NASA RFID Applications

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Outline

• Inventory management in space
  – Apollo, Space Shuttle, Space Station

• Potential RFID uses in a remote human outpost

• Ultra-Wideband RFID for Tracking

• Passive, wireless sensors in NASA applications
  – Micrometeoroid impact detection
  – Sensor measurements in environmental facilities

• E-textiles for wireless and RFID
Apollo Inventory Concept

Top level stowage drawing showing Command Module stowage layout

Sample table of items contained in modular container locations – used to layout vehicle and train crews on item locations

<table>
<thead>
<tr>
<th>Stowage location (a)</th>
<th>Equipment</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5</td>
<td>Headrest pads</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Heel restraints</td>
<td>3 pair</td>
</tr>
<tr>
<td></td>
<td>Sleep restraint ropes</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sextant adapter for 16-mm camera</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Spotmeter</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Two-speed timer</td>
<td>1</td>
</tr>
<tr>
<td>A6</td>
<td>Carbon dioxide absorbers</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Television monitor with cable and strap</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>12-foot television cable with strap</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Television-camera bracket</td>
<td>1</td>
</tr>
</tbody>
</table>

(Reference Apollo Experience Report: Crew Station Integration - Stowage & the Support Team Concept, 1972)
Shuttle Inventory Concept (non-Transfer to ISS)

- Crew is provided hard copy of items listed by location (no part numbers, serial numbers, etc., provided)
- Crew also has the ability to look items up in laptop database, but often requests item locations from Mission Control
The Inventory Management System (IMS) is used to track items on the ISS

- Handheld barcode reader is used by the crew for quick on-site updates
  - Data from the barcode reader may be passed to the onboard IMS database by RF or serial hardline connection to the laptop
  - Expedition 15 will use the new PDAs to access IMS and perform barcode scans.
- IMS software application is used for complex updates
  - Manual crew entries into onboard database on laptop
  - Flight control team entries into ground database
- Databases are synchronized by uplinking and downlinking “Delta Files”
Objectives:

- flight certify a commercial RFID interrogator and tags
- demonstrate RFID inventory of crew items and office supplies at bag and item level
RFID – Lunar Outpost

- High probability applications
  - Inventory management
    - Crew supplies (e.g., personal items, office supplies, clothing)
    - Food, medicine
  - Real-Time Localization
    - EVA tools, equipment
  - Monitoring/verifying inter-habitat supply transfers
  - “Boneyard” inventory
    - Real-time access to surplus parts
- Smart tag and other potential applications
  - Monitor tool exposure limits and provide warnings (e.g., temperature extremes, shocks)
  - Storage of calibration information on sensors, LRUs
  - Passive tag tracking

Example: passive COTS tag with 64 bit ID code, temperature and range telemetry
Evaluate UWB-RFID system Sapphire DART

Customize the system and enhance the tracking performance

Active UWB RFID for Tracking Applications
• Laboratory test configuration for Sapphire DART

UWB Precision Tracking
UWB Precision Tracking

- UWB TDOA high resolution proximity tracking for robonaut
  - Theoretical analysis and simulation for TDOA proximity applications
  - Lab tests show sub-inch tracking resolution
Passive, Wireless Sensors

- Where possible, no-batteries
- Reduces wire, crew time, certification costs, weight, power, and size
- Numerous conceivable applications

64-bit SAW-based COTS RFID tag

AirGATE Technologies / CTR tag

8-bit SAW-based COTS RFID tag

Potential applications for wireless ice sensor system

Passive sensor arrays (enlarged)

Interrogator

Ice sensor
• 70 MHz SAW-based sensors
  – G. Studor (JSC), R. Brocato (SNL), et al

• Key advantage: integrates existing sensor types into passive, wireless system

• Targeted application: micrometeoroid impact detection

• Requires efficient, miniaturized antennas
HF Antennas

- **Significant size reduction of the antenna**
  - Half-wave dipole ($0.5\lambda_0$, 2.14m)
  - Miniaturized spiral-loaded slot antenna & ground plane ($0.07\lambda_0 \times 0.11\lambda_0$, 0.3m x 0.46m)

- **Habitat walls are electrically conductive**
  - Cannot use wire antenna directly against conducting wall
  - Integration of miniaturized HF antenna with habitat walls
    - E-textile antennas

EIGER Simulation
HF Passive Sensor Antennas

- Miniature Spiral-Loaded Slot Antenna

Prototype 4
(45.7cm x 30.5cm x 0.32cm)

2.5% BW Gain > -5dBi
Habitat Module Interrogator-to-Tag Coupling

- Coupling between two 70MHz antennas
  - Received power levels at different locations in the mockup
  - Model effects of blockage with equipment in habitat module
NASA Use of 2.4 ISM SAW-Based RFID

Courtesy RFSAW, Inc.

Courtesy AirGATE Technologies
RF Collision Avoidance Methods

- Spatial diversity through adaptive digital beamforming

- Chamber A: Vacuum and Thermal Cycle Testing of Flight Hardware
- Objective: replace wired thermal and pressure sensors with wireless sensors
  - Reduces setup time between vehicle configuration changes
- Stage: feasibility assessment
- Thermal limit cold side: 20K
- Applications for vibration and acoustic facilities are also being explored

Approximate dimensions

~ 80’
45’
40’
Environmental Facility Wireless Sensors

- Adaptive interrogation of wireless temperature and pressure sensors
- Goals: $T_{\text{low}} = 20\text{K}$; 1000s of T-sensors; 100s of P-sensors

72-Element, S-Band, Adaptive, Digital Beamforming for Tag Interrogation

JSC Chamber A
(Vacuum & Thermal Cycle)
Antenna System Approach

- No active sensor system elements inside the chamber

- Adaptive digital beamforming offers many design degrees of freedom
  - The system can learn optimal channel weighting coefficients prior to commencement of tests

- Interrogator aperture:
  - Small transmit aperture - attempt to minimize transmit directivity
  - Large receive aperture – high directivity for spatial diversity

- Additional collision avoidance obtained through:
  - polarization division and code division
Small Transmit Aperture for Broad Illumination

Transmitter / receiver

tags
Large Receive Aperture for Spatial Diversity

- Digital samples on each receive element

- Beams are formed digitally
  - number of simultaneous beams limited only by external processors

- All tags within transmit beam are read by multiple, simultaneous receive beams
Example of Spatial Diversity: Schelkunoff array

Chamber Simulation Tag 5

8 Element Schelkunoff Array
Patch width = 4.14 cm
Substrate thickness = .445 cm
Element spacing: \( d = .62 \lambda \)
Conductive fabric circuits and antennas can be manufactured in an art-to-part process (e.g., see NASA MSC-24332, DARPA efforts).

Performance can be indistinguishable from conventional counterparts for many circuits, including RF/microwave circuits and antennas:
- Equiangular spiral
- Microstrip patch antennas
- Quadrature hybrid coupler

![Graph](image)