RFID Technology Evolution, Applications, and Trends

TRB Research Initiatives in RFID

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Outline

- **RFID Technologies & Evolution**
- **Current Application Areas**
- **Trends**

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RFID Typical Practical Goals

- No battery or long battery life – years
  - Aftermarket Automotive or other uses
- Secure ID number storage & reading
  - Factory programmed and locked
  - Vs. **Authentication** of tag and/or reader
- Small scratch-pad read-write memory for systems where back end communications cannot be assured. Read-only is often viable.
- Tag Communications correlated to item/vehicle
  - Untagged item/vehicle identification
- FCC Regulatory Approval & Frequency Rules

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Typical Transportation Requirements

- Accurately Read vehicle Toll Tag
  - <5 in 10,000 misses = >99.95% success rate
  - <1 incorrect number in 10,000,000 transactions
  - Avoid shadowing, cross-lane reads, out of sequence reads, duplicate transactions
  - Handle bumper-to-bumper traffic and open road
- Lane Controller verifies Tag Status and lights Traffic Signal or tag light – Account OK or Low?
- Do not stop! Safety First.
- Replenish tag/account elsewhere/automatically

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History of RFID – See Shrouds of Time by Dr Jeremy Landt, AIM Pub

- IFF Radar 1939
- Harry Stockman, "Communication by Means of Reflected Power", Proceedings of the IRE, pp1196-1204, October 1948.
- Article Surveillance 1 bit 1960's
- Lab & Commercial interest 1970's
- Animal ID 1970's
- Automatic Vehicle ID – AVI
  - Golden Gate Bridge 420 KHz 1972
  - Lincoln Tunnel 1973 three other technologies
- Rail 1980's-Long Island RR & AAR Test Track
- Trucking – Arizona & HELP project late 1980's

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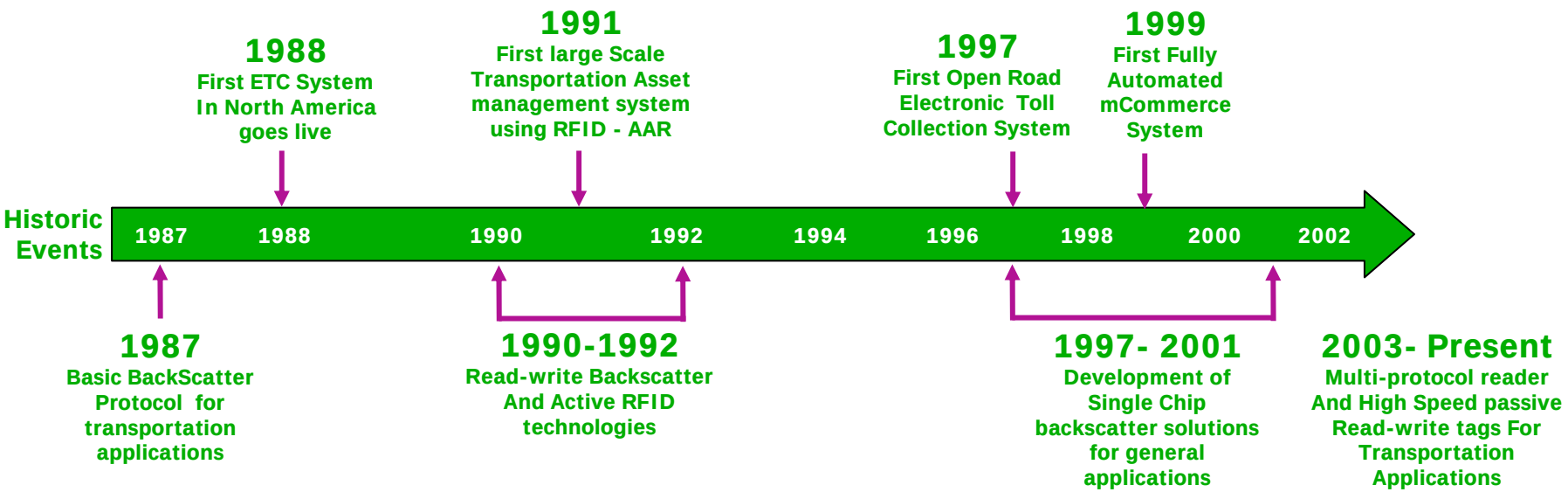
Recent Timeline



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Technologies used for RFID communication

- Radar – Modulated Backscatter- CW
  - Unsynchronized Tag Response
- Pulse/Field Trigger – LF or UHF RF or IR
- Addressed Data Modulation - Commands
  - Subgroup Requests & Sorting
- Tag response – MB, FSK, AM, OFDM, BPSK, QPSK, QAM
  - Some Frequency Doubling Systems LF & UHF
- Swept Frequency or Frequency Hopping
  - Often for Higher Power Unlicensed Operation
- UWB Ultra Wideband 5.8 to 7.2 GHz
- Horizontal or Circular Polarization

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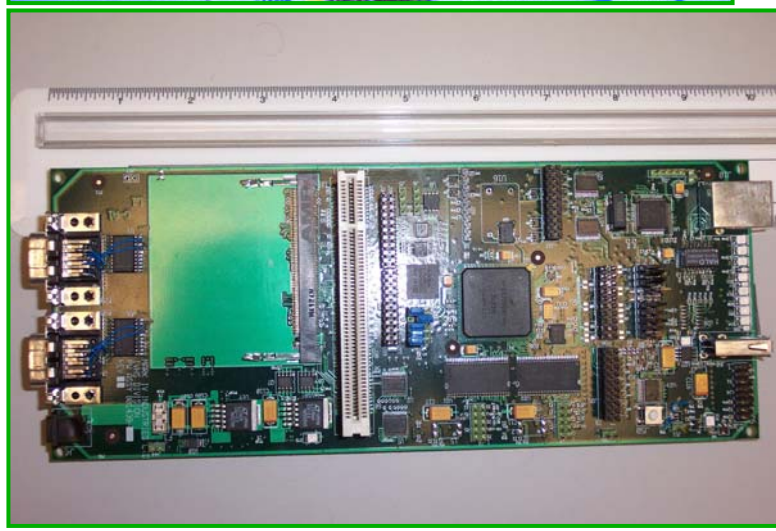
Technologies used for RFID Circuits

- SAW – Surface Acoustic Wave
  - Reflector Positions form ID
- CMOS UHF RF powered- IF only
  - Passive or semi-active battery assist – Single Chip
- Low Frequency Inductive powered
  - With UHF communication
- Full active receiver and transmitter
  - Sleep cycles and wakeup
  - TDMA
- Complex integrated circuits for 802.11a-like OFDM – powered by vehicle



General - Modulated Backscatter

- MB technique is the basis of many toll & supply chain systems in US and Europe (5.8 DSRC).
- CW transmitter
- Tag often operates over many frequencies
- Transponder (tag) provides identification via modulation of backscatter reflection
  - RF interrogation field powers the microwatts needed for tag operation
- Antenna Keyed In and Out of Circuit at data rate
- Homodyne Receiver in Reader– Transmitted signal mixed with reflected signal to immediately convert to base band IF signal

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Typical Technology Development

- Basic Techniques demonstrated
- Commercialized early application
- Standards – de-facto or Standards Org
- Higher Data Communication Speed
  - ↗ Multi-protocol readers
- More memory
- Read-Write on the fly
- Display or Lights Feedback
- Authentication

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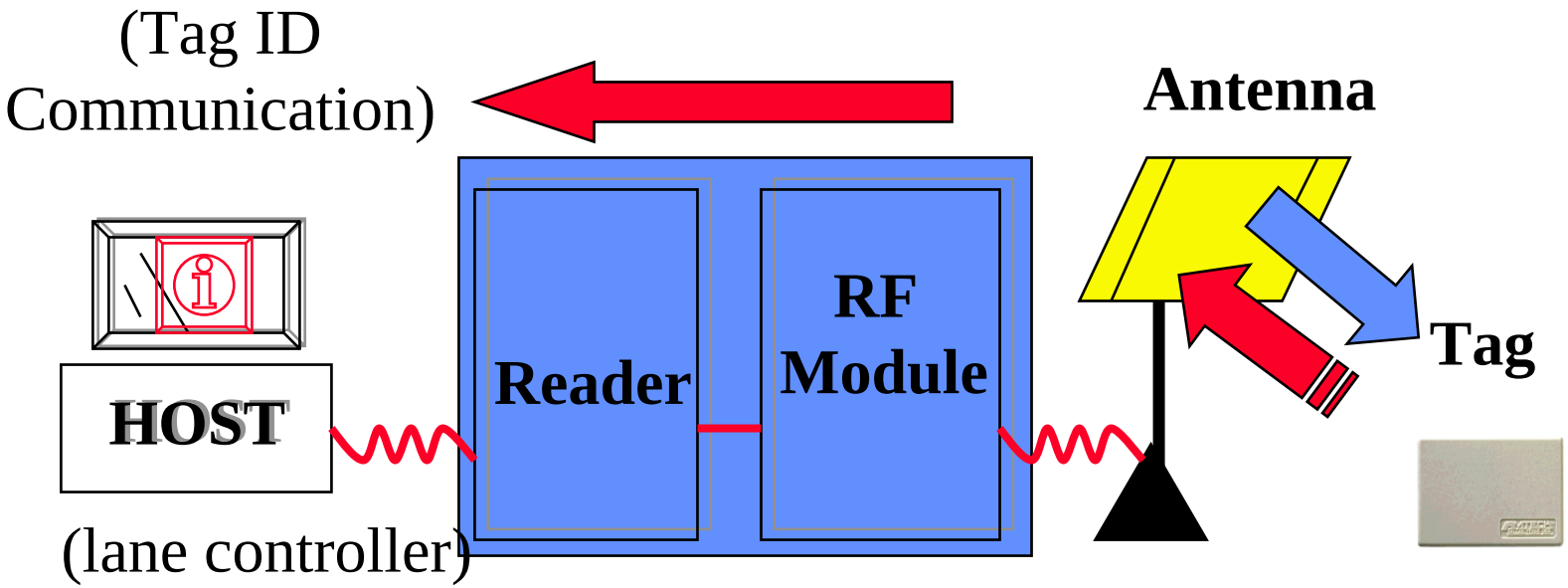
RFID - Components

- **Radio Frequency ID Systems Diagram:**



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RFID Challenges

- Antenna Coverage Volume
- Polarization / Orientation of tag
- Minimizing metal / conductive shielding
- Poor Mounting causing Failed Writes or Reads
- Minimal Time in Antenna Pattern
- Achieving useful Data Rates in error-prone RF
- RF Interference
- Null Zones or Long Range Reflections
- RF Power Levels – sufficient but not too high to properly locate tag, match to sensed vehicle
- Tag power consumption – Battery Life

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RFID Applications

- Item ID: Retail, Conveyor line, Process Control
  - Tag carrying item characteristics / contents
- Item Location and Surveillance
- Container Door Security, Alarm, Temp. and ID
- Building or Border Access Control
- Vehicle Access Control or Toll Collection
- Smart Card Payment
- Location Signposts – Rail or Buses, AVL
- Traffic Management – Weigh Station Bypass
- Safety Communications
- Information Download or Upload

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Harold the Tagged Animal ~1976

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Toll and Traffic Management

- Cash free, card-free, and hands-free operation for patrons
- High accuracy - Revenue collection transactions
- High reliability, Traffic throughput and congestion avoidance
- Harsh environments - External and extremes

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Tag Capabilities – Generalized

- **Read-Only Rail Standard**
  - 120 bit, 13 ms.+read, 20/40 KHz, Sub-bit encoding for effective data rate ~9600 baud
  - Band: 902-904, 909.75 to 921.75MHz
  - Read Range 5 - 25 feet
  - 80 mph
- **Read-Write Toll**
  - 128 to 256 bits, Triggered Read 500 Kbaud
  - 100+ mph
  - Reader or Controller determines what to write to specific tag before it exits antenna zone

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AEM Automatic Equipment Monitoring

- **Rolling Stock/Container Readers**

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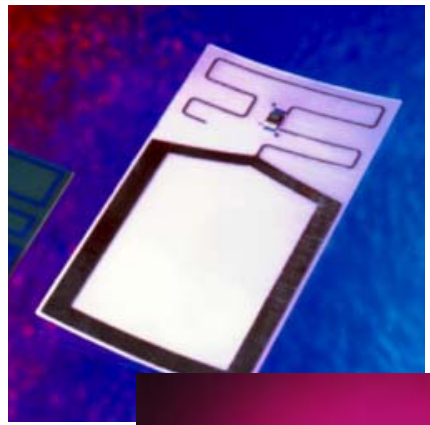
Single Chip Sticker Tag – Used in Supply Chain and Toll Collection



- Single Integrated Circuit
- High Performance
- UHF Frequency
- Beam Powered – No Battery
- Read/ Write capable
  - ↗ Extended memory
- Beam powered – No Battery
- Requires proper commands to cause tag to respond via backscatter

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Unusual Tags & Applications

- Waterproof External /License Plate / Pavement
- High Temperature - Thaw Shed
- Bullet Proof – slot antenna
- Modem Tag
- Tire ID
- Sensor Tag
- Tamper Resistant Tag
- Display Tag
- Smart Card
- Runner ID & Timing
- Multi-band operation around World

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American DSRC WAVE 5.9 GHz

- Digital Short Range Communication
  - Wireless Access for Vehicular Environment
- FCC Allocation & Regulations 90.379
  - 7 each 10 MHz channels (combine some to 20 MHz)
  - OFDM-Orthogonal Freq. Division Multiplexing
  - 802.11a – at twice the symbol length/half bandwidth
    - Needed for multi-path ISI (inter symbol interference) minimization
  - ASTM E-2213 Physical/MAC Layer Standard
- IEEE standards for higher layers 802.11p
- Auto Manufacturers researching incorporating into vehicles for Safety Communication

5.9 GHz DSRC APPLICATIONS- 1999 ASTM Committee

- ACCESS CONTROL
- PROBE DATA COLLECTION
- TRAFFIC INFORMATION
- TOLL COLLECTION
- GAS (FUEL) PAYMENT
- DRIVE-THRU PAYMENT
  - PARKING PAYMENT
  - FAST FOOD PAYMENT
  - PHARMACY PAYMENT
- IDB DATA TRANSFER
  - DIAGNOSTIC DATA
  - REPAIR-SERVICE RECORD
  - VEHICLE COMPUTER PROGRAM UPDATES
  - MAP and MUSIC DATA UPDATES
- RENTAL CAR PROCESSING
- IN-VEHICLE SIGNING
  - WORK ZONE WARNING
  - HIGHWAY/RAIL INTERSECTION WARNING
  - ROAD CONDITION WARNING
- ROLLOVER WARNING
- MAINLINE SCREENING (WEIGH-STATION CLEARANCE)
- BORDER CLEARANCE
- UNIQUE CVO FLEET MANAGEMENT
- ON-BOARD SAFETY DATA TRANSFER
- TRUCK TRACTOR-TRAILER SAE DATA BUS INTERFACE
- DRIVER'S DAILY LOG
- VEHICLE SAFETY INSPECTION
- EMERGENCY VEHICLE SIGNAL PREEMPTION
- TRANSIT VEHICLE SIGNAL PRIORITY
- TRANSIT VEHICLE DATA TRANSFER
- LOCOMOTIVE DATA TRANSFER
- LOCOMOTIVE FUEL MONITORING
- **INTERSECTION COLLISION AVOIDANCE**
- VEHICLE to VEHICLE DATA TRANSFER
  - VEHICLE STOPPED or SLOWING WARNING

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Ad Hoc Networks

- Peer to Peer Network – Tag to Tag
- MANET- Mobile Ad Hoc Networking
- Mesh Communication Network
- Resolve the Hidden Transmitter Problem
  - 5.9 GHz OFDM Range about 600 to 1000 feet typically from roadside to vehicle
- Packet Network relaying
  - Data more important than location and ID

Reader & Antenna Technology

- High speed applications 100 mph
  - Read only or Read-Write
- 2W synthesized – FCC 30 Watts ERP
- High gain antenna
- Internal electronic attenuator
- Overhead antenna mounting
- Open Road – Multiple Lanes with no barriers and lane changing
  - Lane Center and Lane Edge Antennas

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Overhead Antenna Design

- Match object presence with identification
- Minimize Null Zones in pattern e.g. from Yagi
  - Panel Antenna preferred
- Broad Area Coverage Low Gain Antennas
- 4X distance or 10 db power “rule”
- Typical Panel Antenna Focused zone 13 dBi Gain – Horizontal Pattern
  - Front to Side >15 dB rejection
  - Beam width ~ 35 degree E & H plane
  - Overhead mounting to control range
- Match Windshield Angle – 15 degree angle towards oncoming traffic

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Frequencies and Power Levels

- Typically licensed 912.5 to 919.0 MHz
  - Synthesized 500 KHz steps
  - FCC ITS Radio Service – 90.351
  - Band Shared with Federal Government - IRAC
- 30-500 Kbits/second data rate, Manchester encoding in reader interrogation commands
- Panel gain antenna pointed down in toll lane
- Feed line, internal and external attenuation results in less than 30 watts ERP
  - Typically < 1 w ERP at Horizon

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RF Spectrum for RFID Readers

- Country Dependent
- FCC Equipment Authorization & ID #
- Some Equipment requires Site Licenses
- Bands – Often shared – Most used:
  - LF – 66 & 132 KHz
  - HF – 13.56 MHz
  - VHF – 49 MHz
  - UHF – 315, 433, 902-928 MHz, or 2.45 GHz
  - Microwave – 5.8 GHz (Europe) 5.9 GHz US
- Data Bandwidth, Latency, and Number of Readers at site influences Frequency selection

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Marketplace Trends

- GPS Location and ID Determination
- Cellular Network for communication
- DSRC 5.9 GHz
- Fuel Tax Replacement
- More highly integrated applications with Vehicle Navigation system
- Satellite Tracking – Continuous Visibility
- Simple, Low Cost & Completely separate RFID
- No Display on Tags

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Trends in Technology

- Single Chip Tags with Read-Write Operation at Highway Speeds, and multi-mode operation
- Increased Security
- Mutual Authentication for High Value Parking
- Registration Stickers/Plates with RFID- EVR
- Multiple Readers for different bands or Multi-Protocol Readers in same band
- Time Difference of Arrival or Angle of Arrival for Tag/Object Location

Additional Trends in Technology

- Multiple Application integration of processors and GPS receivers
- Higher circuit integration & Lower current
- Integrated with vehicle data bus & Power
- DSRC 802.11p transponders also use 802.11a
- Communication Handoff between Roadside Units

Conclusion

A Variety of Technologies and System Designs Contribute to Fertile Environment for R & D

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