tag Singulation Process

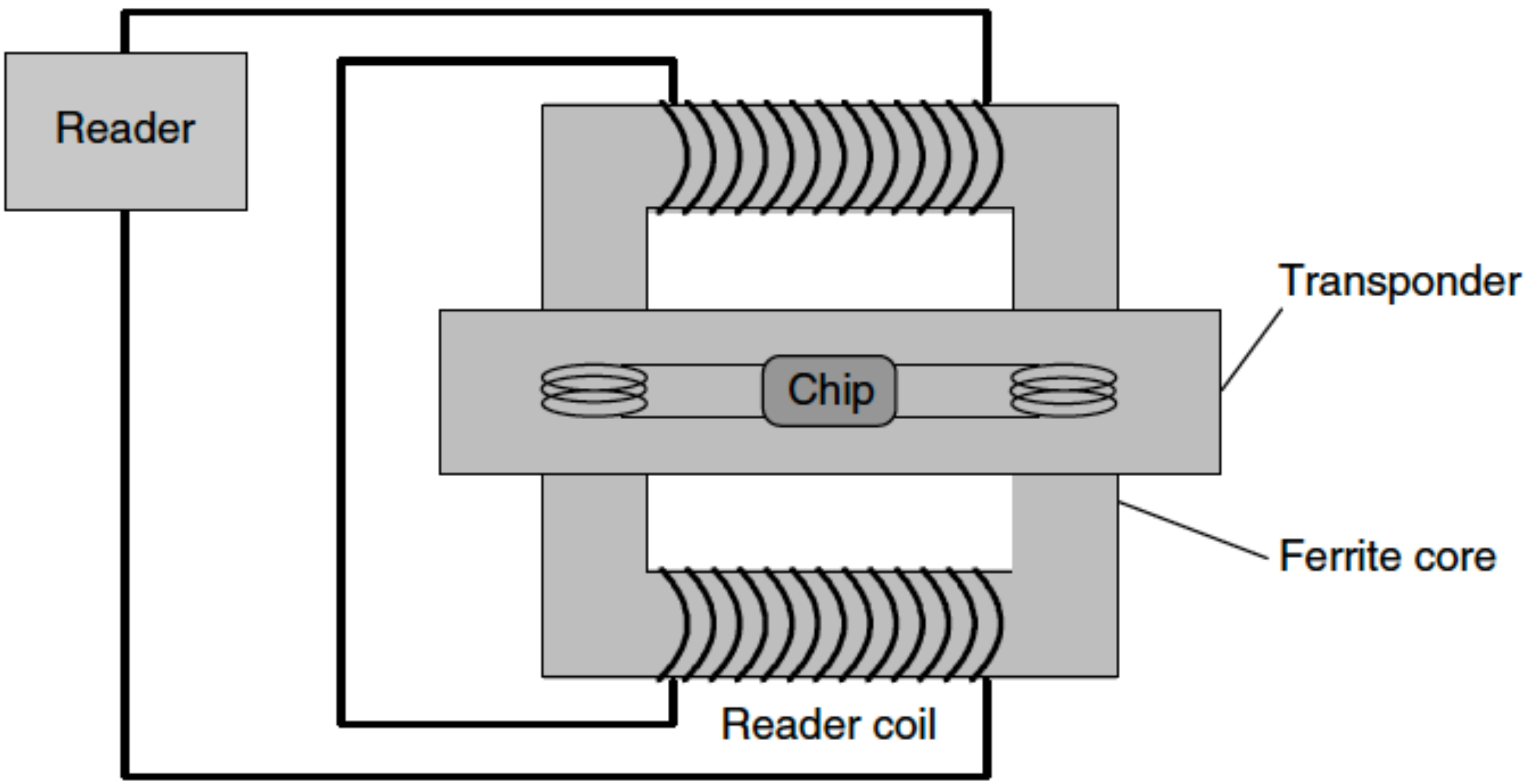
read individual tag from group of all tags in range of reader

Basic process:

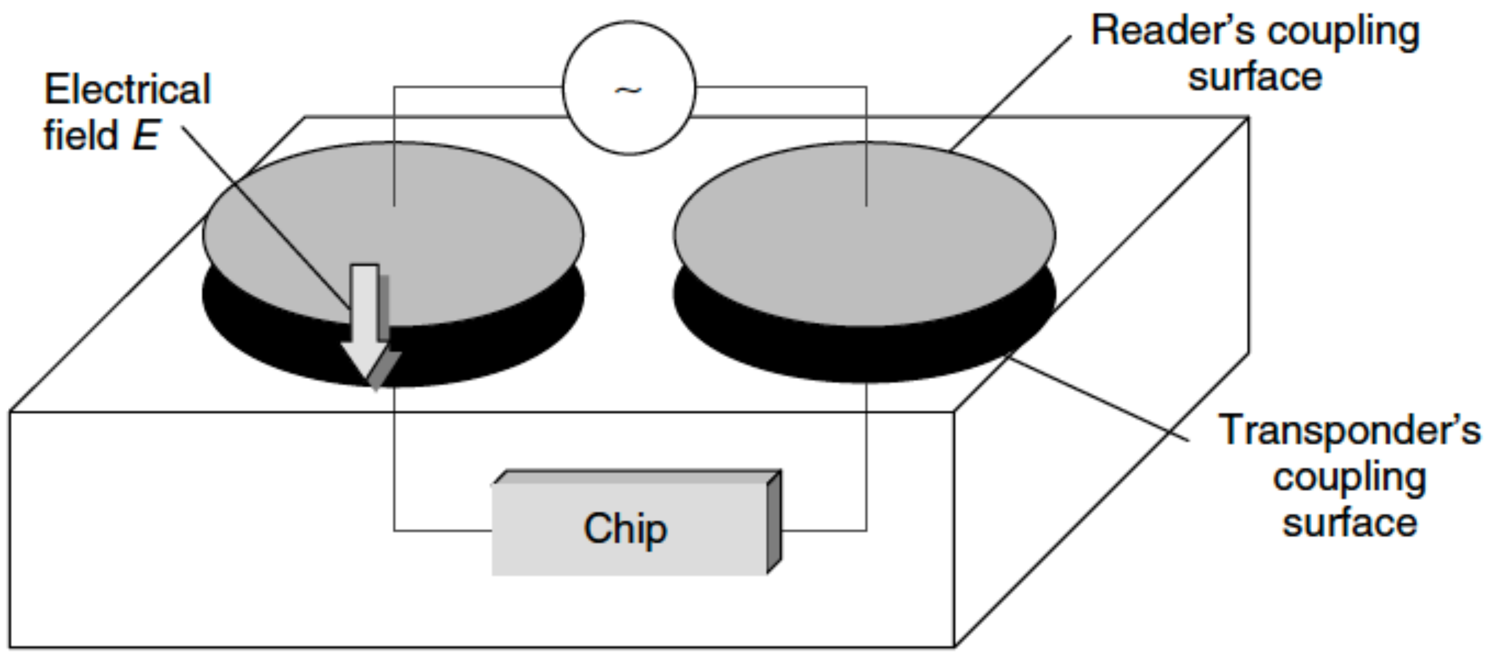
1. All tags within range of reader backscatter their MSB to the reader.
2. Reader responds with either a 1 or a 0.
3. If tag bit equals reader bit, tag backscatters the next bit in it's code . If instead, tag bit does not equal reader bit, tag goes mute for remainder of singulation.
4. Process continues until reader has completely read a single tag.
5. Reader conducts consecutive singulations until all tags in its range are read.
6. Reader can interrupt the singulation process to send commands to a single tag, a subset of all tags in range, or globally to all tags in range.

Readers

Close coupled magnetic reader



Close coupled capative reader



UHF Reader Standards

GEO / Country	Frequency Band
North America	900 – 930 MHz
EMEA	866 – 868 MHz
Korea	908.5 – 914 MHz
Australia	918 – 926 MHz
China (PRC)	TBD
Japan	TBD

Transmitter	North America
Output Freq. Band	902 – 928 Mhz
Output Power	4 watts EIRP
TX Channel step	500Khz
Hop frequency	2.5 to 20 times per second
TX Channels	902.75, 903.25, …, 927.25Mhz
Modulation	Typically ASK –- 20% to 100% modulation depth

Note: EIRP = 1.64X ERP (Effective Radiated Power)

Reader Implementation Challenges

- Reader must deliver enough power from RF field to power the tag
- Reader must discriminate backscatter modulation in presence of carrier at same frequency
- 70db magnitude difference between transmitted and received signals
- Interference between readers
- Hugh volume of tag data – readers need to filter data before releasing to enterprise network

RFIDs Today!

- **Cost:**
  - **Tags - currently 50 cents – need to be 5 cents or less**
  - **Readers – currently thousands of dollars – need to be hundreds of dollars**
  - **Implementation – distribution centers relatively low tech – need networking, power, etc.**
    - **Cost benefit - must be significant enough to justify RFID cost:**
      - **Retailers operate with small margins (< 5%). If RFID can increase operational efficiency by 1% = major competitive advantage**

- **Read accuracy:**
  - **accuracy not established – needs to approach 100%:**
    - **Metal containers, liquids, Etc. impact tag readability**
    - **Taq/reader orientation: polarization effects**
    - **Reader configuration: cooperative networks of readers**
    - **Interference from other readers and other radiators**

- **Design Robustness:**
  - **Needs to be robust enough to survive/function in warehouse environments**

- **Security:**
  - **Read security, Data security, etc.**

- **Privacy:**
  - **See next slide**

Privacy Issues

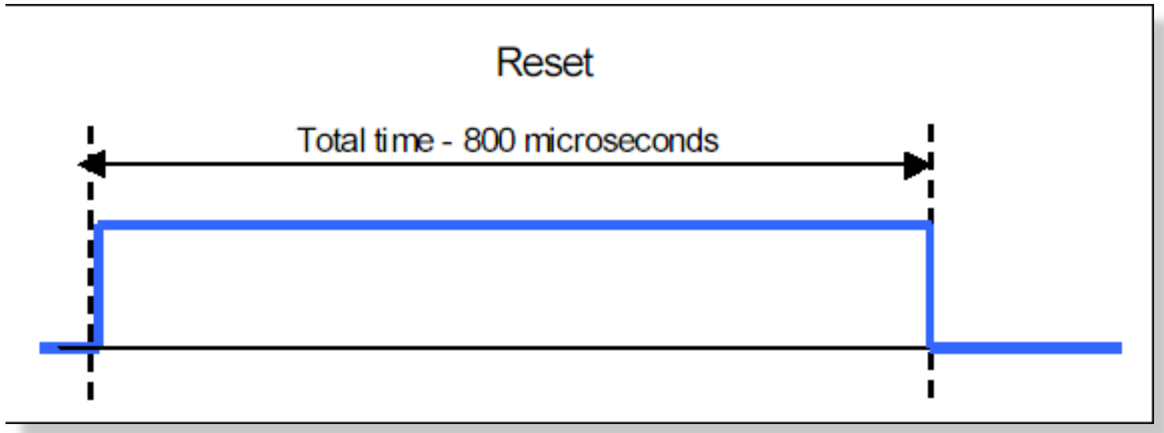
10-17-04

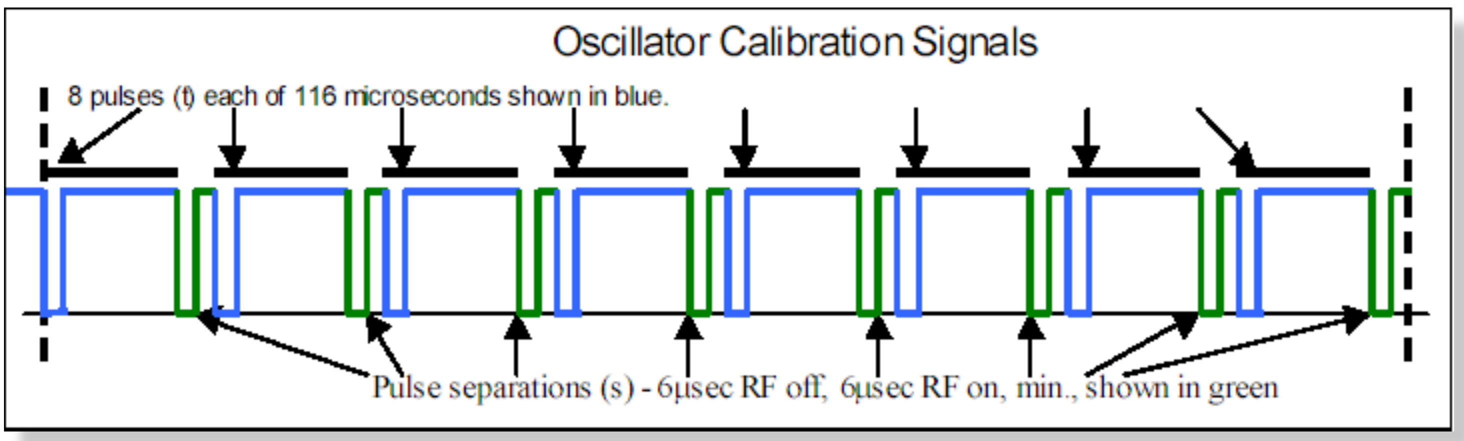
The Future

- **What fundamental changes does RFID herald in?**
- **What are the probable consequences of these changes?**

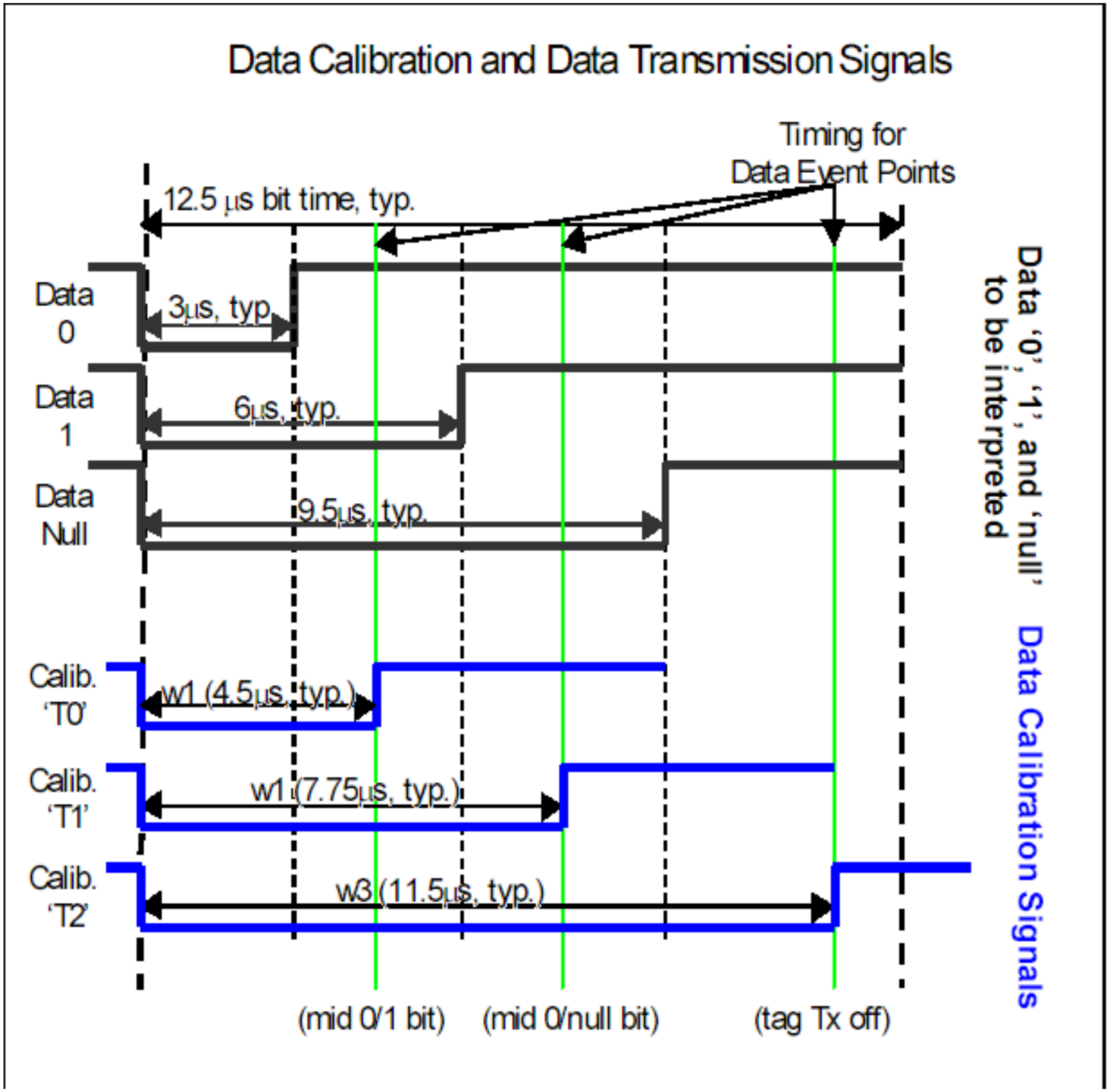
Protocol Details

Class 0 Tag Start-up Signals: Reset and Oscillator Calibration

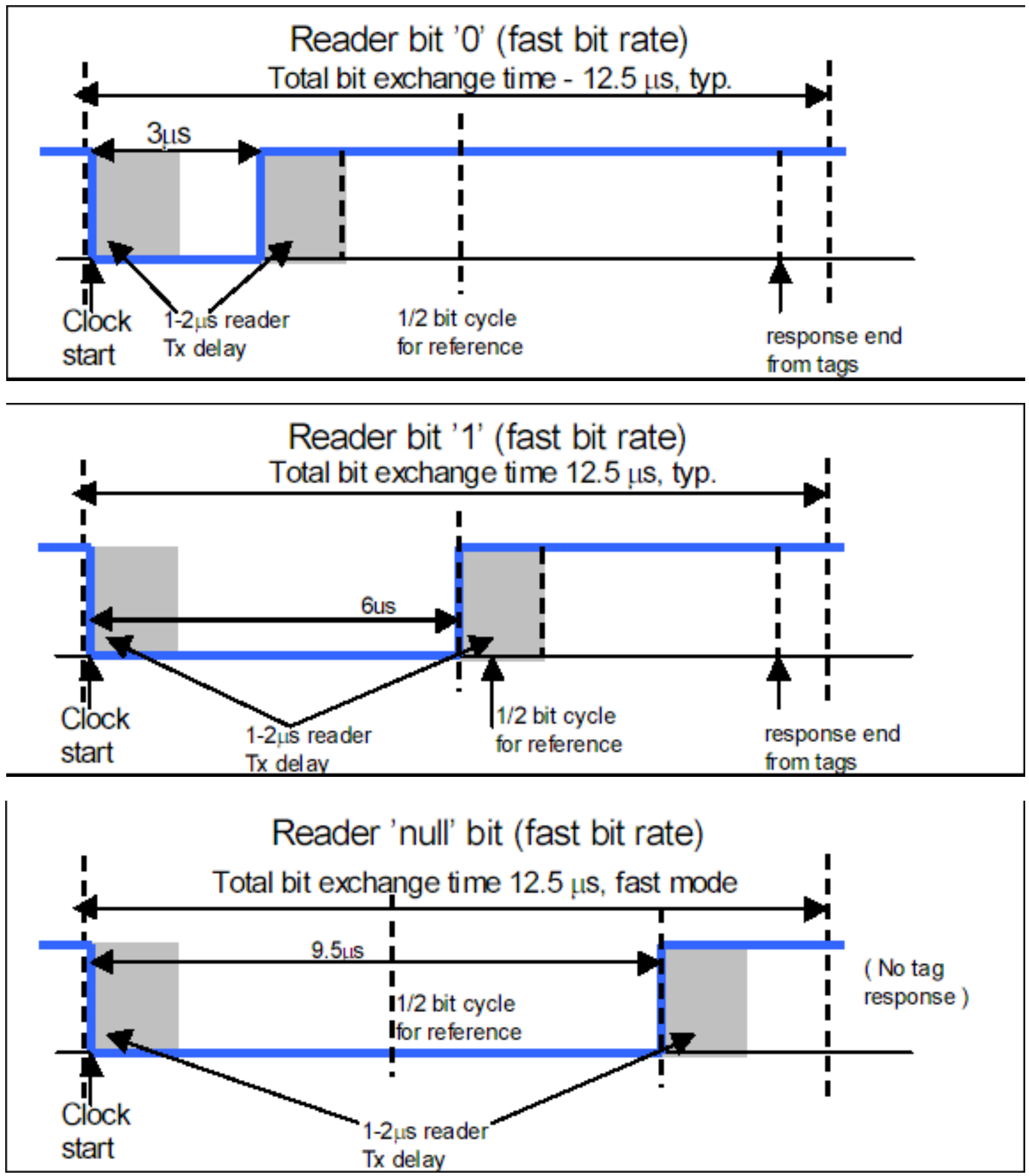




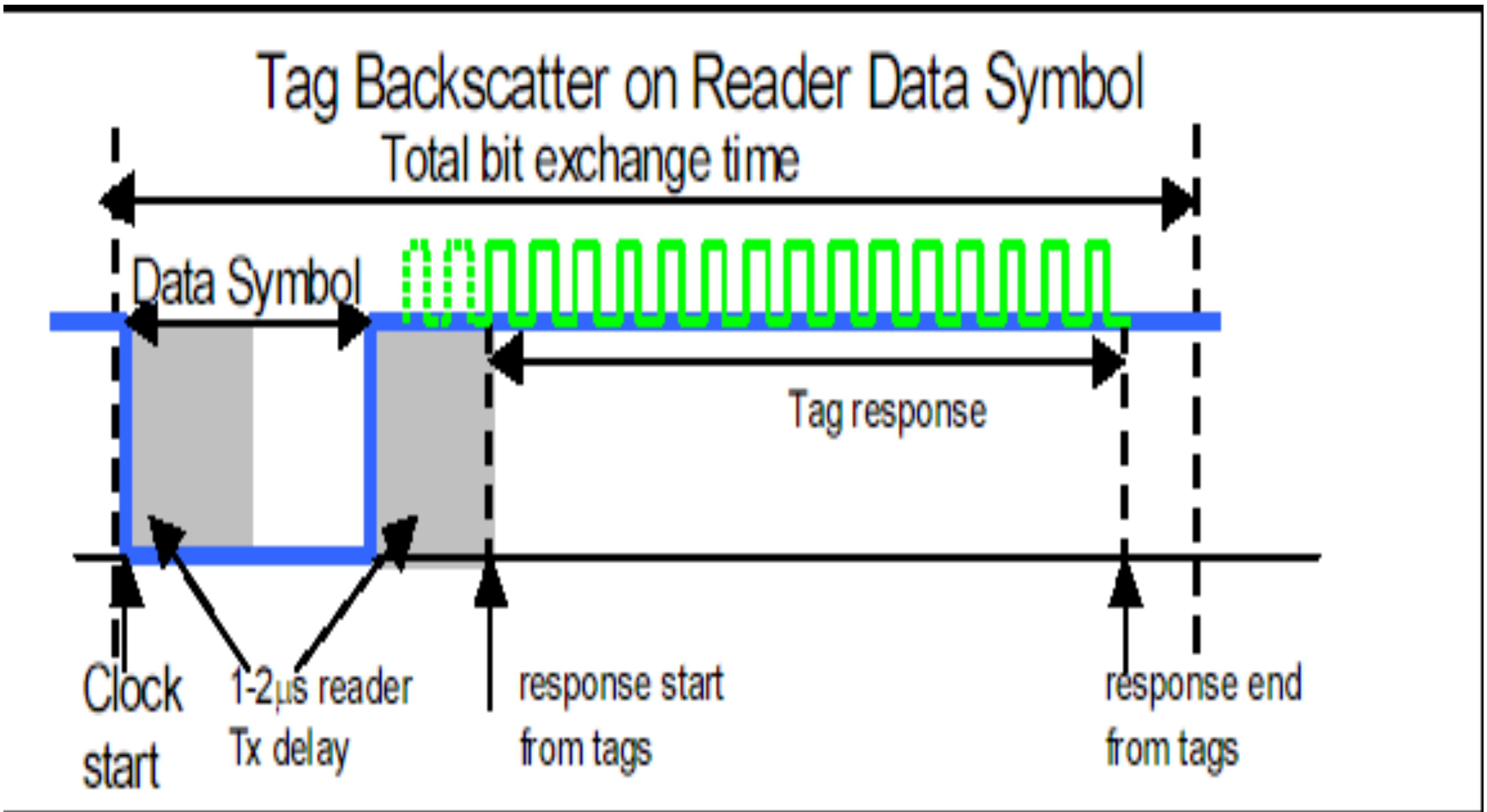
Class 0 Tag Start-up Signals: Data Calibration



Reader Bit Definitions



Tag Backscatter



Possible Reader/Tag Communication Pairs