NASA RFID Applications

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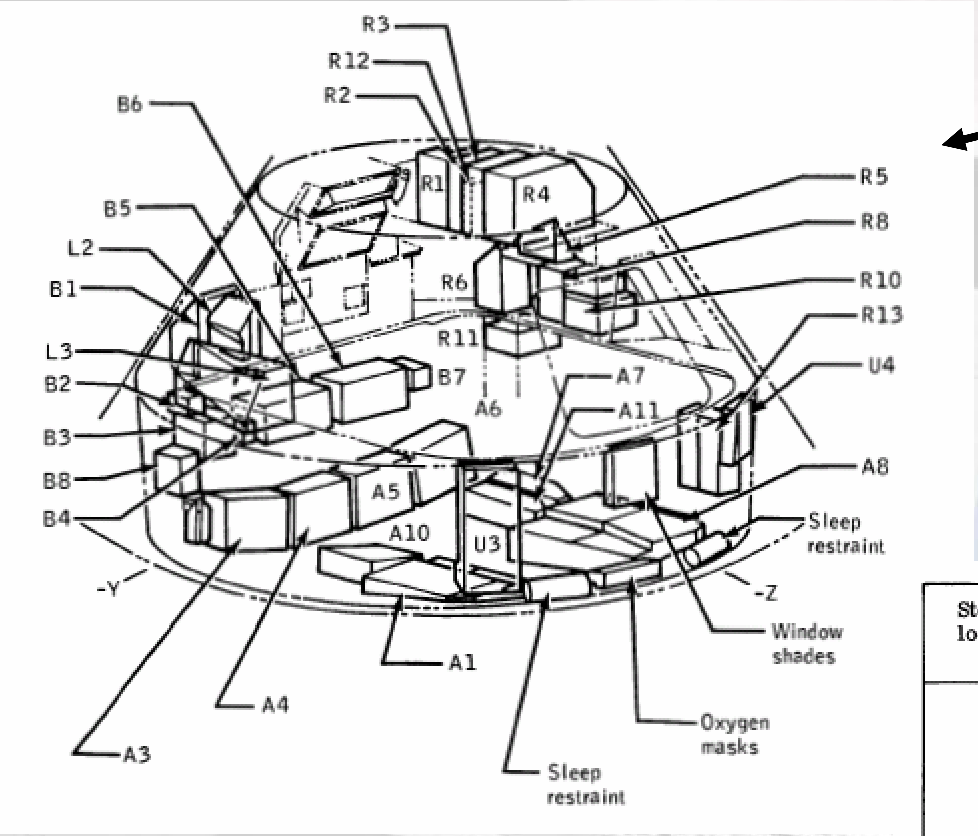
Roadmap

- Inventory management in space
  - Apollo, Space Shuttle, Space Station
- Potential RFID uses in a remote human outpost
- Passive, wireless sensors in NASA applications
- 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

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

(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 times calls down to Mission Control if item locations are needed

STS–109 MIDDECK STOWAGE

FORWARD LOCKERS

MF14E
Food, Menu
FRED

MF14G
Clothing, CDR
Clothing, CDR

MF14H
Bags
  Helmet Stowage (2)
  Inflight Stowage, Restraint (10)
  Jettison Stowage (10)
Bungee, Adjustable (7)
Canister, WCS (Coffee Can)
Covers
  HUD (4)
  Parachute (7)
Hoses
  Personal Hygiene
  WCS Canister

MF14H
(Cont)
Kits
  Comm
    Cables
      Comm, 4 ft
      Comm, 14 ft
    Mic, Handheld (3)
    VLHS (2)
  Saliva
Mirror (2)
O2 Bleed Orifice
Pip Pin (12)
Pip Pin, Escape Pole (Spare)
Switch Guard, Computer
Tape
  Gray, 1 in
  Gray, 2 in
Ziploc, 8 in (20)
Ziploc, 12 in (8)

MF14K
Air Bottles
Breaker Bar, 3/8 in
Breakout Box
Filter, Waste Water Dump
Kit, RMS D&C
Turnbuckles

MF14M
FDF | Bag, WVS

MF14O
Food, Menu
Food, Menu

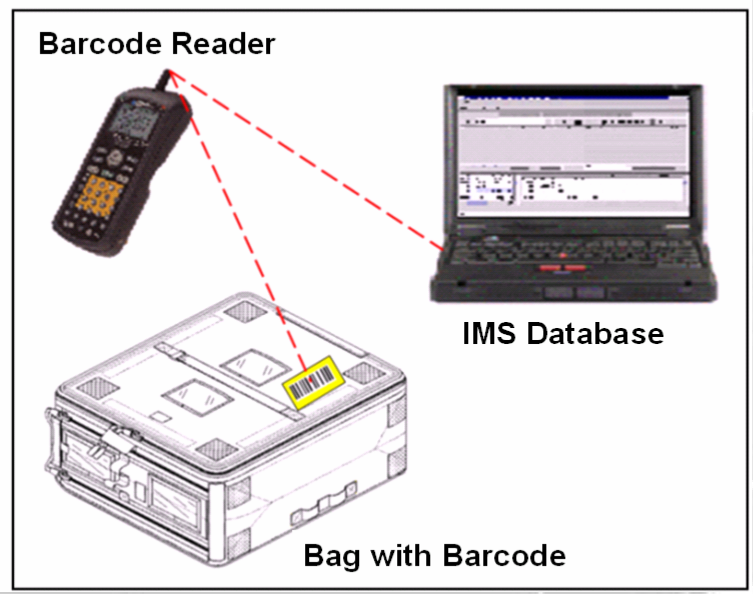
MF28E
Food, Menu
Food, Menu

MF28G
Clothing, PLT
Clothing, PLT

(Reference STS-109 FDF Flight Supplement)

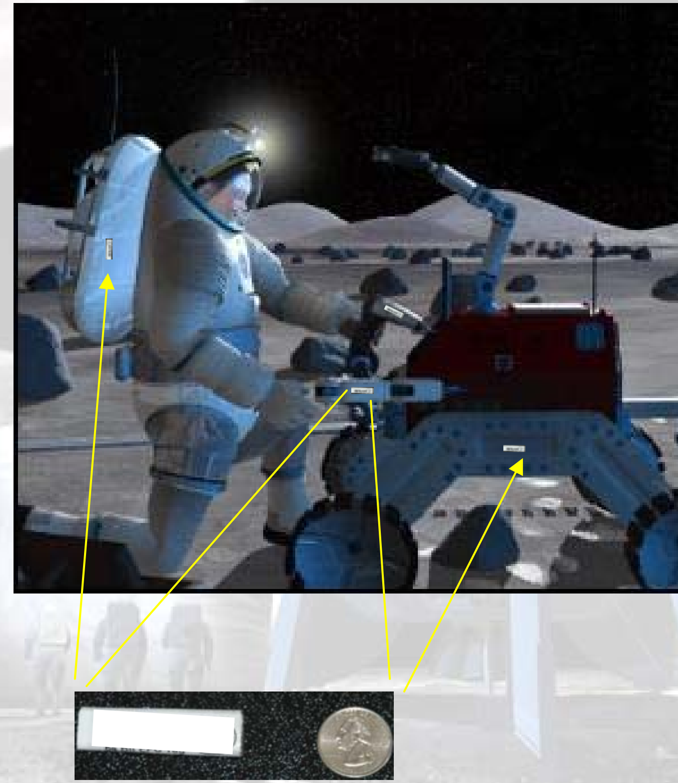
Current ISS Inventory Concept

- 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"



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

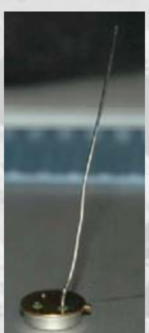
Passive, Wireless Sensors

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

64-bit SAW-based COTS RFID tag

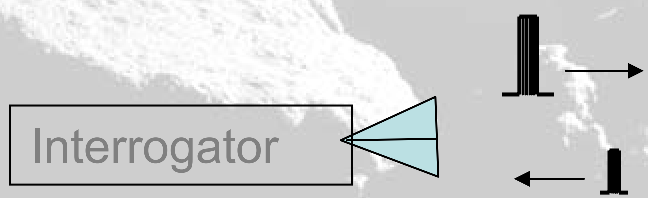
Potential applications for wireless ice sensor system

Passive sensor arrays (enlarged)

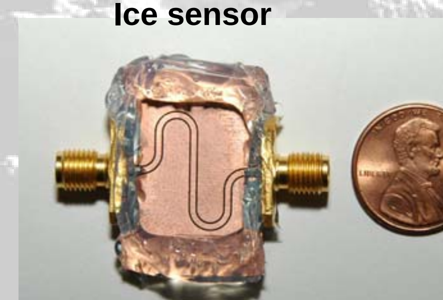


AirGATE Technologies / CTR tag

8-bit SAW-based COTS RFID tag

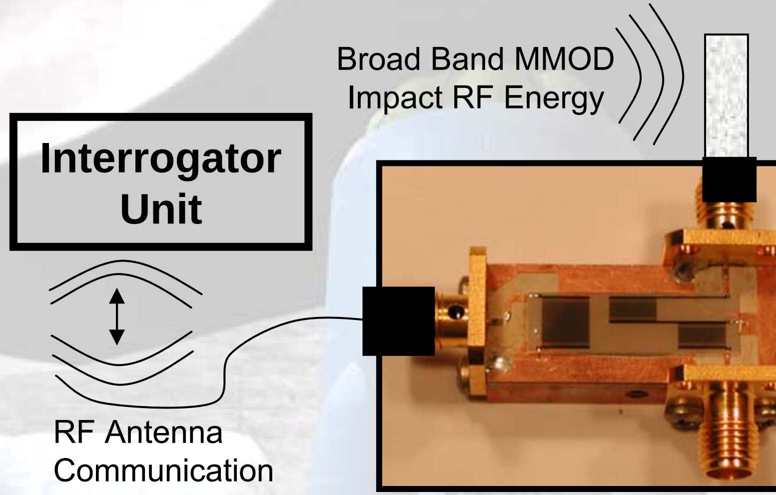


Ice sensor

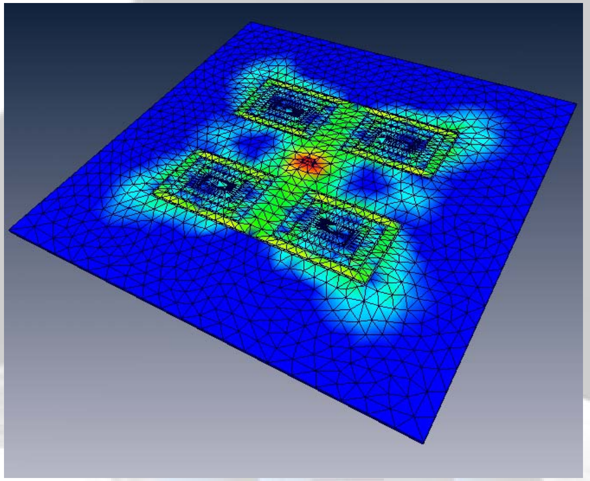


Antennas for HF SAW Sensor System

- 70 MHz SAW-based sensors
  - G. Studor (JSC), R. Brocato (SNL), et al
- Key advantage: integrates existing sensor types into passive, wireless system
- System discussed in earlier presentation
- Requires efficient, miniaturized antennas



HF Antennas

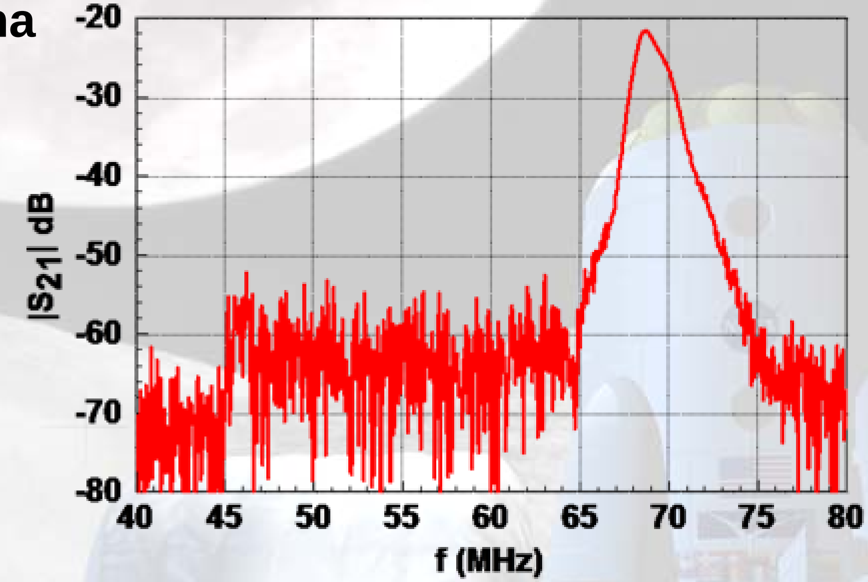


EIGER Simulation

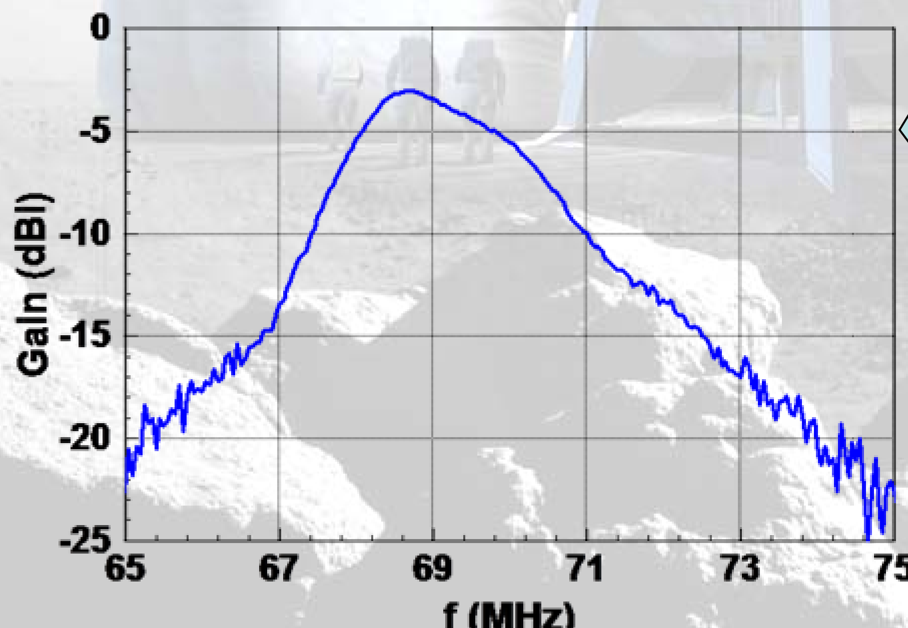
- ❖ Significant size reduction of the antenna
  - ❖ Half-wave dipole ($0.5\lambda_0$, 2.14m)
  - ❖ Miniaturized spiral-loaded slot antenna & ground plane ($0.07\lambda_0 \times 0.11\lambda_0$, 0.3m x 0.46m)
- ❖ Habitat walls are electrically conductive
  - – Cannot use wire antenna directly against conducting wall
  - – Integration of miniaturized HF antenna with habitat walls
    - ▪ E-textile antennas

HF Passive Sensor Antennas

- **Miniature Spiral-Loaded Slot Antenna**

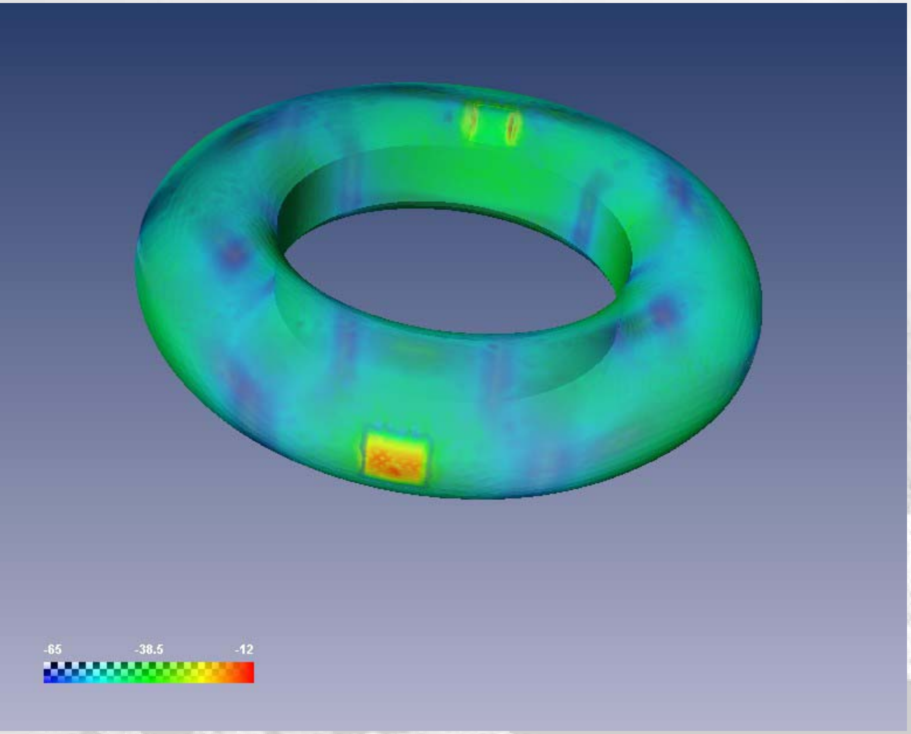


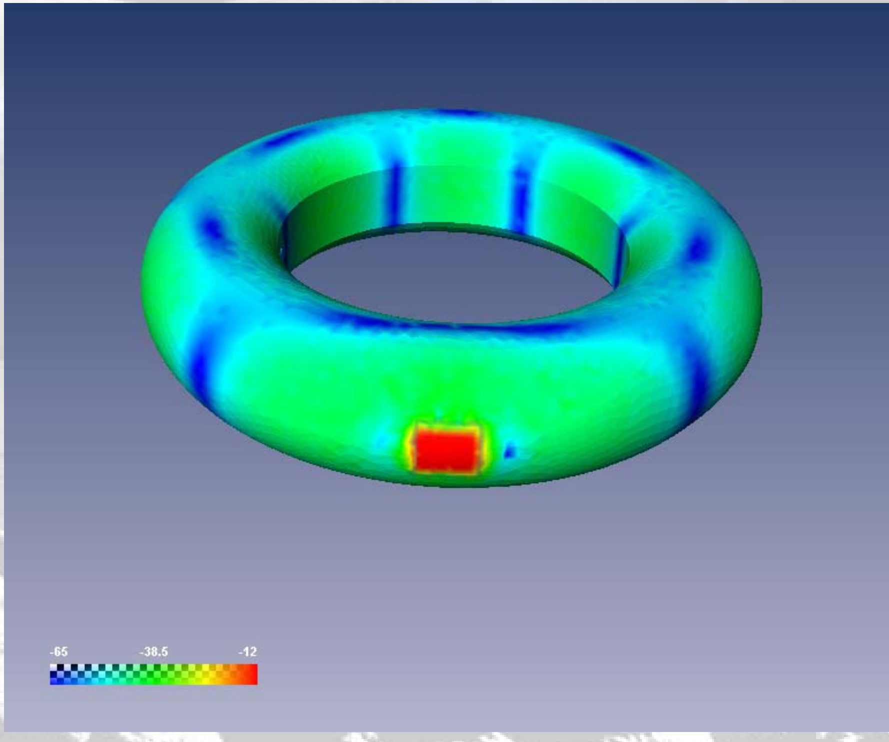
Prototype 4
(45.7cm x 30.5cm x 0.32cm)



Habitat Module Communications

- Coupling between two 70MHz antennas
  - Received power levels at different locations in the mockup
  - Model effects of blockage with equipment in habitat module





Effects of Wavelength on SNR

If we fix the interrogator antenna gain (G_t, G_r):

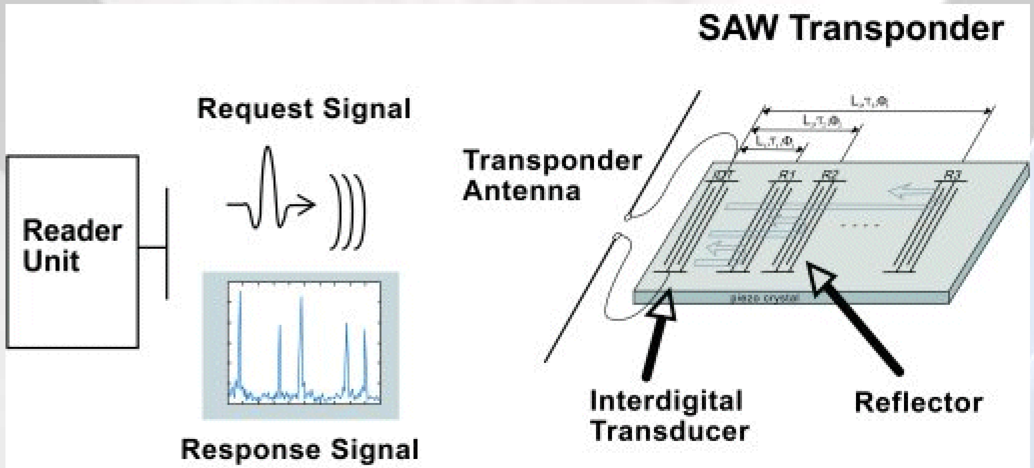
$$SNR = \left(\frac{\lambda}{4\pi}\right)^4 \frac{1}{R_r^2 R_t^2} \frac{P_t G_t G_r G_{tag}^2}{kTBF_n L_{tag}^2}$$

If we fix the interrogator antenna area (A_t, A_r):

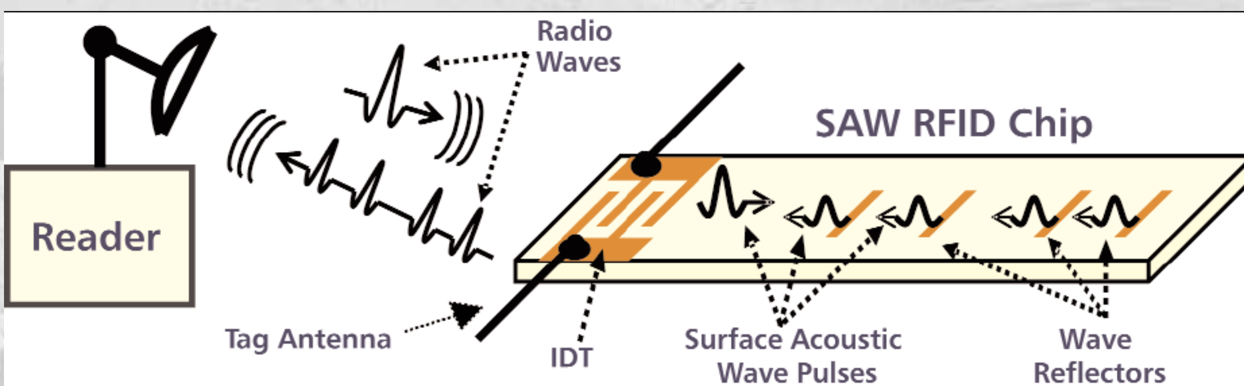
$$SNR = \left(\frac{1}{4\pi}\right)^2 \frac{1}{R_r^2 R_t^2} \frac{P_t A_t A_r G_{tag}^2}{kTBF_n L_{tag}^2}$$

Fixing the area and increasing frequency may require some type of antenna pointing.

NASA Use of 2.4 ISM SAW-Based RFID



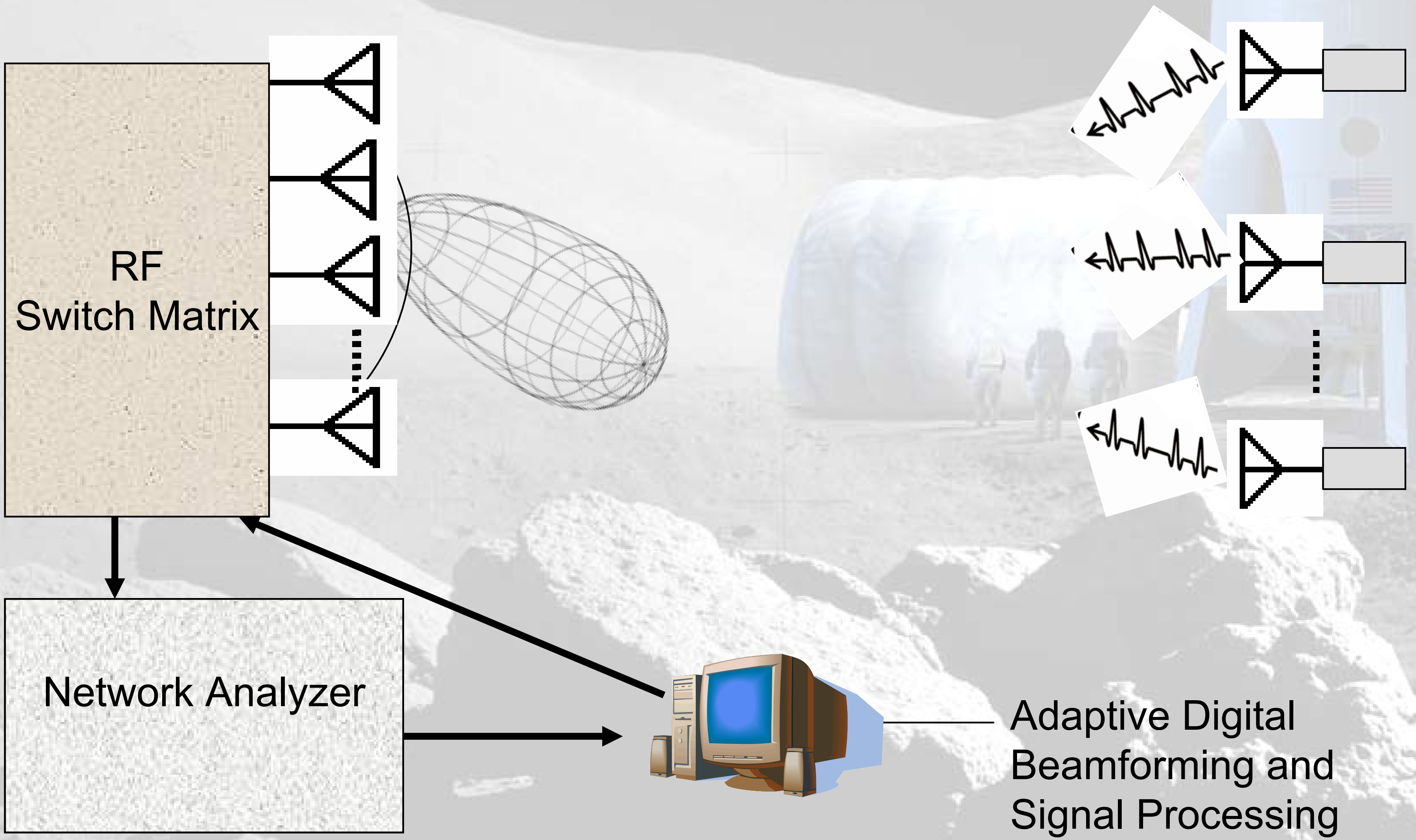
Courtesy AirGATE Technologies



Courtesy RFSAW, Inc.

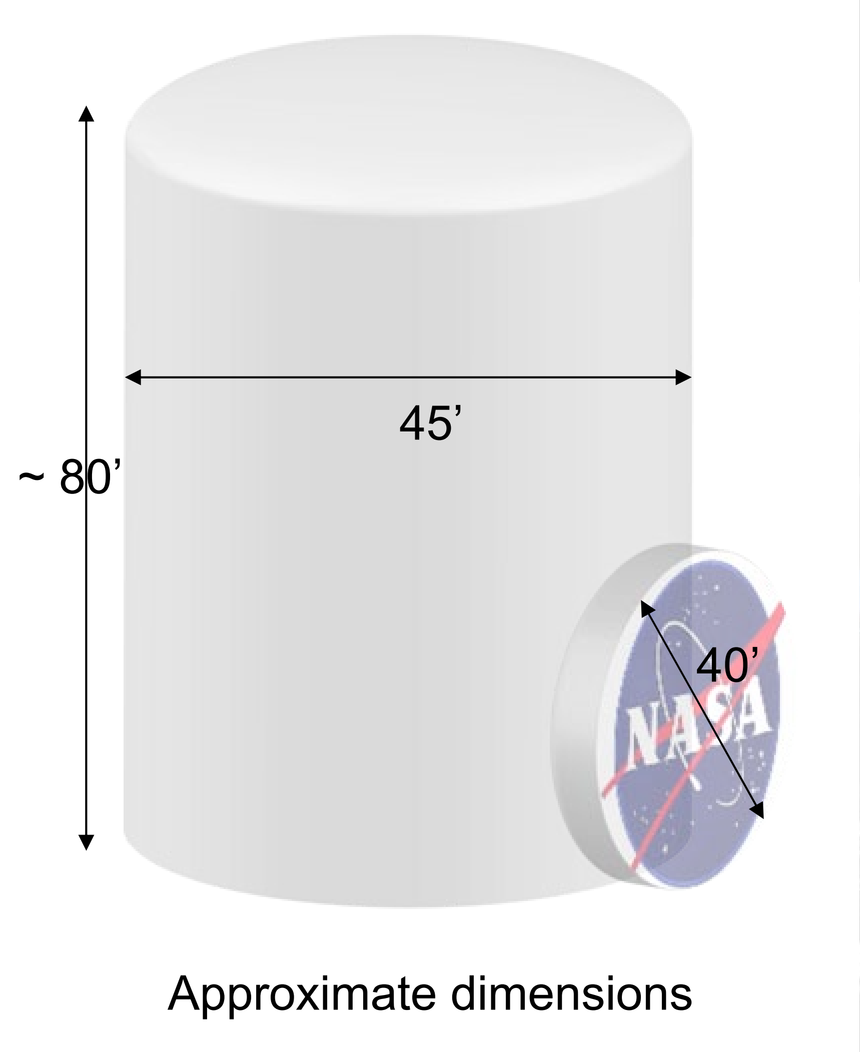
RF Collision Avoidance Methods

- Spatial diversity through adaptive digital beamforming



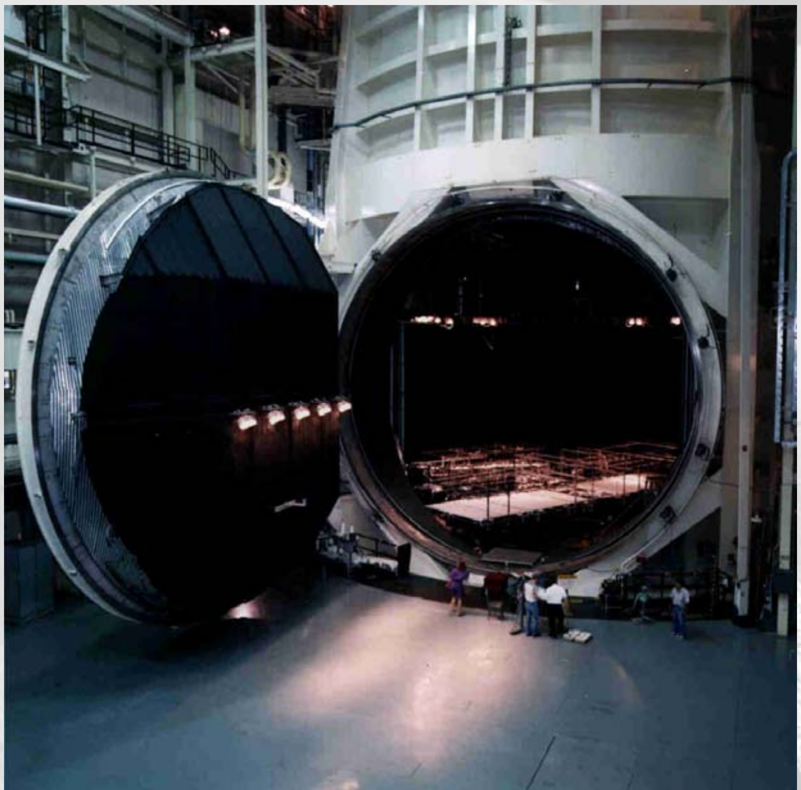
JSC Chamber A Passive, Wireless Sensors (CHAPS)

- 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



Environmental Facility Wireless Sensors

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



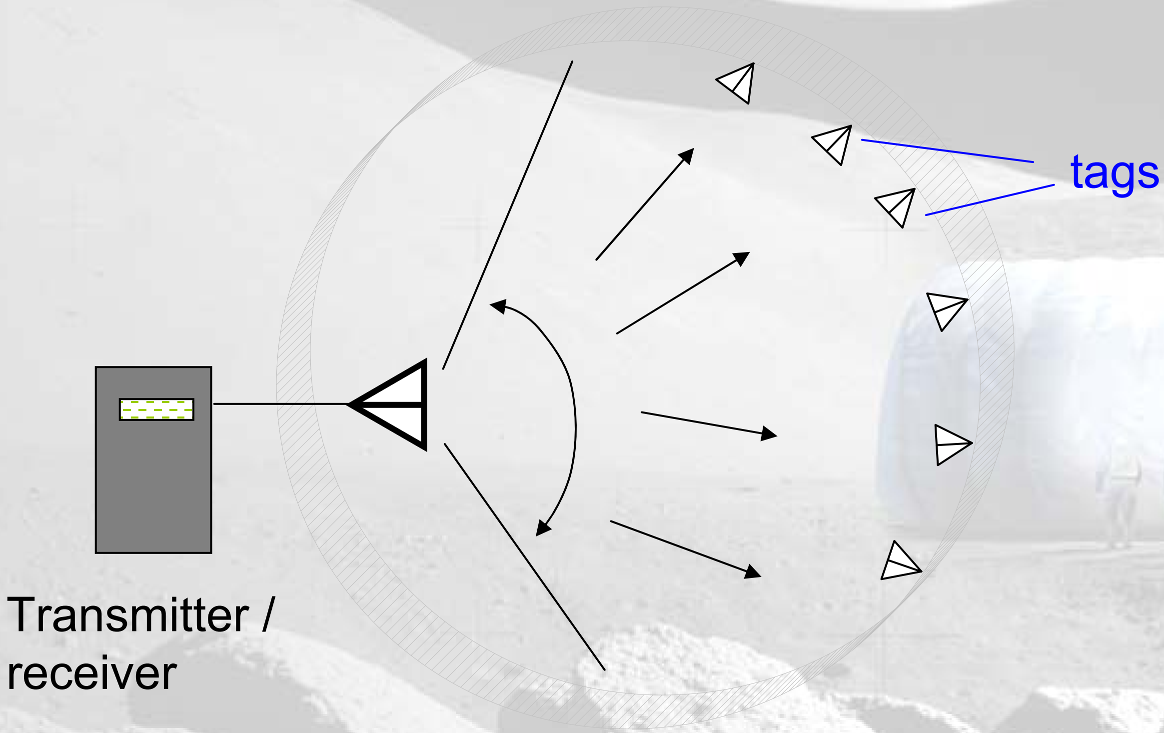
JSC Chamber A
(Vacuum & Thermal Cycle)

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

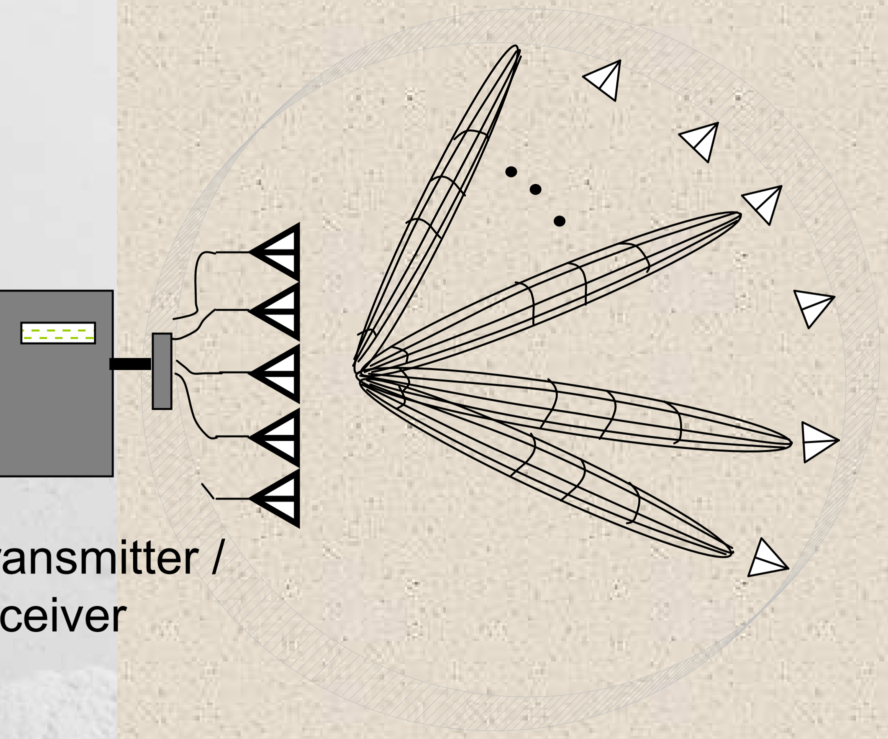
Antenna System Approach

- 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



Large Receive Aperture for Spatial Diversity



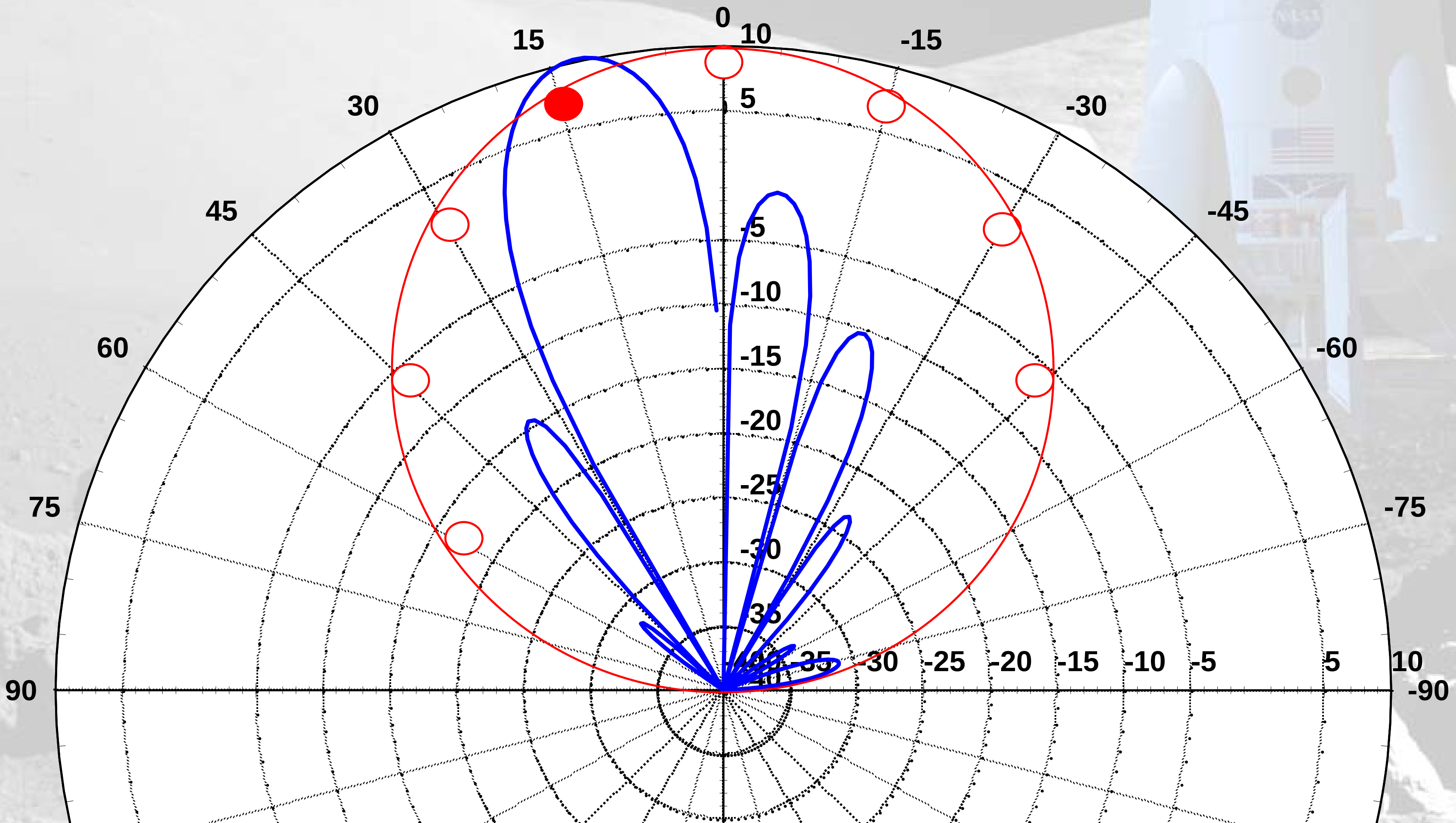
- Digital samples on each receive element
- Beams are formed digitally
  - number of beams limited only by external processors
- Ideally, all tags within transmit beam are read

Example of Spatial Diversity: Schelkunoff array

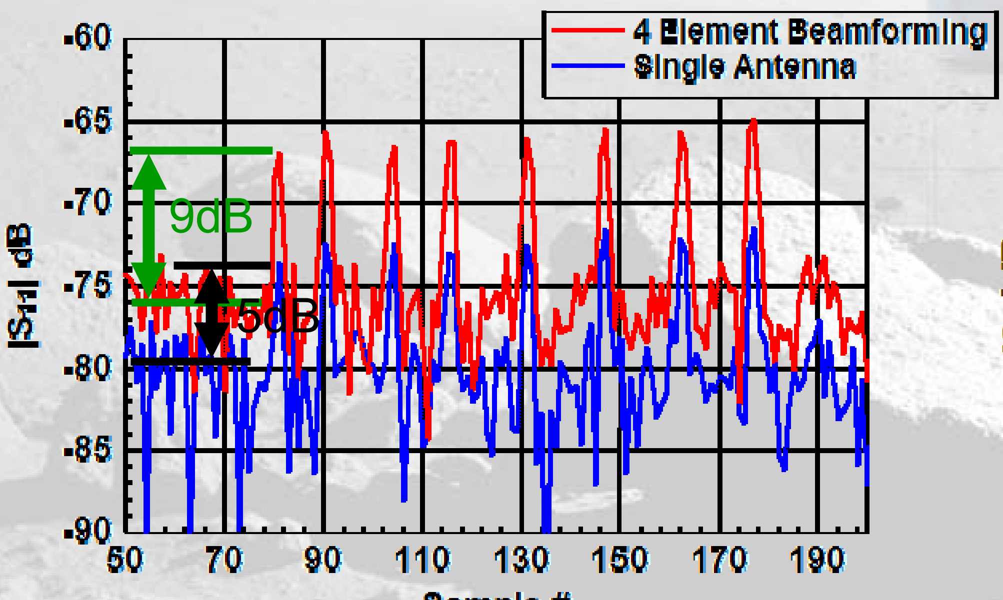
Chamber Simulation Tag 5

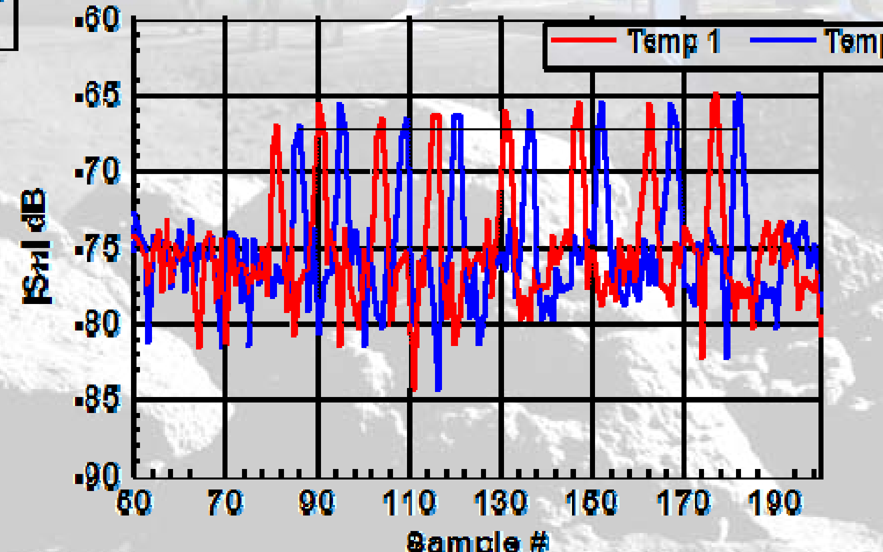
8 Element Schelkunoff Array

Patch width = 4.14 cm
Substrate thickness = .445cm
Element spacing: d = .62 λ

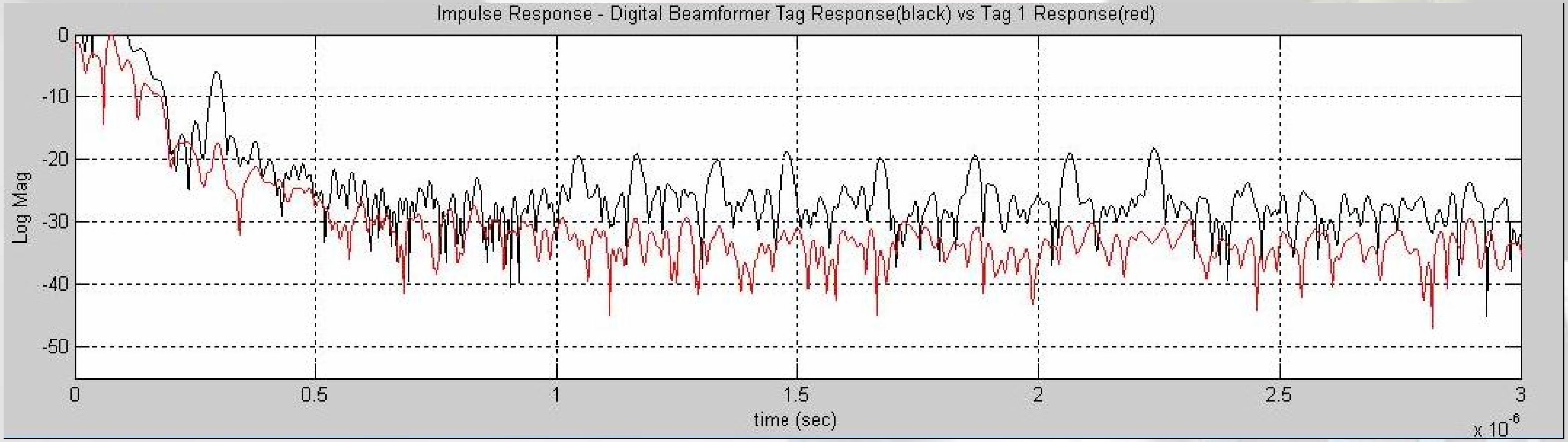


Beamforming and Temperature Sensor Demo





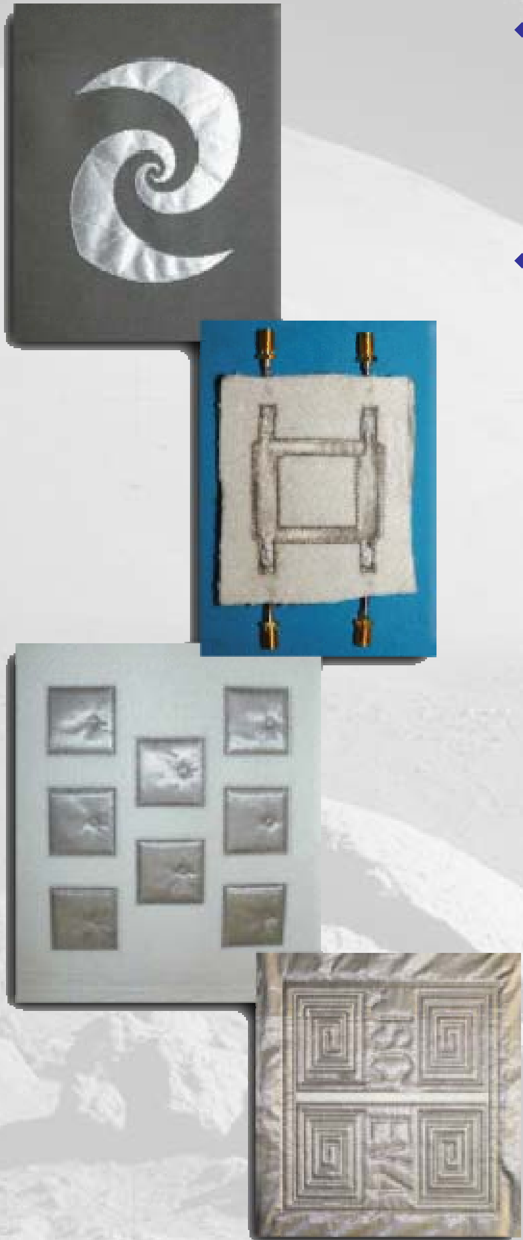
Status



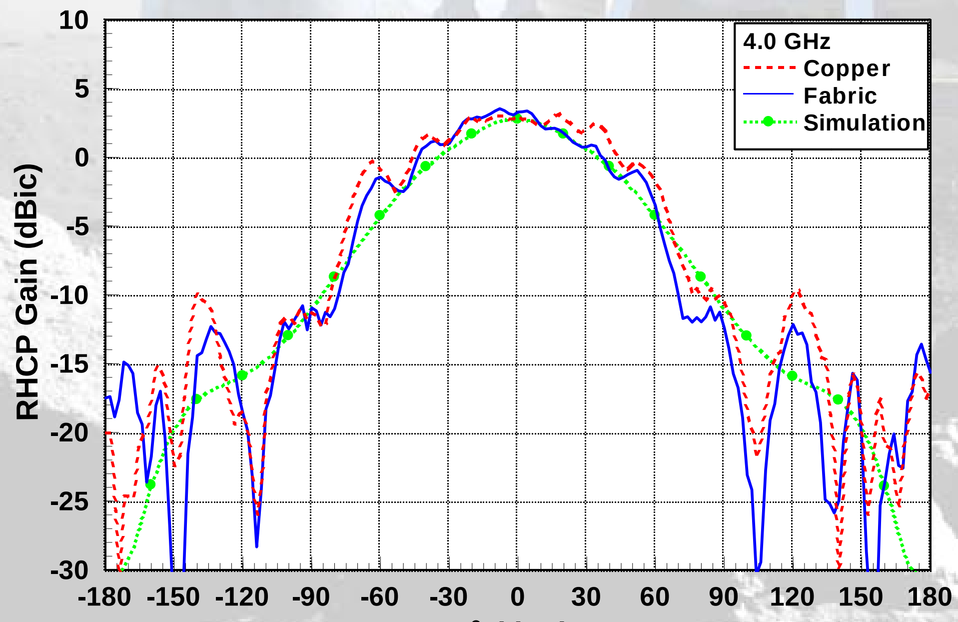
- Characterizing digital beamforming array in anechoic environment
  - Extracting signal from noise through digital summation

- Test in Chamber A by Summer 2007

E-Textiles at NASA



- 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



…more to come

IEEE

Symposium for Space Applications of Wireless & RFID 2007

May 8-9, 2007
Houston, TX

http://www.ghg.net/ieeegbs/swirf2007/