A CDMA-based RFID Inventory System

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Who We Are & Our Introduction to RFID

Texas State University & NASA

- Johnson Space Center Research Grant

Capstone

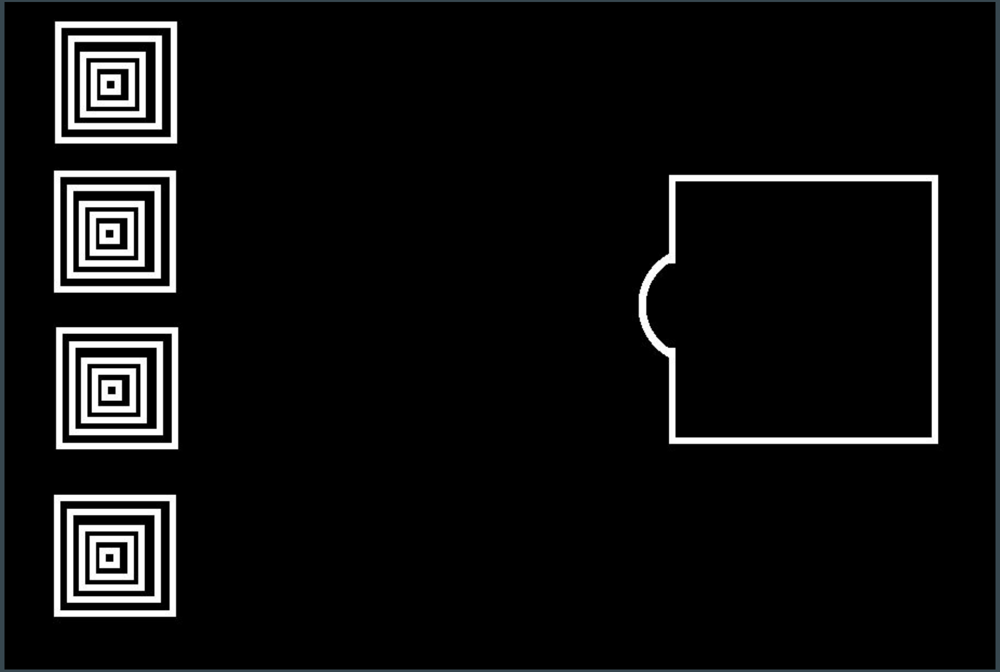
- Senior Design Project (January 2015 - December 2015)
- NASA Sponsorship
- “The team choosing this project will be tasked with developing, testing, and implementing a technique to incorporate direct sequence spread spectrum technology into the current generation (Class 1 Gen 2) of passive RFID tags. Success will provide the capability for a single RFID reader to simultaneously receive information from multiple RFID tags”

Statement of Problem

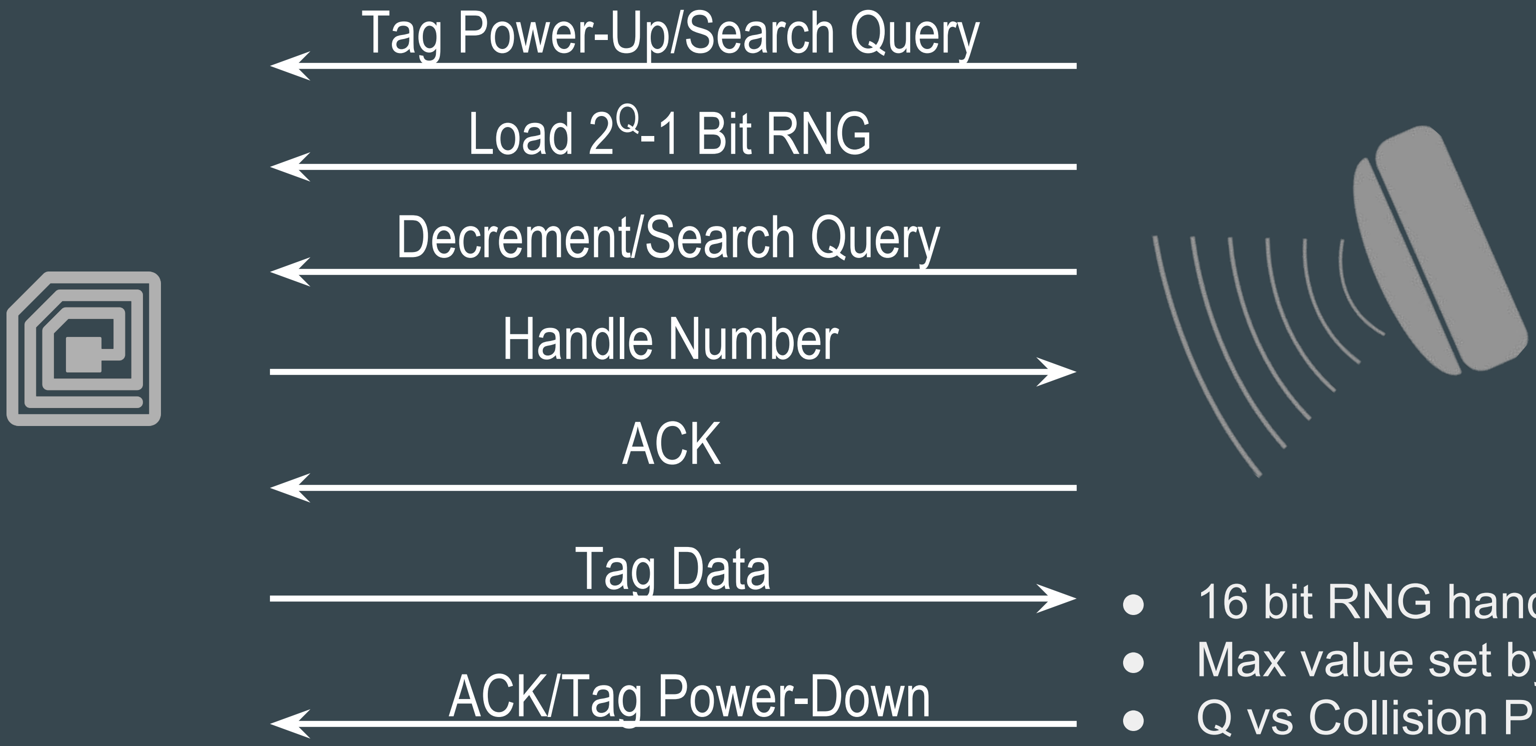
Reading Multiple RFID Tags Simultaneously

Current MUX Protocol

- Framed Slotted ALOHA
- Time Division Multiplexing



Current Tag Reading Protocol



- 16 bit RNG handle
- Max value set by Q
- Q vs Collision Prob.
- Q vs D/S Query

Preliminary Analysis of TDM System

Small System (5 tags)

Let Q = 6

System Count $2^6 - 1 = 63$

Probability of collision = 0.15

Min. number of interrogator transmissions = 69 (No collisions)

Greater if collisions occur

Inefficiencies

Collisions

- Multiple tags generate same handle
- Protocol starts over for all unread tags

Decrement/Search Query (Empty slot)

- Waste of Power/Information

Possible Solutions

- Simultaneity
  - ~~TDM~~
    - Very fast but not truly simultaneous
  - ~~Frequency Division Multiplexing (FDM)~~
  - Code Division Multiple Access (CDMA)
- Bandwidth
  - Limited

Code Division Multiple Access (CDMA)

- Spreading Codes
  - Orthogonal Codes
    - XOR yields noise
  - Encoding = Spreading Code (XOR) Data
  - Processing Gain (G_p)
- All transmitters (tags) respond simultaneously
- Reader decodes and despreads signal
  - Decoded data = Spreading Code (XOR) Conglomerate Signal

Direct Sequence Spread Spectrum (DSSS)

- Direct Sequence Spread Spectrum
  - Bit Rate - Bandwidth Relationship
    - Effective increase in bit rate
    - Power spectrum “flattened” over entire bandwidth

Implementation

Preservation of Class 1 Gen 2 Parameters

- Size of tag memory banks (128 bits)
- Structure of tag memory banks
- Bandwidth

Implementation Cont'd.

Can be Expanded:
Larger data fields of newer tags
Disable frequency hopping to allow for full bandwidth DSSS

EPC Data

Embedded spreading code

Restrict unencoded data to 8 bits, EPC = 128 bits encoded data

$G_P = 16$

Signal-to-Interference Ratio (PSK, Coherent ASK)

Bit error rate of 10^{-4} - 10^{-5}

Assessment of Design Options

- ~~Design and build new tags~~
- Tag Spoofing
  - Q
  - k all tag once
- Simulation
  - Software
  - Hardware

Software Simulation I

MATLAB (ASK/PSK)

- Creation of 5 8-bit sets of data ("tags")
- Apply spreading code to each "tag"
- Create vector to simulate signal
- Assign random power level of each "tag"
- Sum vectors and add virtual noise (min SNR = 14dB)
- Demodulation and decoding (90% accuracy)

Software Simulation II

Simulink (PSK)

5 tags (transmitters)

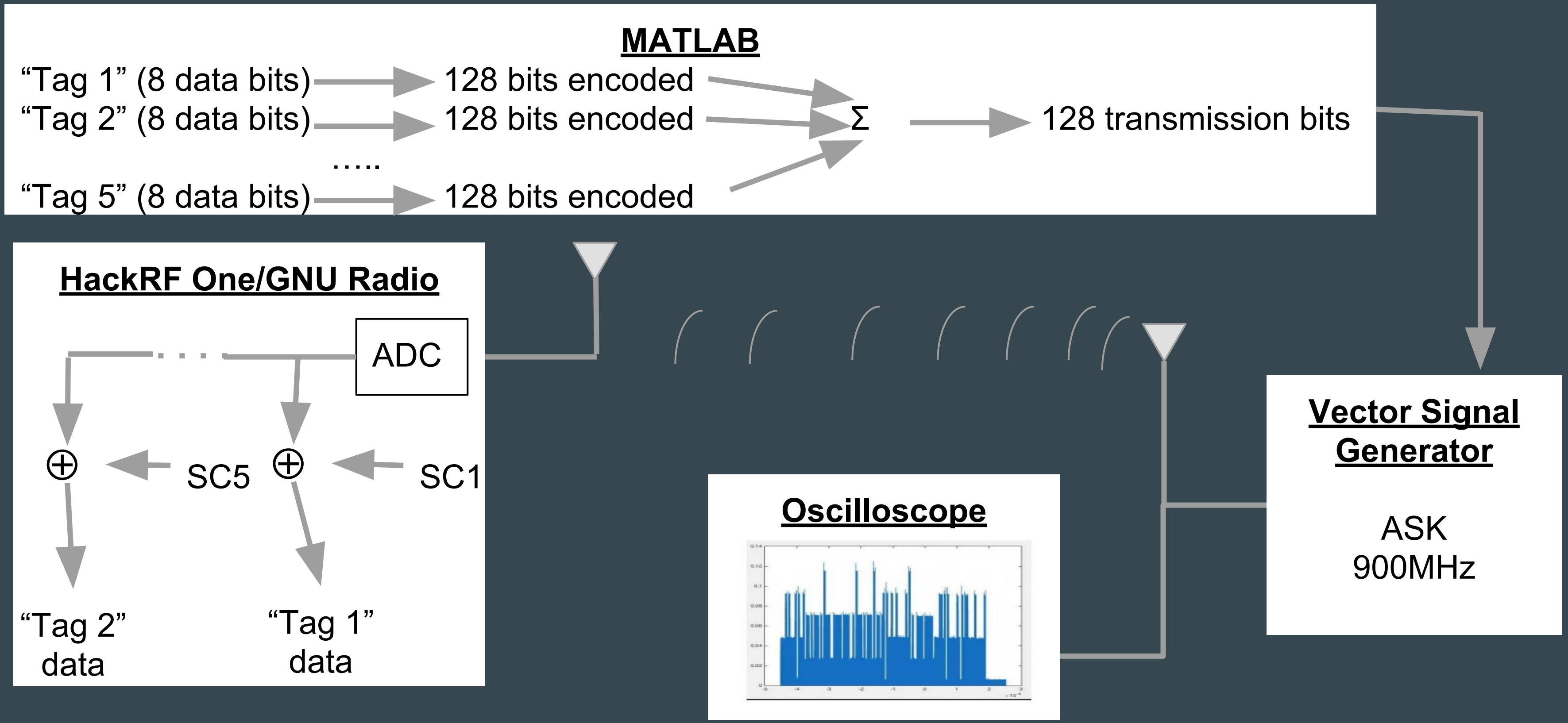
Rayleigh Fading (Randomly generated)

White Gaussian Noise (min SNR = 7.96dB)

Reader (receiver), (90% accuracy)

Adaptive Interference Cancellation (~100% accuracy)

Hardware Simulation



Results

- Up to 98.5% reduction in number of interrogator transmissions (compared to TDM, no collisions)
  - Excludes powerup and bit rate/modulation establishment
- Robustness in the presence of noise
  - 95% Accuracy with SNR = 12dB (Simulink)
- Greater number of tags may require more transmissions
  - Current protocol: +≥4 transmissions for each additional tag (more tags also means higher probability of collision)

Tradeoffs of CDMA

Advantages

- Truly simultaneous
  - Speed
- Robustness in the presence of noise
  - Power reduction or greater accuracy
- No wasted information
  - (Decrement/Search Query Command)

Disadvantages

- Limited number of orthogonal codes
  - Limited number of tags
  - PN Codes
- Greater computational complexity

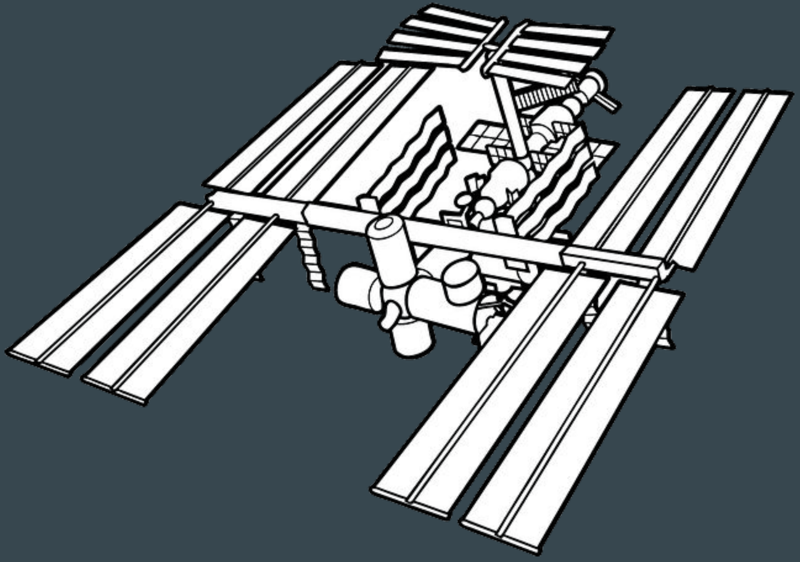
Which applications can benefit from this solution?

Small, closed systems

- Low power requirement (Power = EXPENSIVE)
- Simultaneous reading
- Limited interrogator size/weight
- Security*

ISS Inventory System

Race Tracking



Ongoing & Future Work

More tags in hardware simulation

Simulation using FPGA

PSK vs ASK

Using channels of greater bandwidth

- Higher G_P using larger data fields in tag memory

Tester tags

WISPs

Questions?