

RFID

Radio Frequency Identification

RADAR Technology for Commodity Goods

Raj Bridgelall

Symbol Technologies

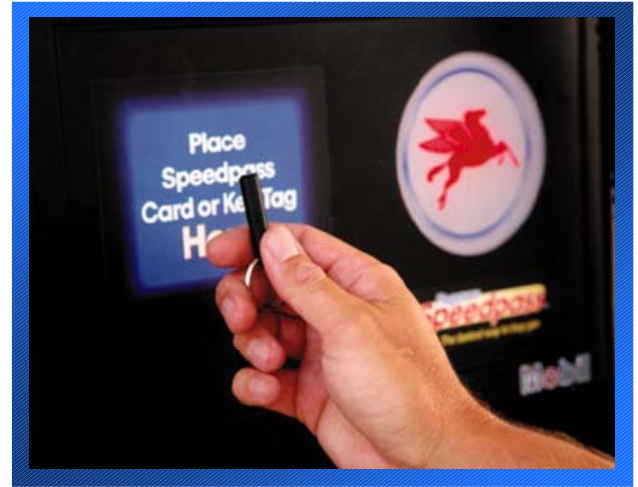
January 2004

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Have You Used RFID Before?



Automated Toll



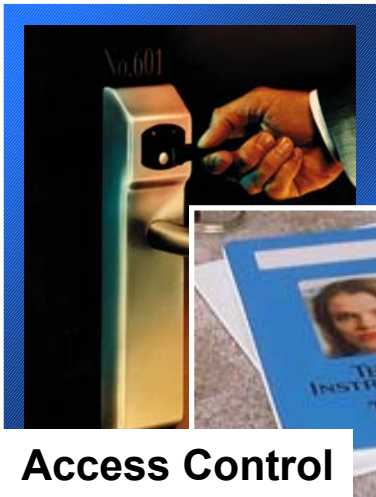
**Mobil Speedpass™
Freedom Pay™**



Smart Cards



Automotive Security



Access Control



Retail Security Tags

Spectrum of Data-Capture Technologies

Manual ID, Short Range, Small Memory

Unattended ID, Long Range, Large Memory

Functionality ↑

Cost →

1D Barcode
• Lowest Cost

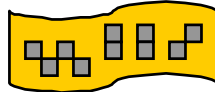


2D Barcode
• Larger Data Capacity
• Greater Data Integrity



Magnetic Stripe
• Durable
• Data Hiding

Chip-less Tags
• Non-Line-of-Sight
• Limited cingulation



Passive Tags

- R/W Memory
- Non-Line-of-Sight
- Simultaneous ID
- Rugged

~900 MHz

13.56 MHz

<135 kHz

Semi-Passive



Active



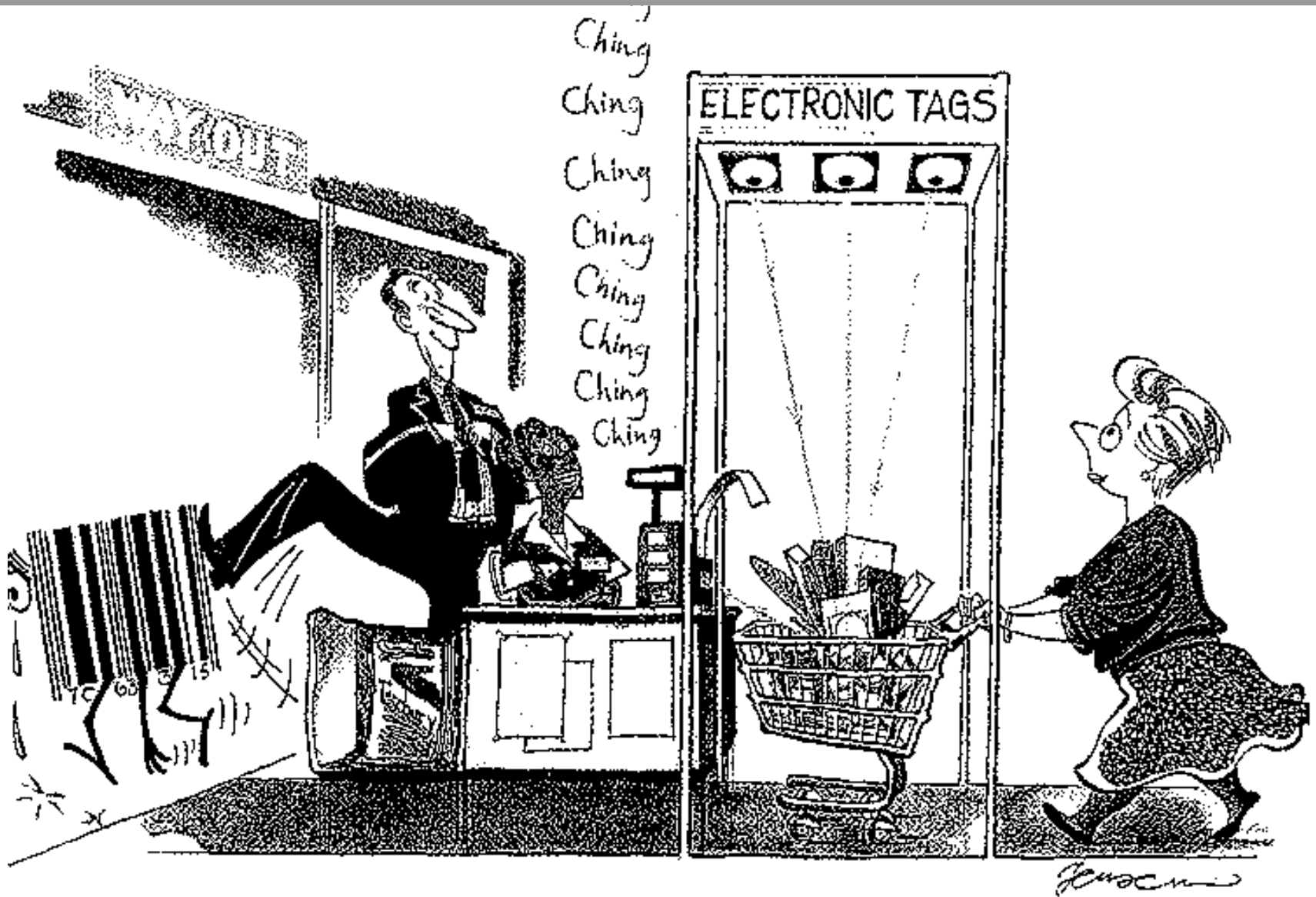
Battery-based Tags

- Much longer range
- Location Finding
- Larger R/W Memory
- Non-Line-of-Sight
- Simultaneous ID

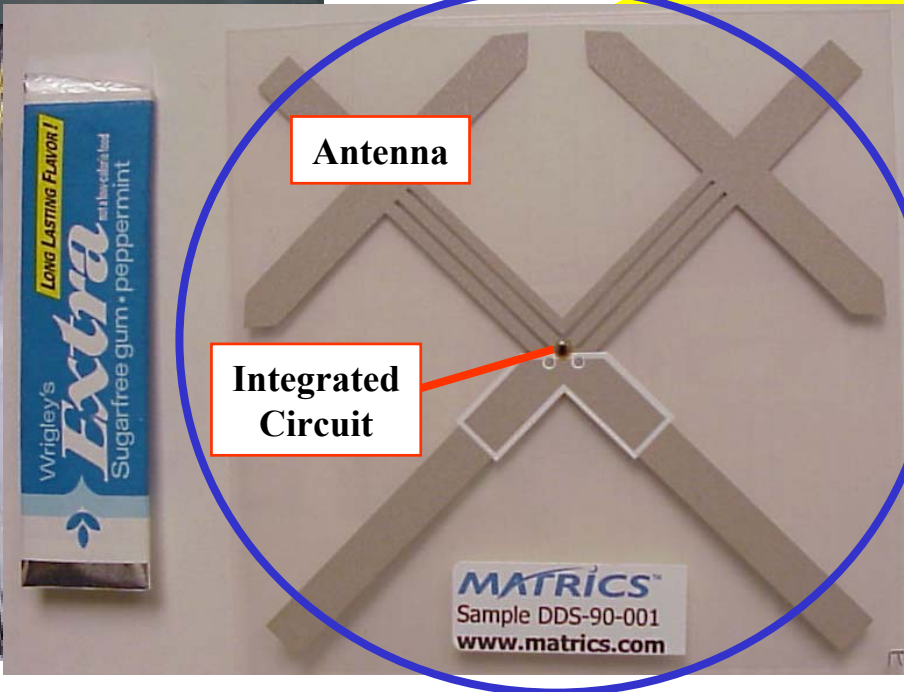
But ...

- Most expensive
- Short useful life
- Less Rugged

Will This Ever Happen?

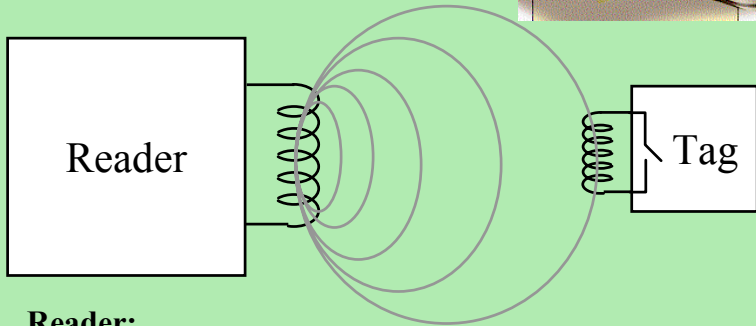
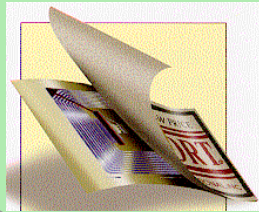


RFID Behind The Scenes



Modes, Types, and Classes of RFID Technology

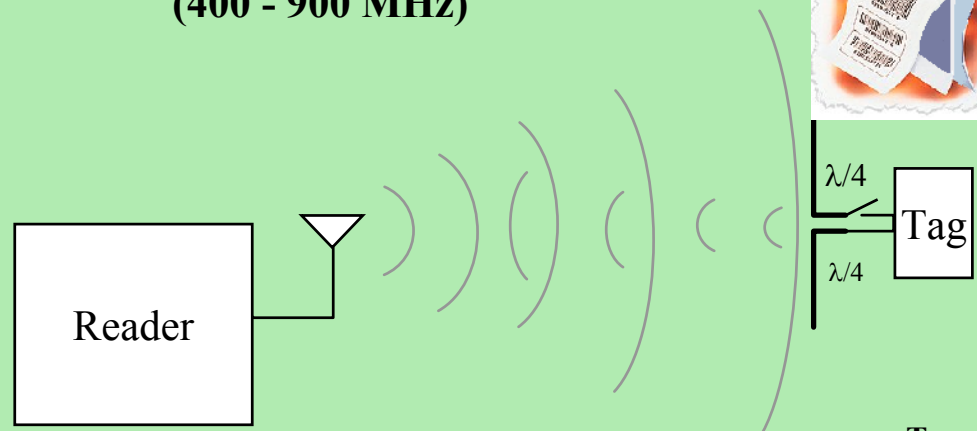
B-Field Mode Inductive Systems (125 kHz & ~13MHz)



Reader:
Detects Load Modulation

Tag:
Modulates Inductive Coupling

E-field Mode Propagation Systems (400 - 900 MHz)



Reader:
Detects Changes in Voltage Standing Wave Ratio

Tag:
Reflects EM

Types	Power	Communication	Cost
Passive	Beam	Backscatter	\$0.15 – \$0.50
Semi-passive	Battery	Backscatter	\$0.80 - \$2
Active	Battery	Radiated EM	\$8 - \$75

EPCglobal

Class 0: Read-Only

Class 1: WORM

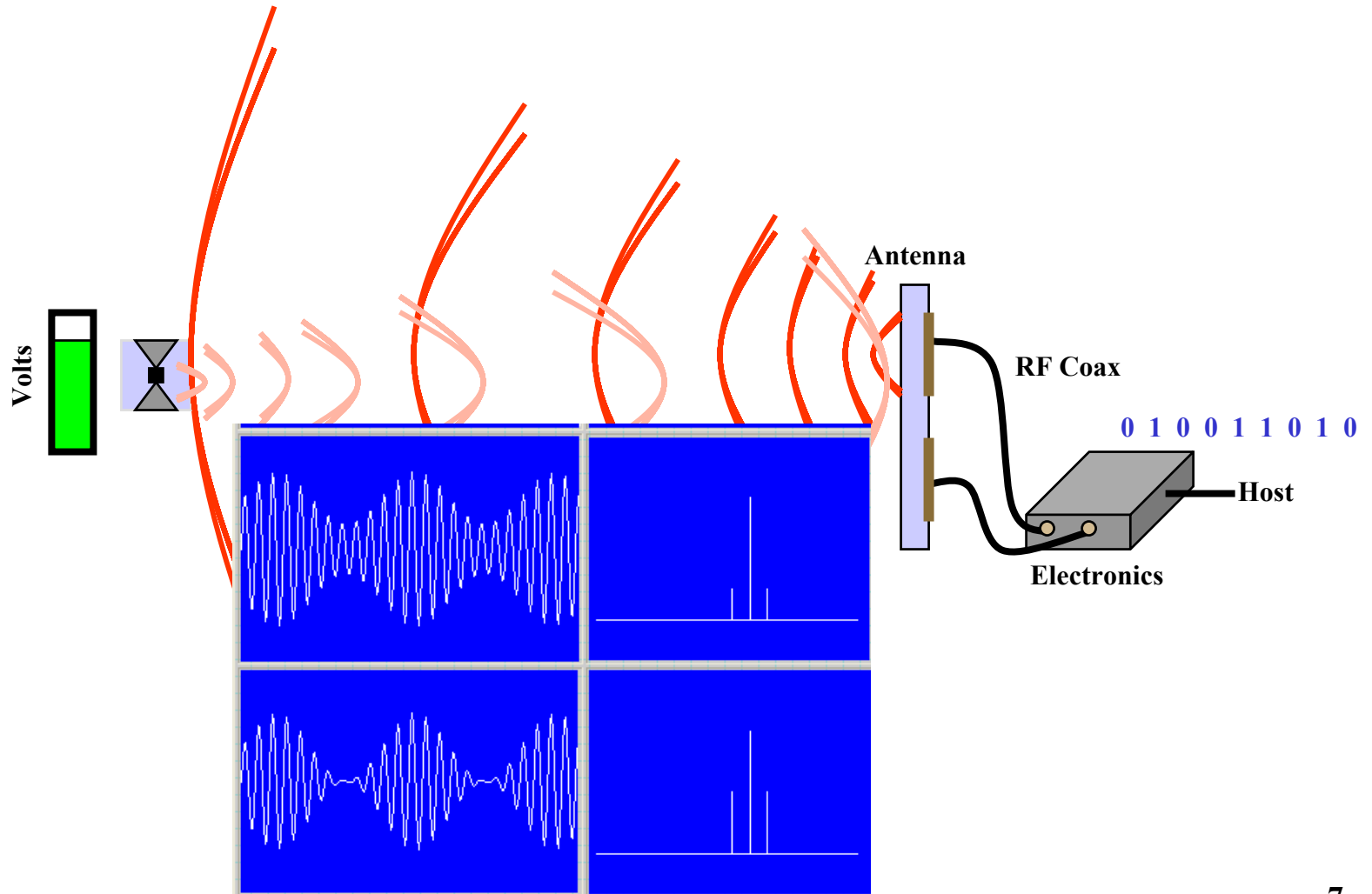
Class 2: Read-Write

Class 3: Sensors

Class 4: Wireless Nodes

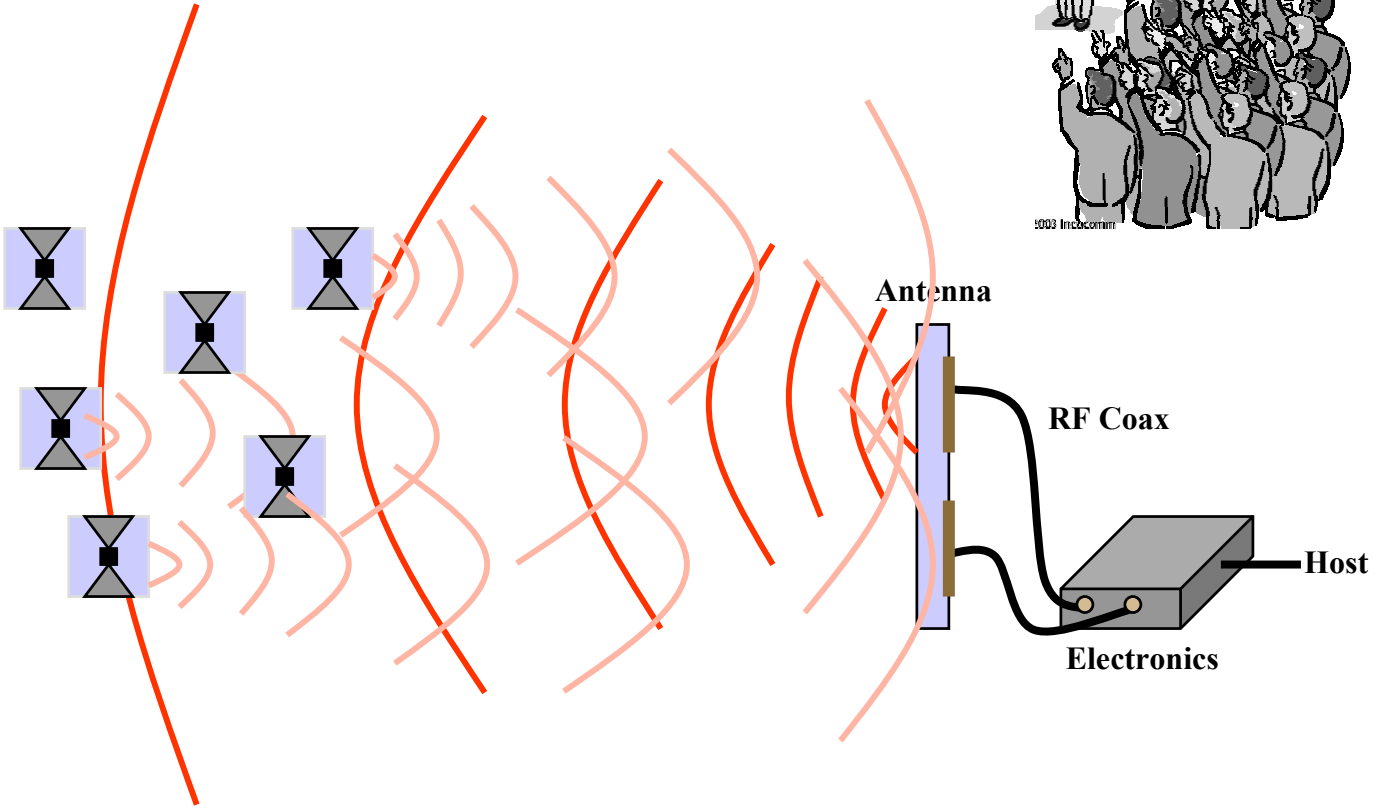
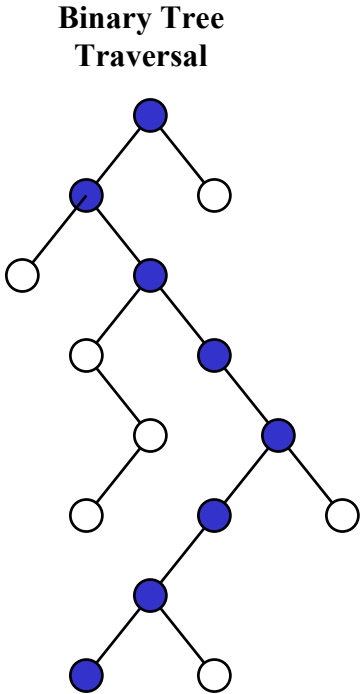
How Does Passive RFID Work?

Single Tag Communications



How Does Passive RFID Work?

Multiple Tag Communications



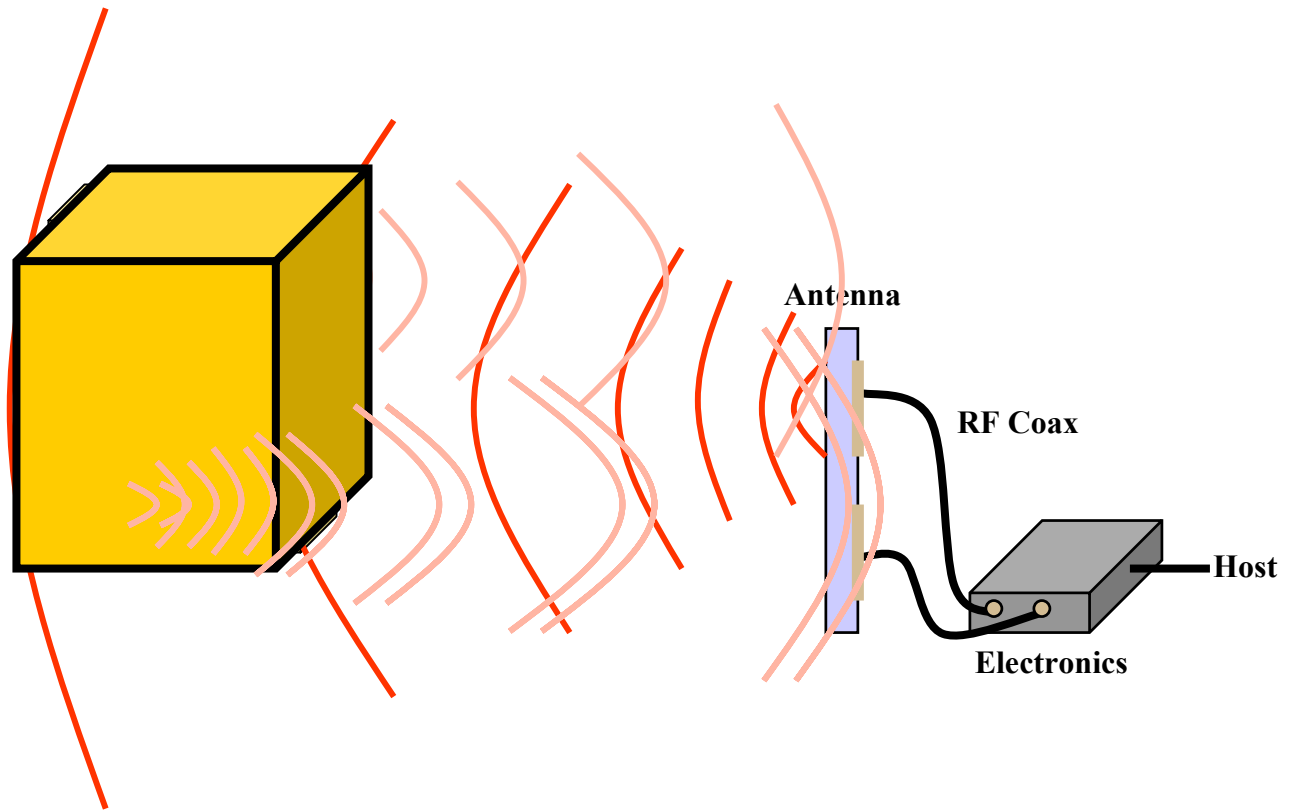
TDMA



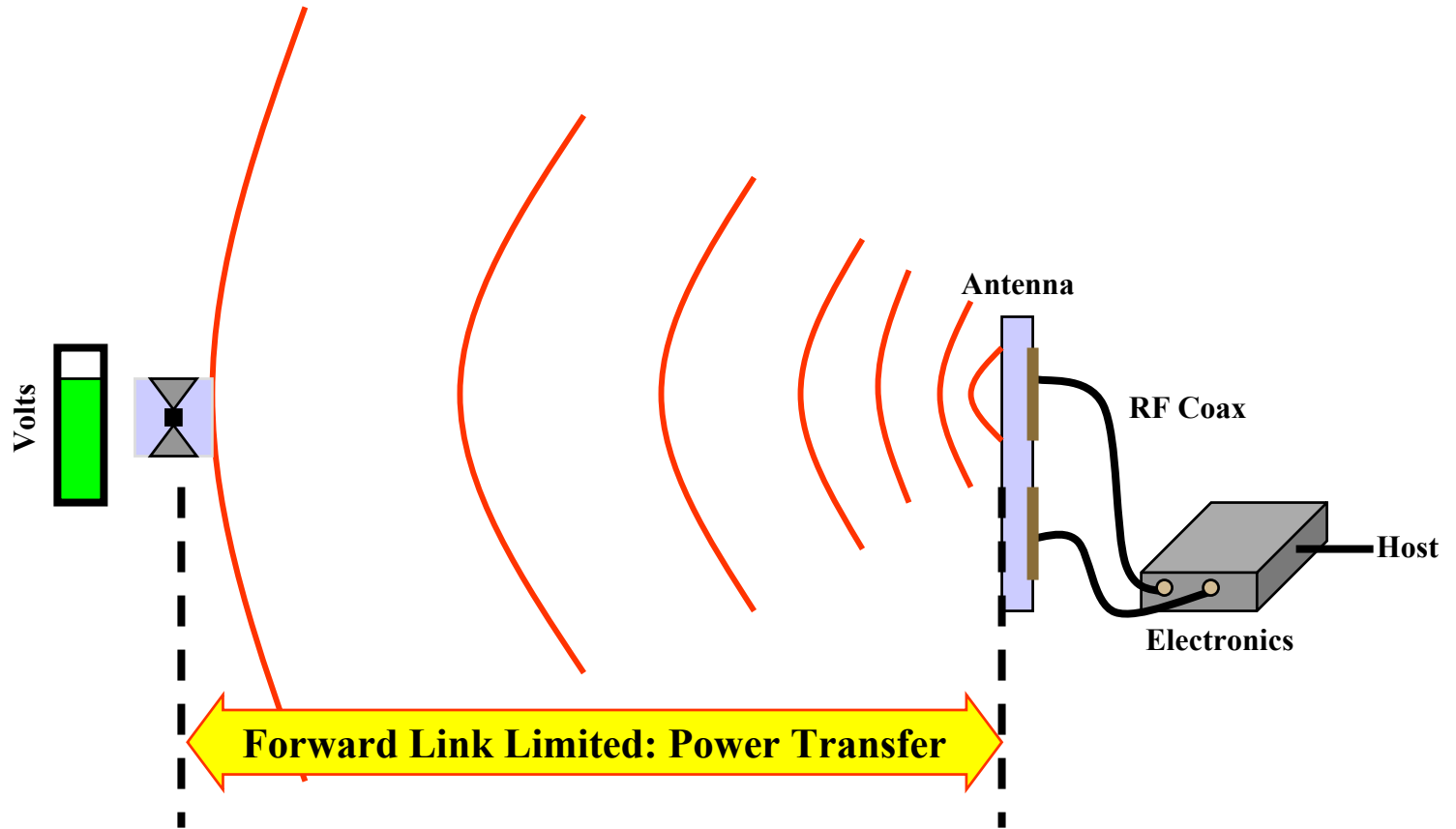
TS: Begin ... End
TS: Assignment

How Does Passive RFID Work?

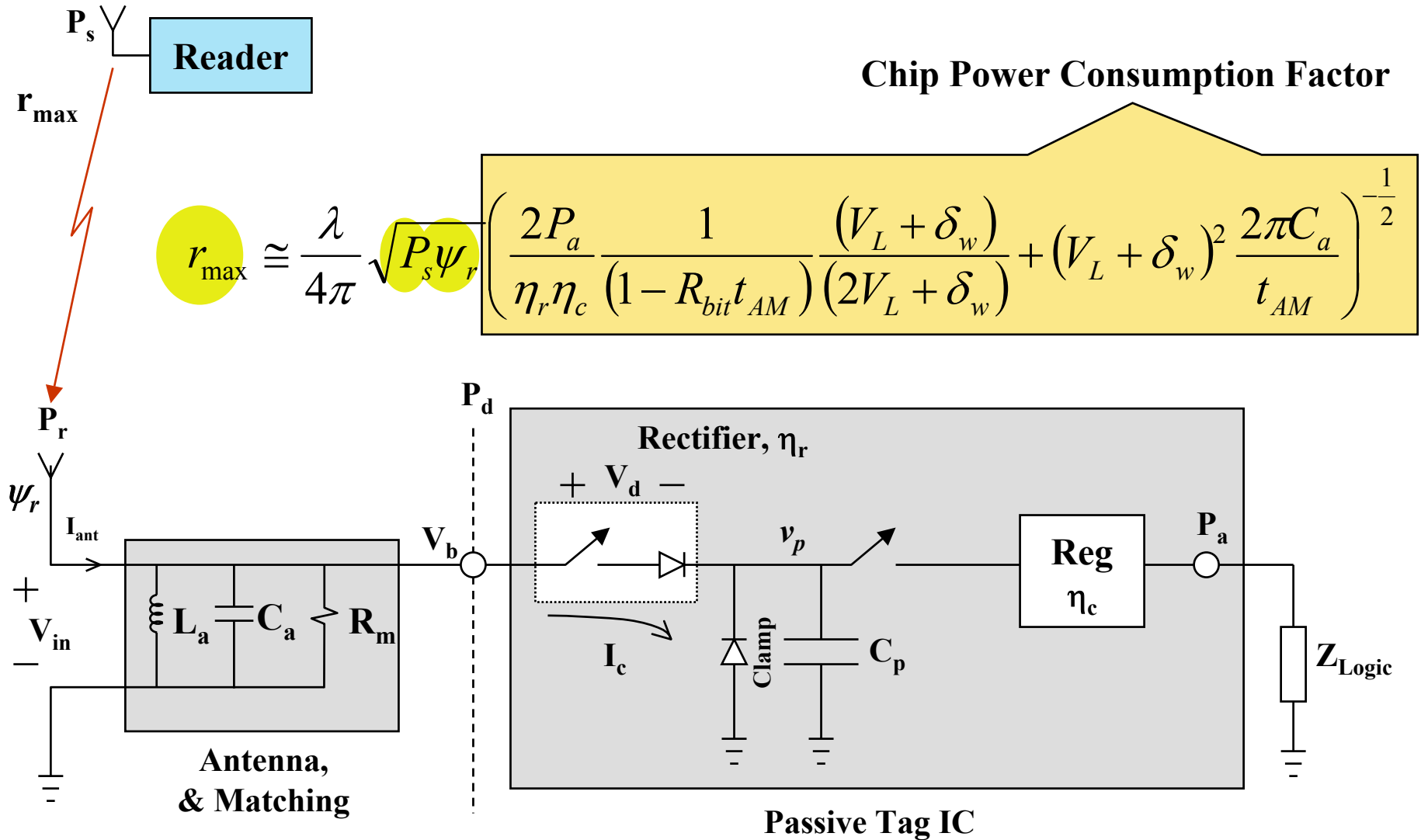
Non-Line-of-sight



Maximum Range for Passive Tags



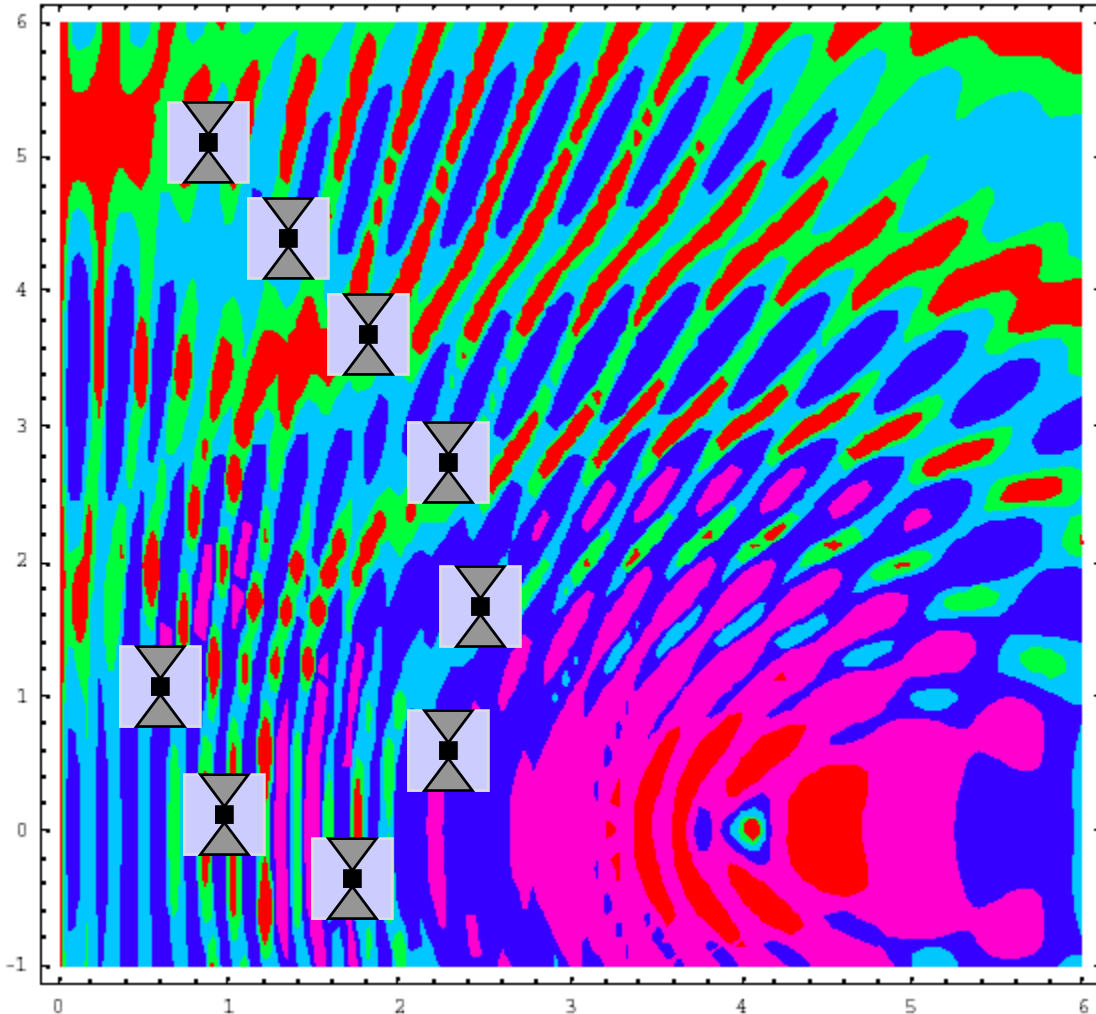
Passive Tag Range is Forward Link Limited



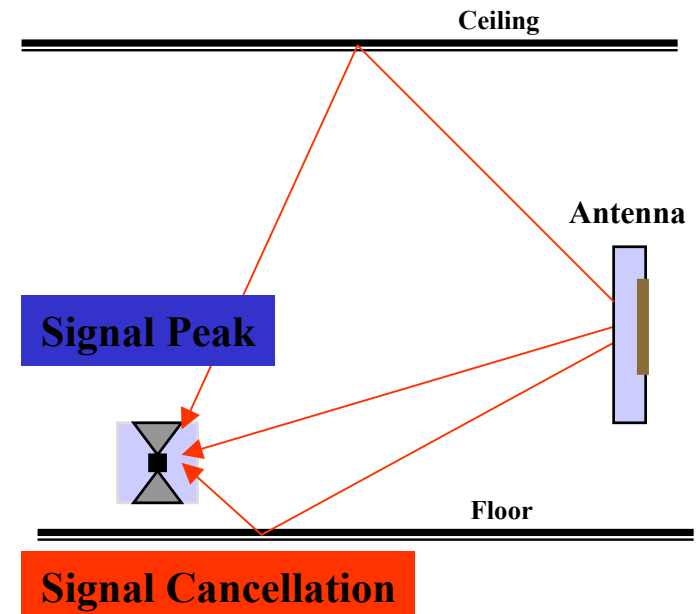
Reference: Bridgelall, R., "System Optimization for Passive RF Sensors," Patent Application, April 2004

Power Distribution in a Multipath Environment

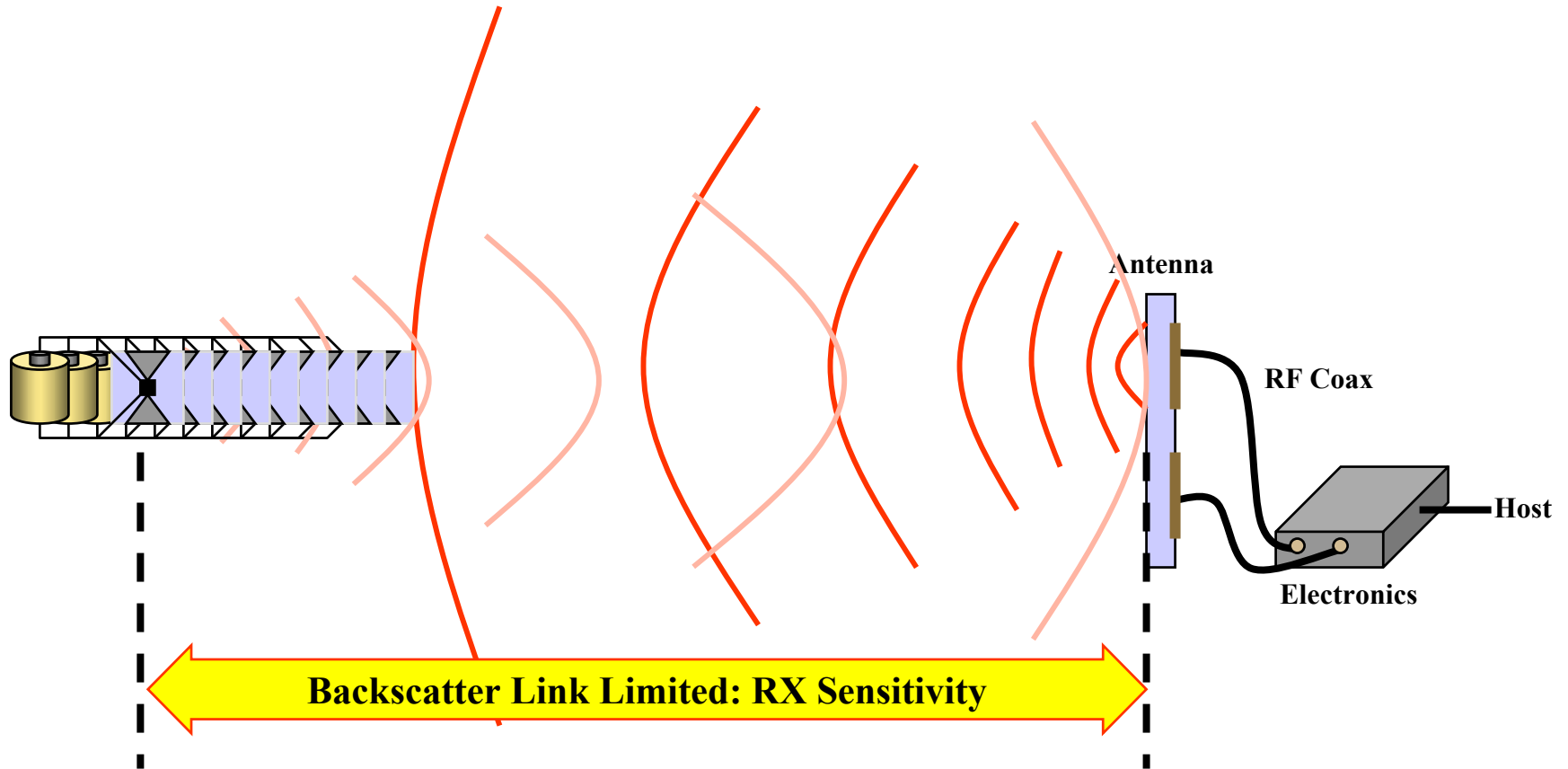
Power Distribution at 868 MHz



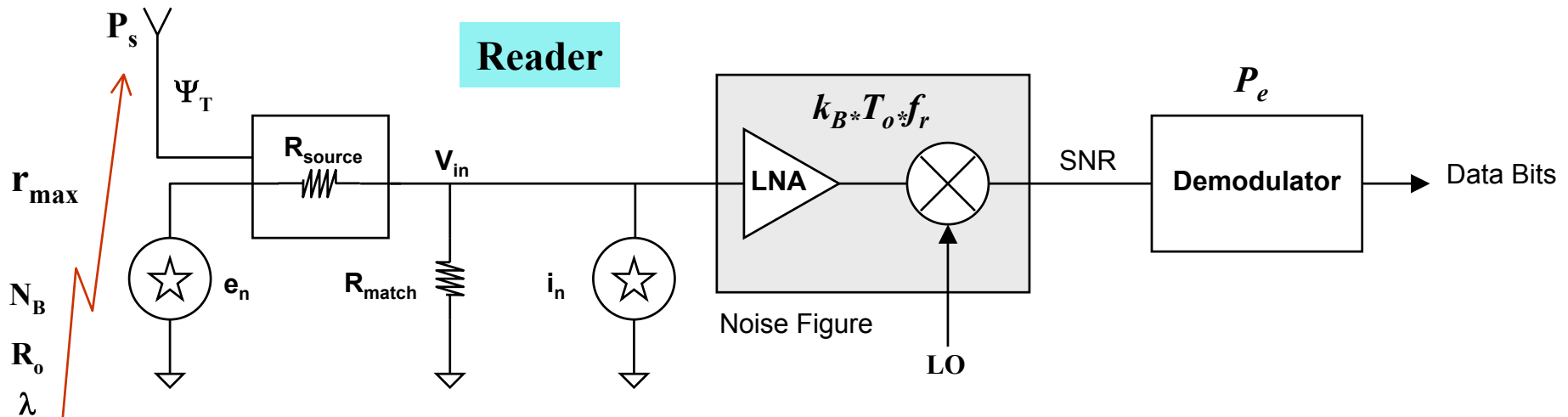
Palomar, Anu-Leena Annala, et al.



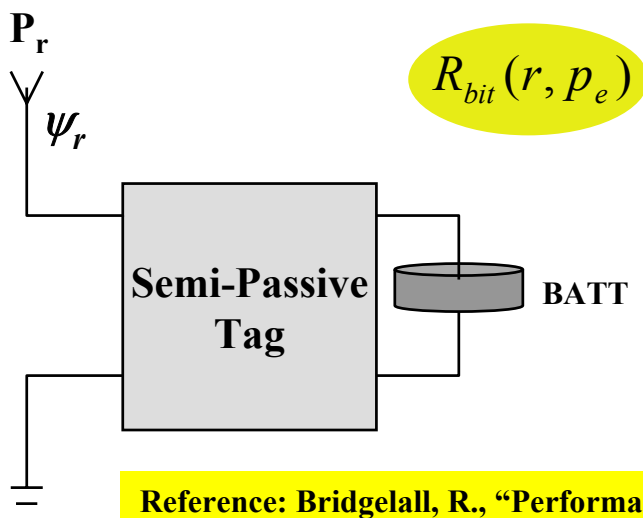
Maximum Range for Semi-passive Tags



Semi-Passive Tag Range is Backscatter Link Limited



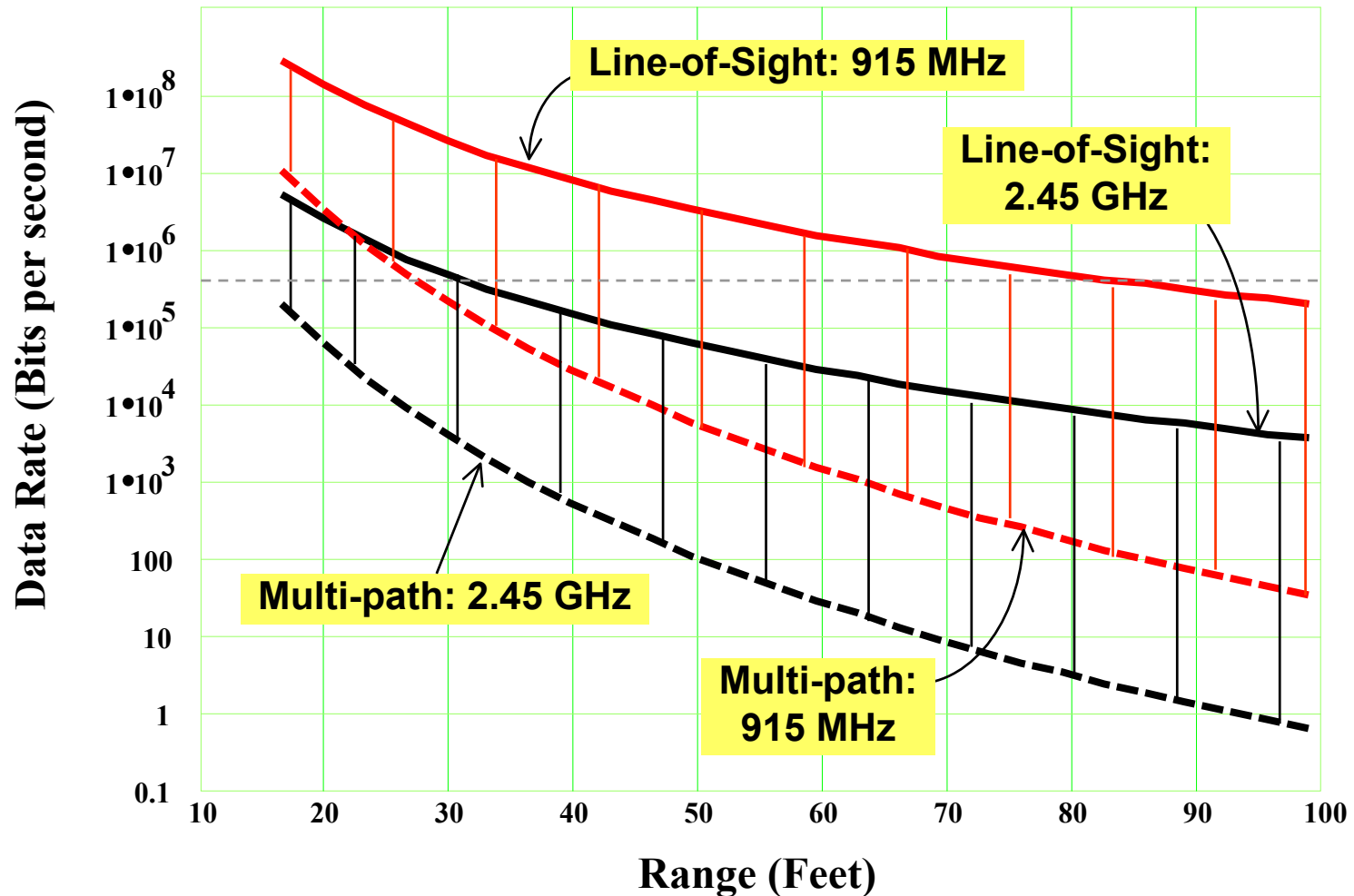
$$R_{bit}(r, p_e) = P_s \Psi_T^2 \Psi_r \left(\frac{\lambda}{4\pi r} \right)^4 \frac{1}{\left(1 + r/R_0 \right)^{2(N_B-2)}} \left(\frac{1}{k_B T_0 f_r} \right) \frac{1}{2 \ln \left(\frac{1}{2p_e} \right)}$$



Receiver sensitivity dominates next

Reference: Bridgelall, R., "Performance Characterization of Active and Passive Protocol Compatible Bluetooth/802.11 RF Tags," Proceedings of the 6th CDMA International Conference, Seoul, Korea, October 30th, 2001.

Semi-Passive Tag Range at UHF and 2.45 GHz



Reference: Bridgelall, R., "Performance Characterization of Active and Passive Protocol Compatible Bluetooth/802.11 RF Tags," Proceedings of the 6th CDMA International Conference, Seoul, Korea, October 30th, 2001.

History of RFID Development

1940	1950	1960	1970	1980	1990	2000
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1948
Harry Stockman
*"Communication
By Means of
Reflected Power"*



1966
Checkpoint &
Sensormatic
EAS
Commercialization
*1-bit Electronic Article
Surveillance*



1979
First
Implantable
RFID for
Livestock



1996
LA Adopts
Pet Tagging



1950's
D.B. Harris Patents
*"Radio Transmission Systems with
Modulatable Passive Responder"*



1992
First RFID
Toll
Collection
System in
U.S.

2003
WAL*MART
Mandate



1975
Los Alamos
Scientific Labs
Declassified
*"Short-range
Radio-telemetry
for Electronic
Identification
using Modulated
Backscatter"*



1940's
RADAR
Perfectd
in WWII



1959
Friend or Foe
*Military Long Range
Transponder*

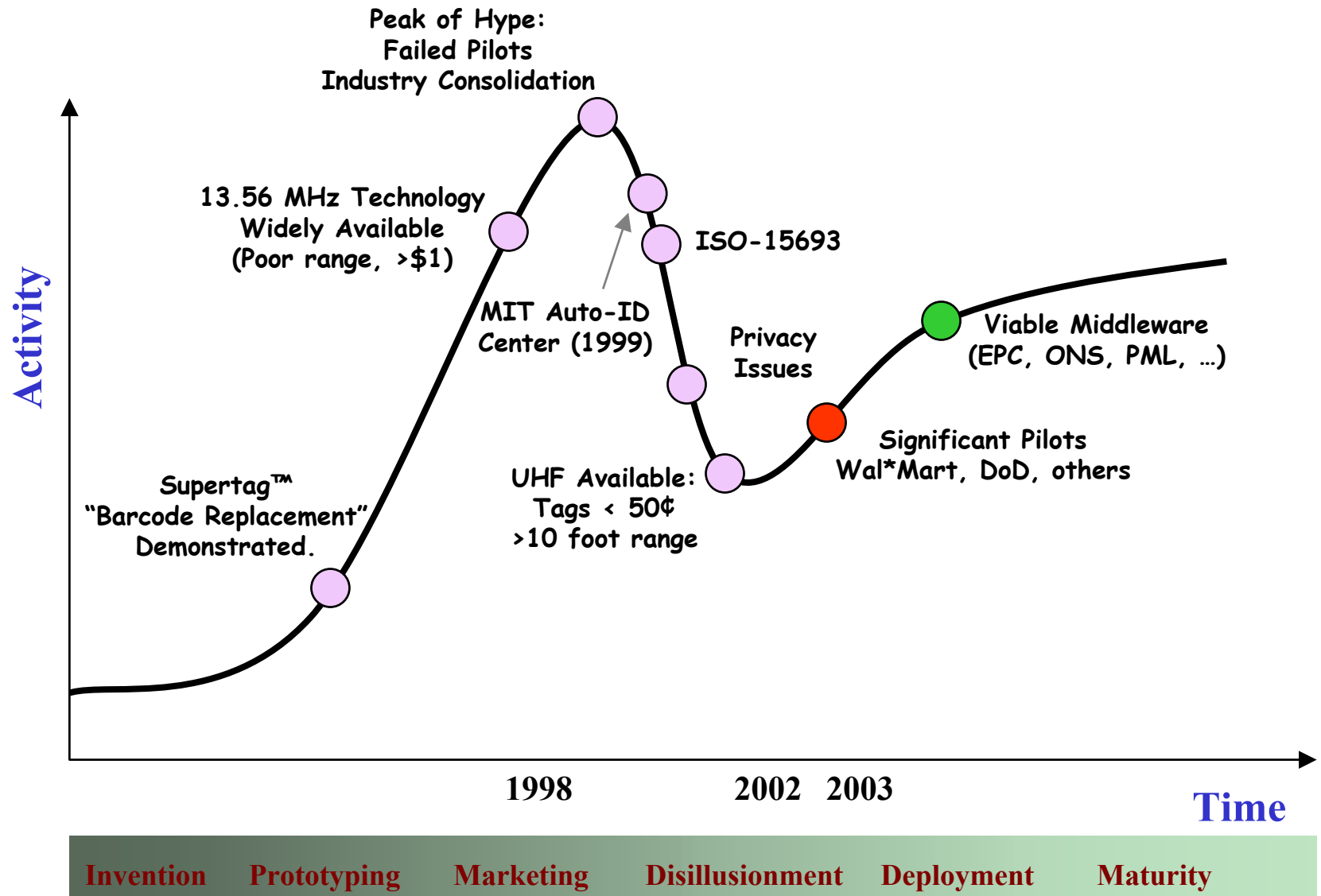


2003
Military Mandate

1949 – Norman Woodman's Barcode Concept

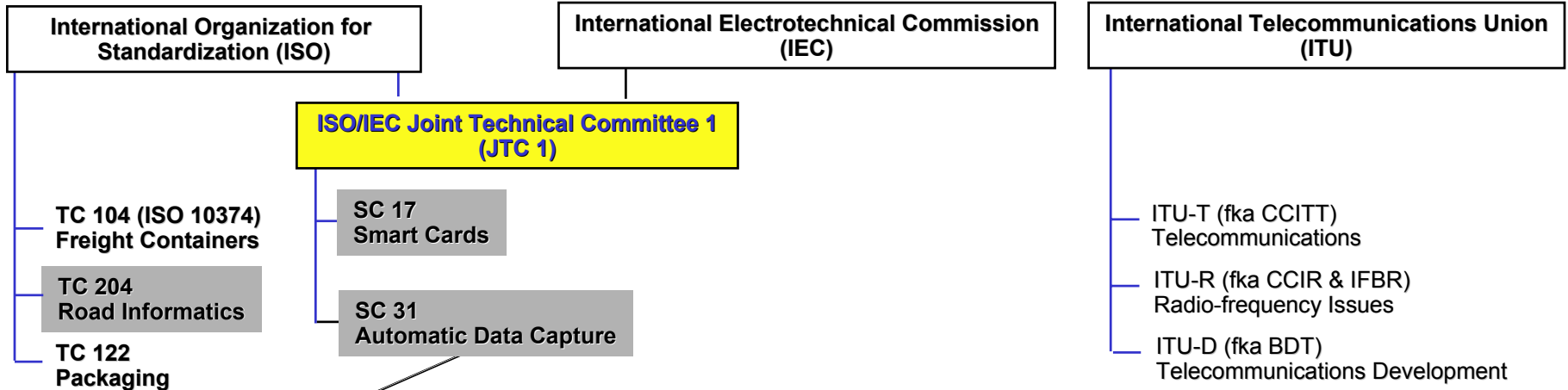
1974 – First Barcode Scanned

RFID Hype Life-cycle



History of RFID Standardization – Complex

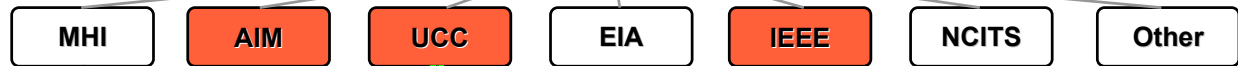
International



Regional



National

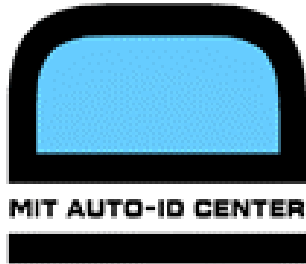


Industry



UCC™ and EAN™ forms EPCglobal™

First End-User Driven Standardization Process in History



Uniform Code Council, Inc.®
The Global Language of Business®

STANDARDS

EAN•UCC
S Y S T E M

EPCglobal
U.S.

ROSETTANET

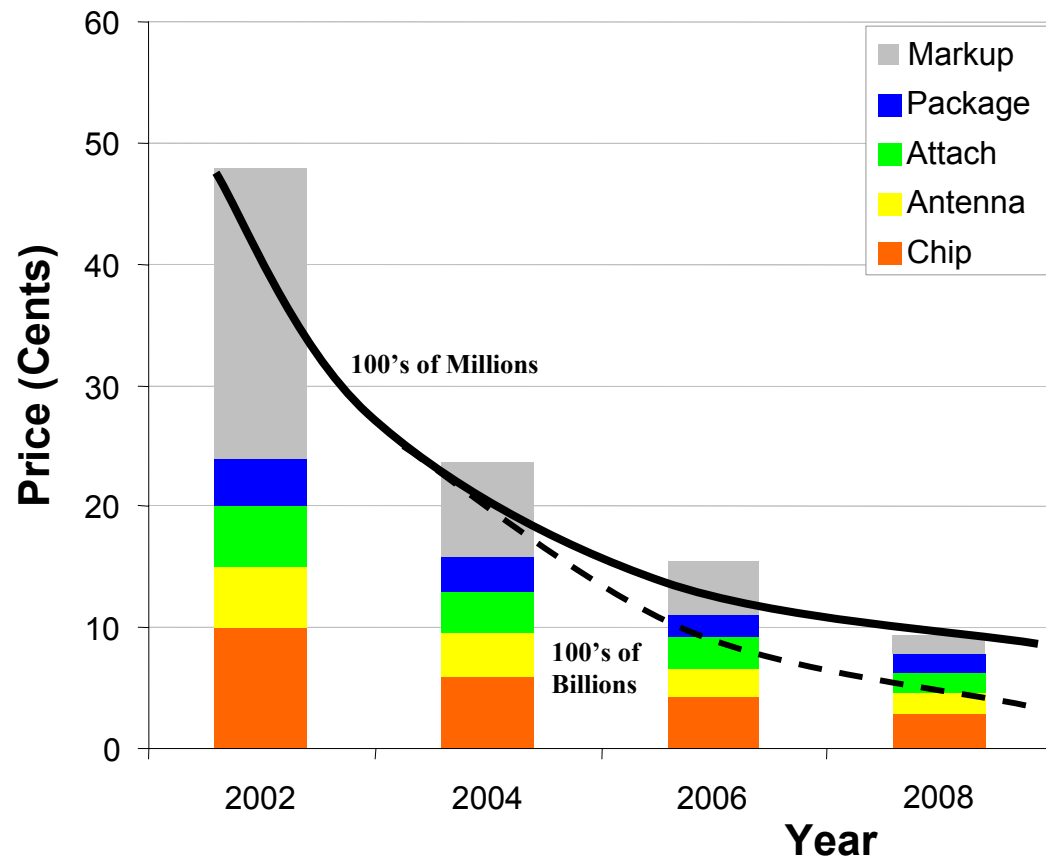
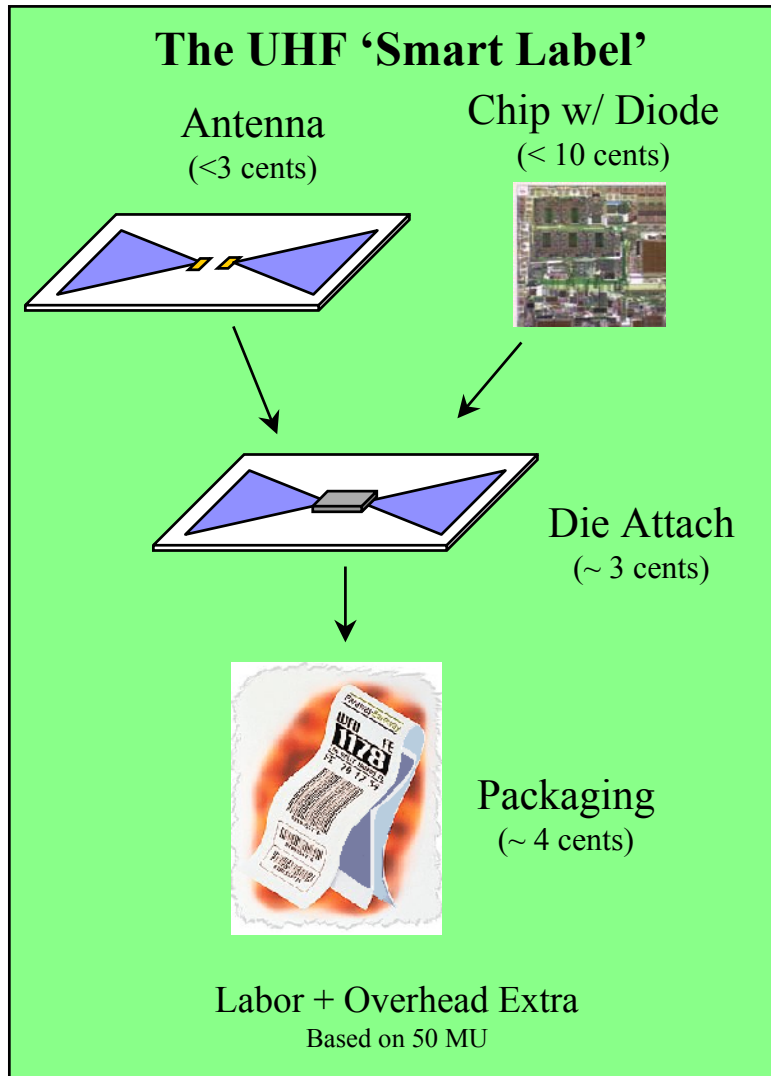
unspsc

IMPLEMENTATION SUPPORT

UCCnet®

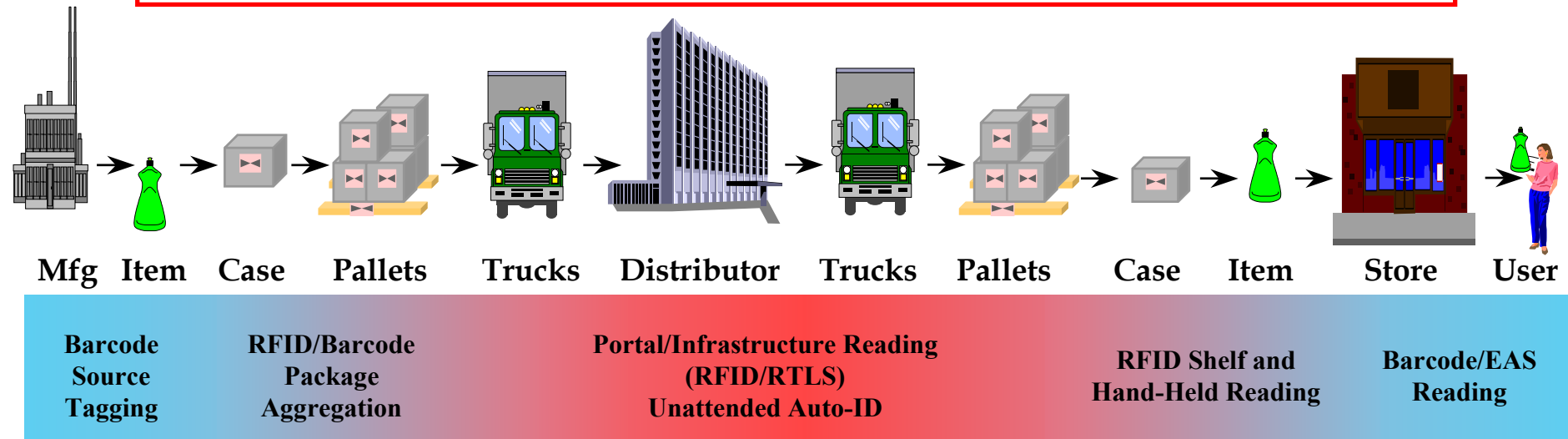
STANDARDSready

Passive Tag Construction and Cost Projections



Emerging RFID Killer Application

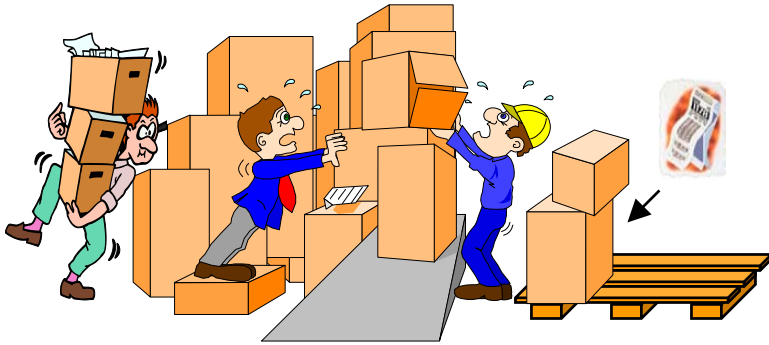
Retail Supply Chain Management – Tracking Goods Across Enterprises



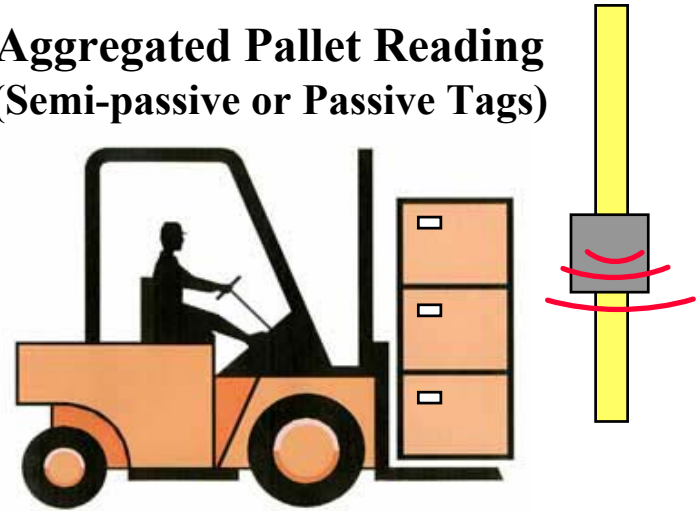
- ▼ The problem = ~\$40B/year
 - ◆ Lost goods, wrong delivery, untimely delivery, ...
- ▼ Costly results according to various studies
 - ◆ 15% of shoppers leave without finding an item.
 - ◆ \$10 billion in goods “lost” during delivery process.
 - ◆ 20% of perishables expire before they are sold.

Stage I - Pallet and Case Level Tracking

**Automated Pallet Assembly
(Barcoded RFID Label)**



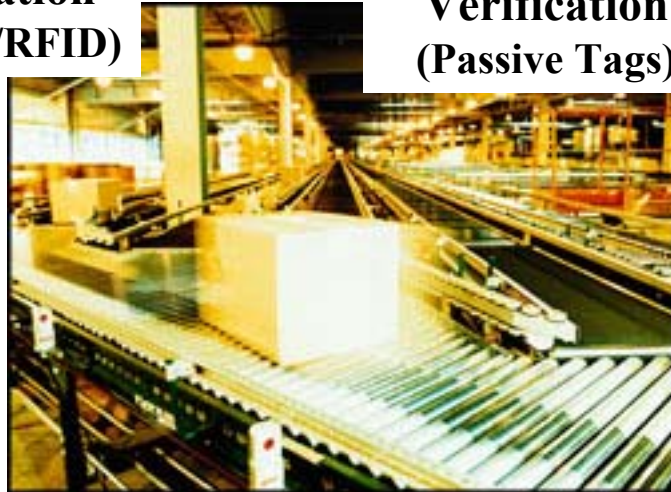
**Aggregated Pallet Reading
(Semi-passive or Passive Tags)**



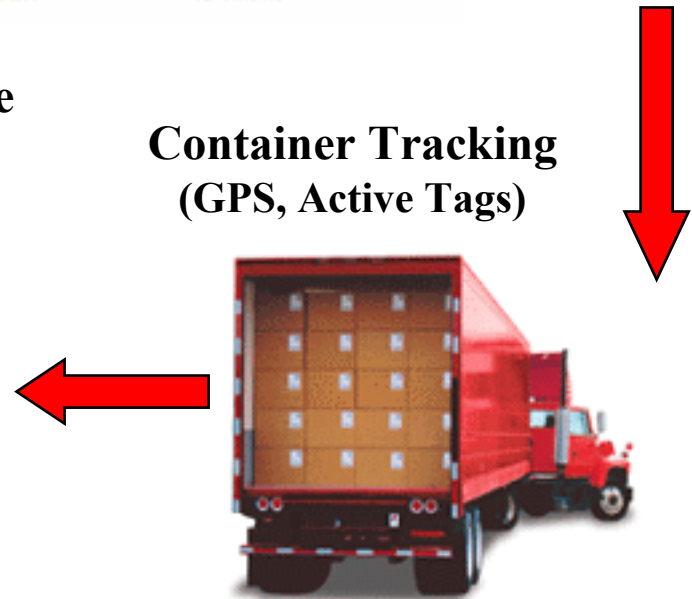
**Manual Case
Verification
(Barcode/RFID)**



**Automatic Case
Verification
(Passive Tags)**



**Container Tracking
(GPS, Active Tags)**



Stage II - Item Level Smart Shelves



Minimizing Shrinkage & Counterfeit



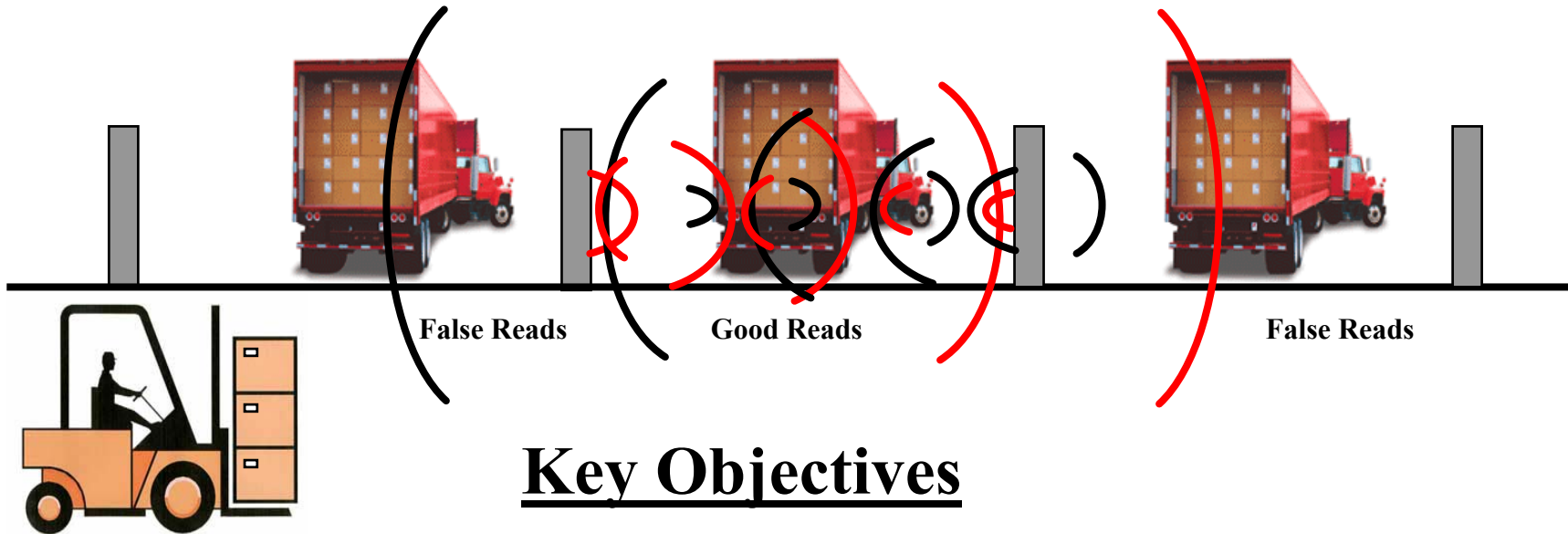
UNITED COLORS
OF BENETTON.

Minimizing 'Out-of-Stock' Conditions

Tough Technical Challenges for Immediate Applications (Non-Item Level)



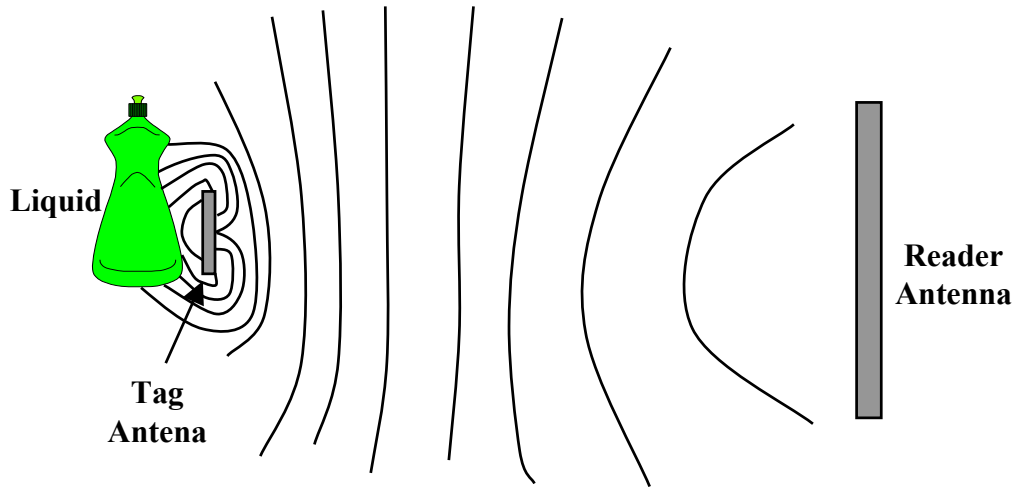
RFID Portals



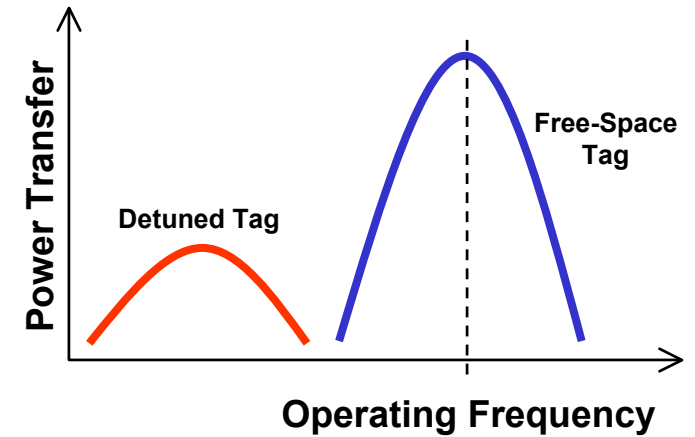
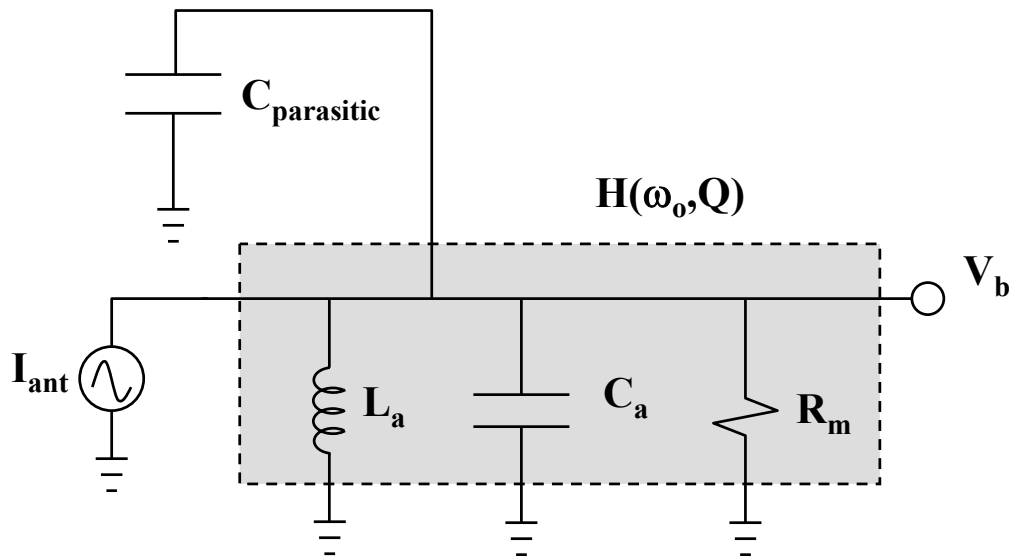
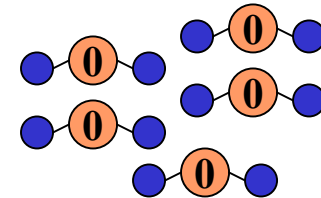
Key Objectives

- ▼ Eliminate cross-portal reads
 - ◆ Stuff gets on the wrong truck – costly error.
- ▼ High throughput
 - ◆ 60 - 100 items at fork-lift speeds.
- ▼ Robustness of reads
 - ◆ Close to 100% of items.
 - ◆ Liquids and metals distort field.

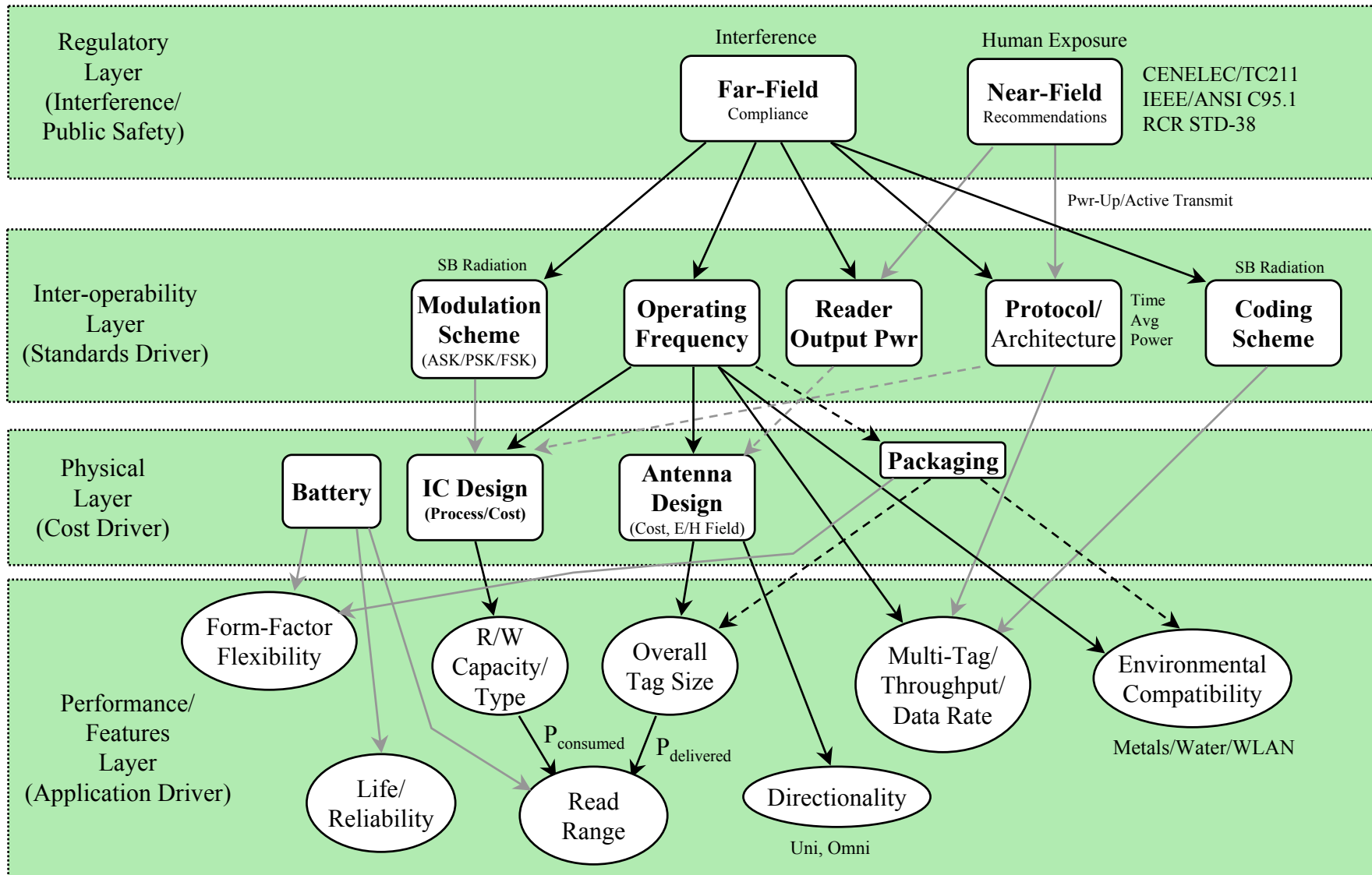
Tag Detuning and Energy Absorption



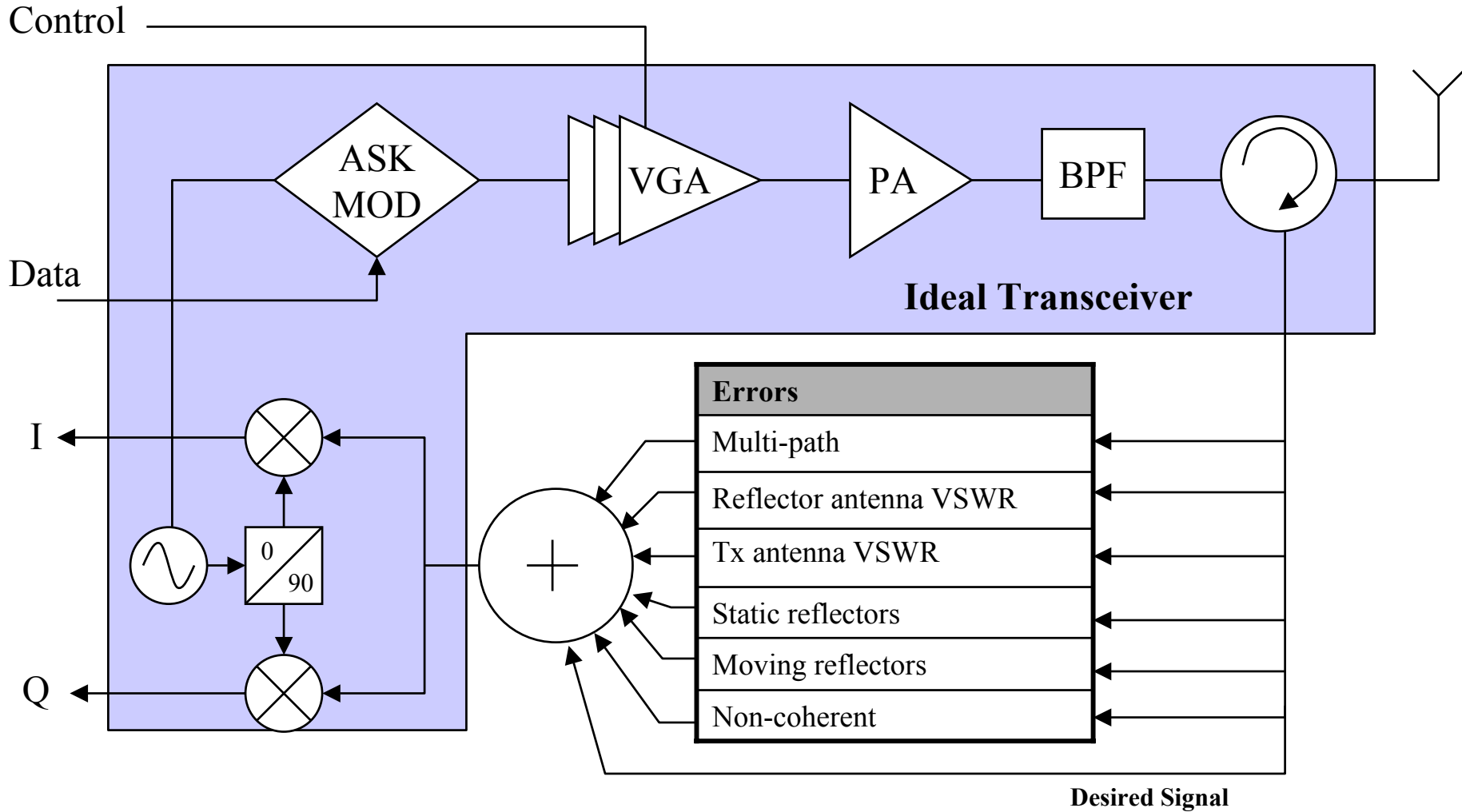
H₂O Dipole Energy Absorption



RFID System Design Considerations

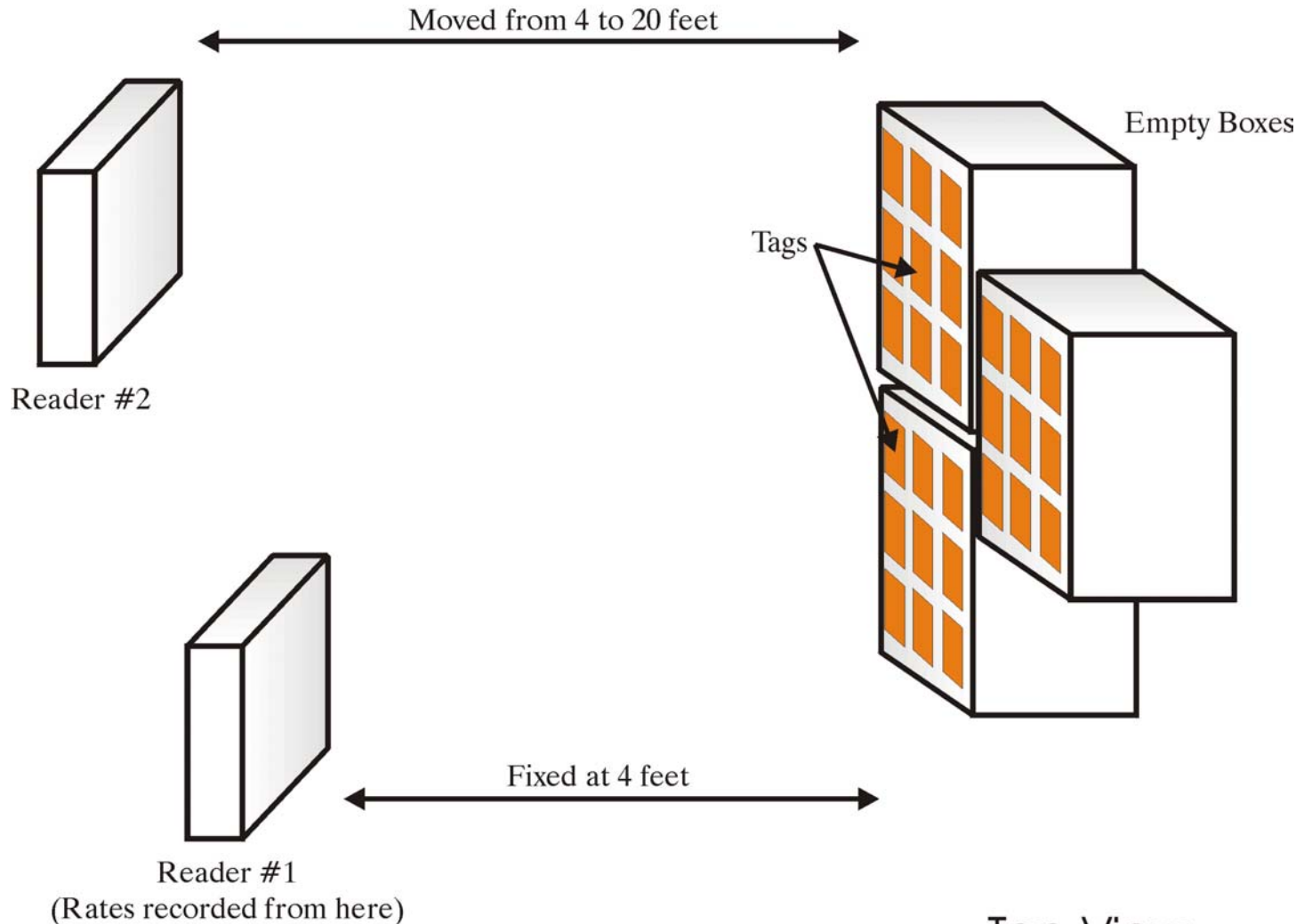


RFID Transceiver Issues



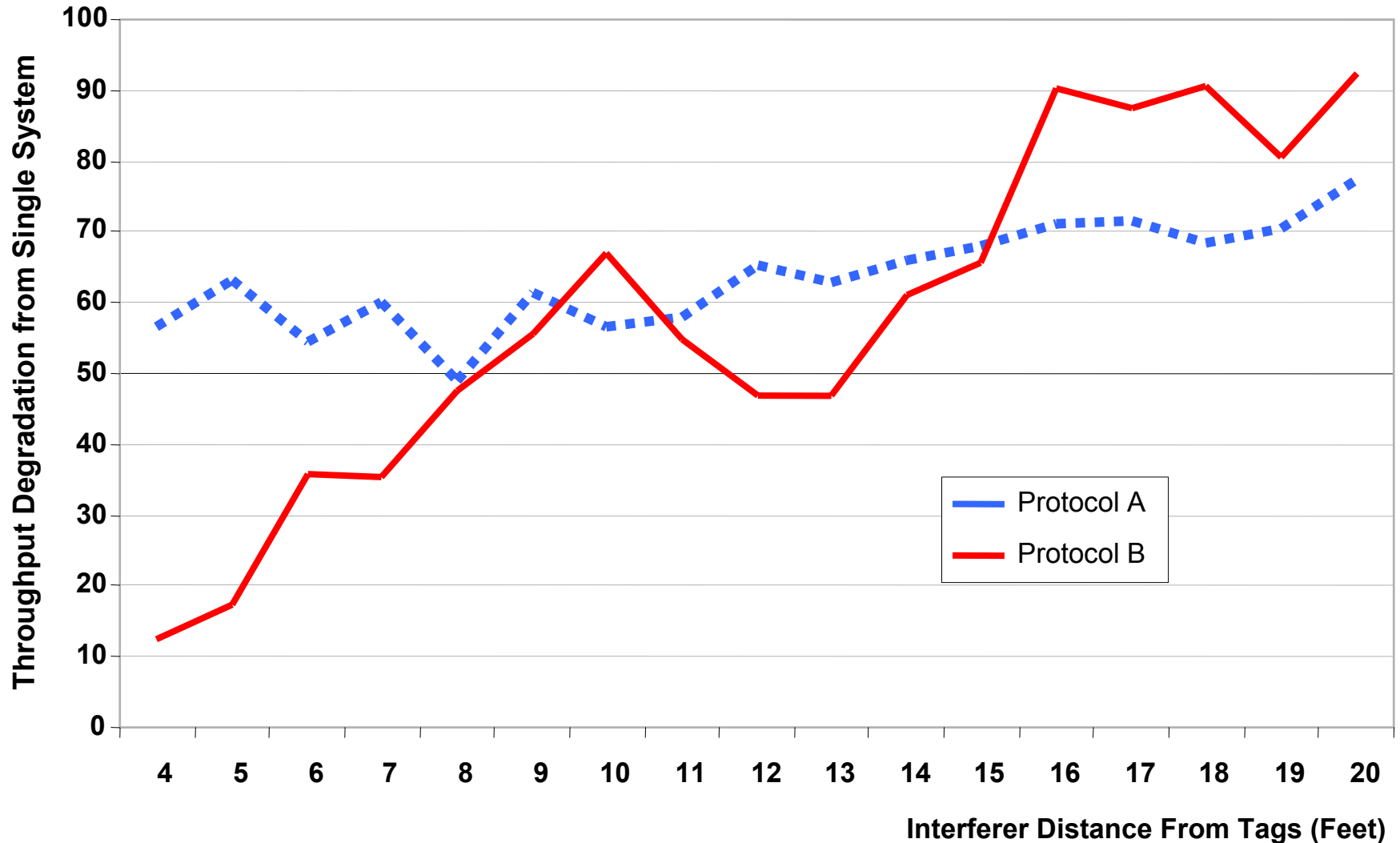
Multi-Reader Interference

System Test: Two Reader Collision Configuration



Interference Throughput For Two RFID Systems

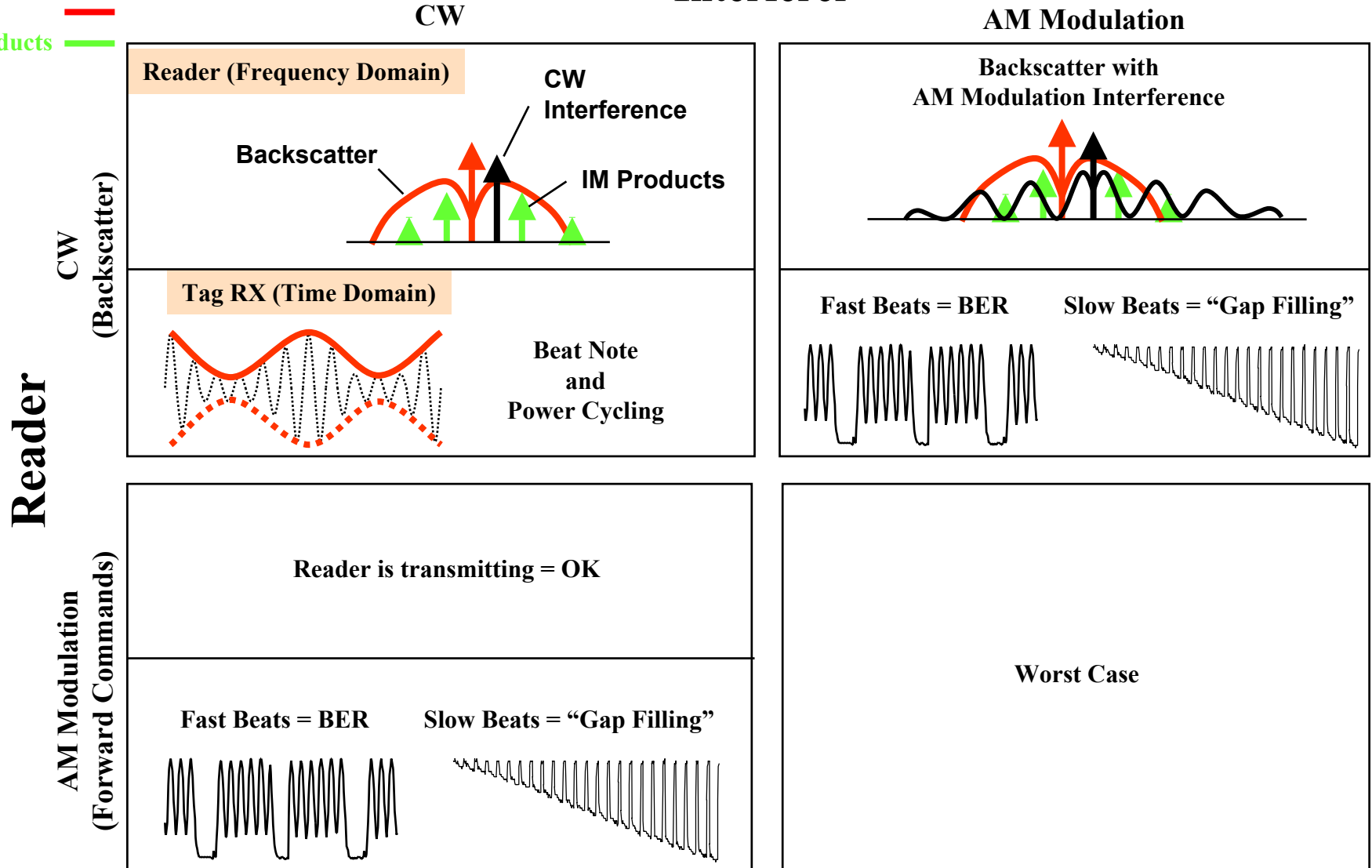
Measured Throughput: Interferers are of the same protocol.



Reader/Tag Interference Scenarios

Interference ———
 Reader ———
 IM Products ———

Interferer



Summary and Conclusions

- ▼ RADAR for commodity goods
 - ◆ Dominant application in retail supply chain asset tracking
 - ◆ Cost declining steadily
 - ◆ Standards emerging rapidly
- ▼ Tough technical challenges remain
 - ◆ Robustness of identification – not 100% accurate yet
 - Metals and water
 - Read zone localization
 - Interference from other RF equipment including other RFID
 - ◆ Speed of identification in all regulatory environments