Rover-Mounted, Real-Time and High-Resolution Microwave SAR Imaging System for Evaluation of Shallow Martian and Lunar Regolith

R. Zoughi, M.T. Al Qaseer & M. Dvorsky
Electrical and Computer Engineering Department (ECpE)
Center for Nondestructive Evaluation (CNDE)
Iowa State University (ISU)
Ames, IA 50011

D. Motes
Texas Research Institute, Austin, Inc. (TRI Austin)
Austin, TX 78733

T. Watt
AVID R&D, LLC
Conifer, CO 80433

Objectives

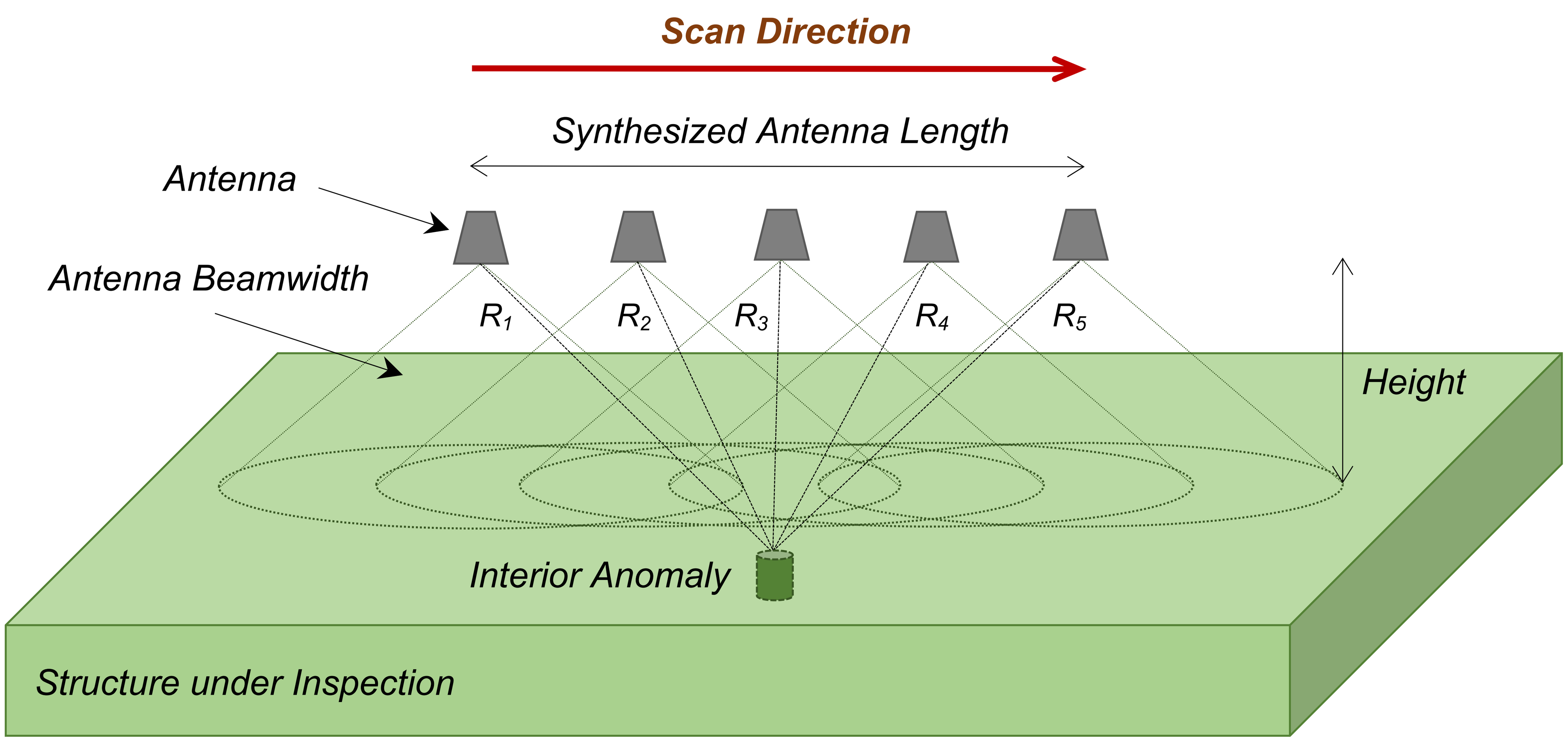
- Microwave synthetic aperture radar (SAR) imager specifically designed for applications relevant to the exploration of the Moon and Mars:
  - Imaging of shallow regolith
  - In-situ resource utilization (ISRU)
  - Detection of rocks, clathrates, CO_2 ice, etc.
  - Monitoring regolith sintering and characterization
  - Monitoring 3D printing of structures using indigenous materials
  - Detection of H_2O ice

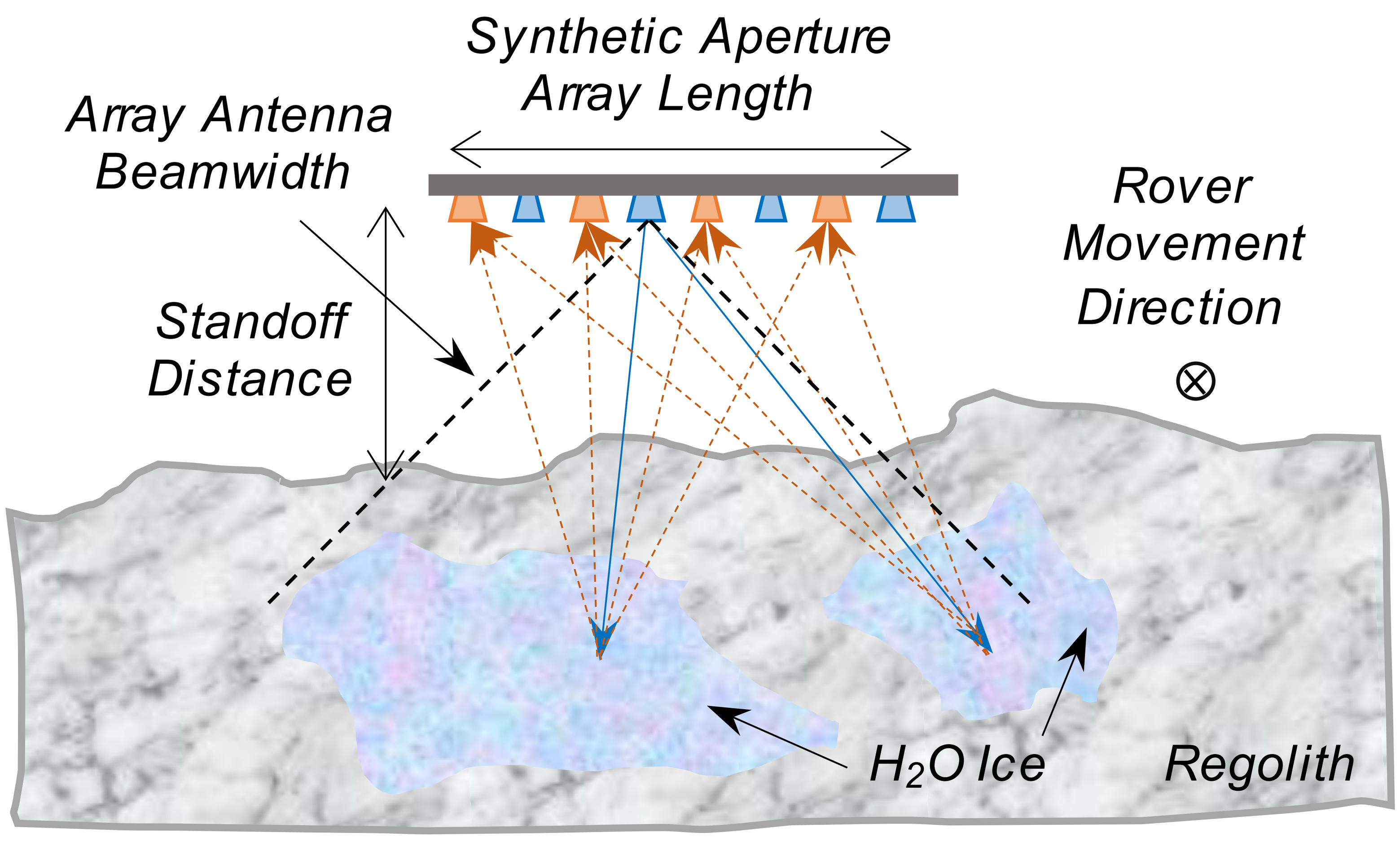
Features

- Imager system attributes include:
  - Mature technology with focus on nondestructive evaluation (NDE) as opposed to air-borne imaging systems – unique nuances must be considered
  - Rover-mounted portable
  - Real-time imaging capability
  - Consideration of a wide range of operating frequency and bandwidth
    - Optimization of depth of penetration
    - Flexibility in attaining desired cross-range (spatial) resolution
    - Flexibility in attaining desired along-range (depth) resolution
  - Low power level requirement
  - Optimization of antenna size and gain pattern for desired performance
  - Staggered multiple linear antenna arrays for high image fidelity and S/N (i.e., no aliasing, multi-static measurements, etc.)
  - Robust against frequency drift, dynamic change in array height (i.e., movement over undulating terrain)
  - Numerous imaging antenna array configurations (options)
  - Adaptive imaging capability – variable resolutions and power savings (on-the-fly optimization)
  - Potential buried target complex permittivity characterization

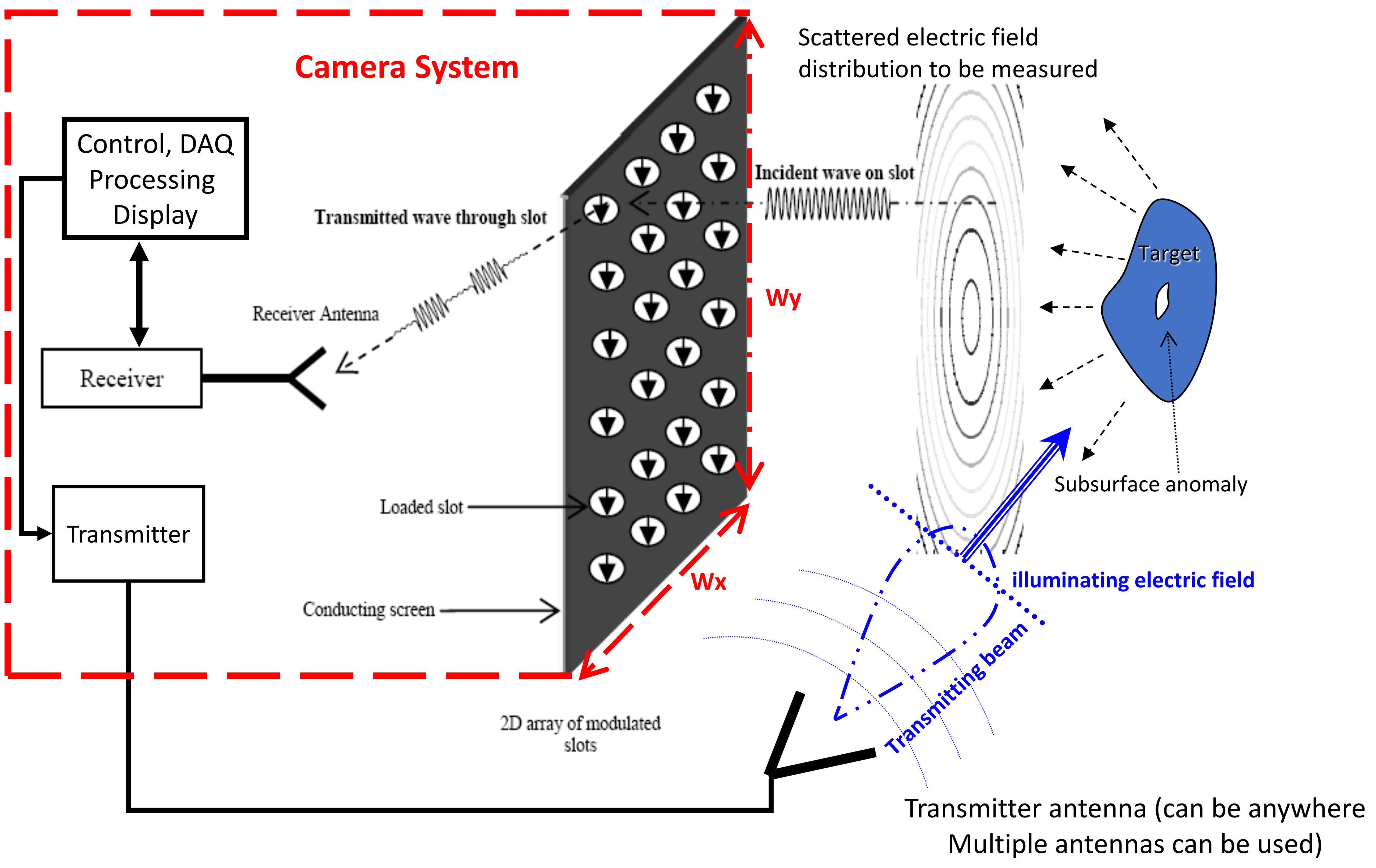
Foundation

- Utilizing an antenna array and movement of a rover to perform 2D scan to collect imaging data

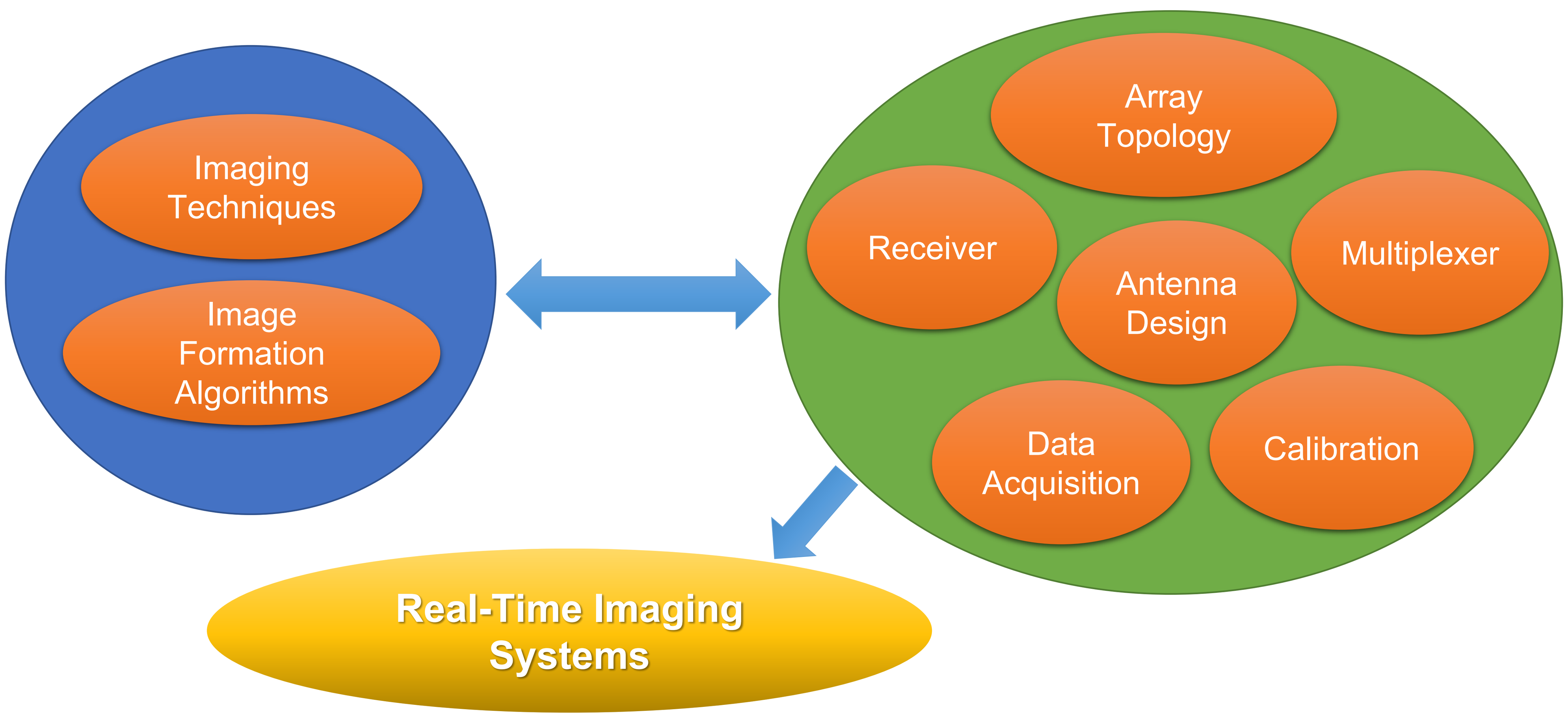




Technology Foundation

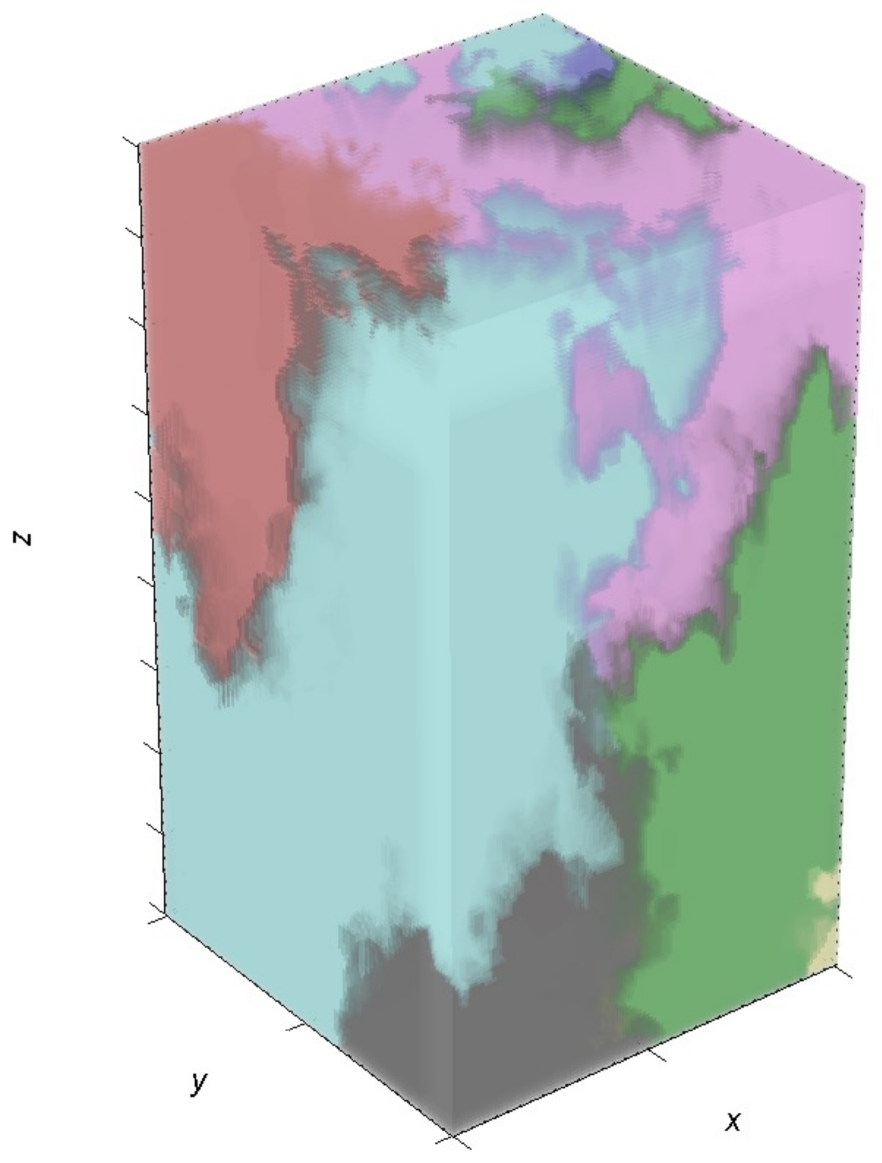


Design Requirements



Application Concepts

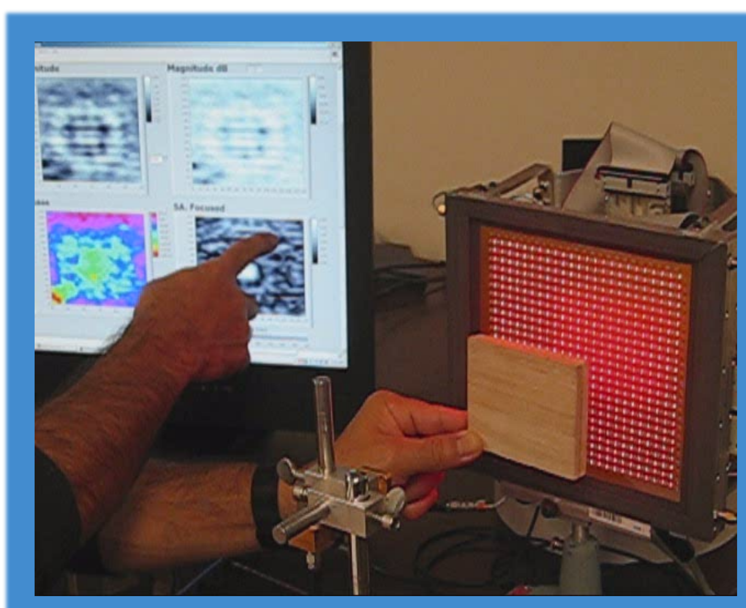
Expectations



Technology Development Chronology

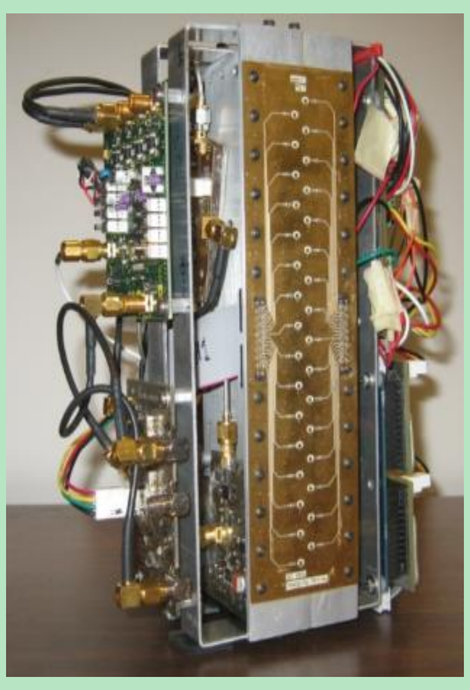
- Single frequency (24 GHz)
- Small aperture
- Transmission-thru

2006



- Single frequency (24 GHz)
- 24 fps
- 6"x 6" aperture
- Transmission-thru

2009



- Single frequency (30 GHz)
- 6" - 1D Array
- Bi-static (one-sided)

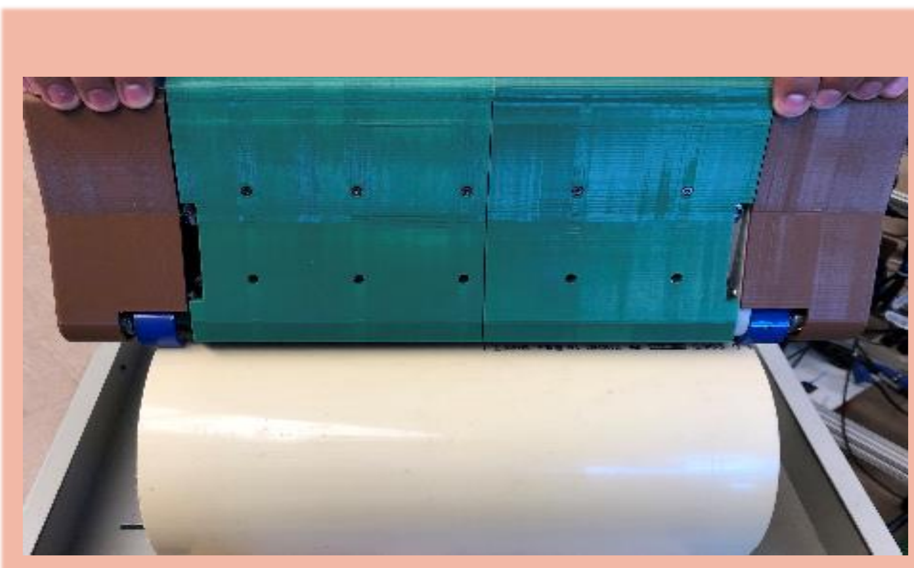
2012

- Single Frequency (24 GHz)
- Small aperture
- Simultaneous operation
- One-sided

2018

- Wideband (20-30 GHz)
- 30 fps
- 6.5"x 5" aperture
- Mono-static (one-sided)

2015



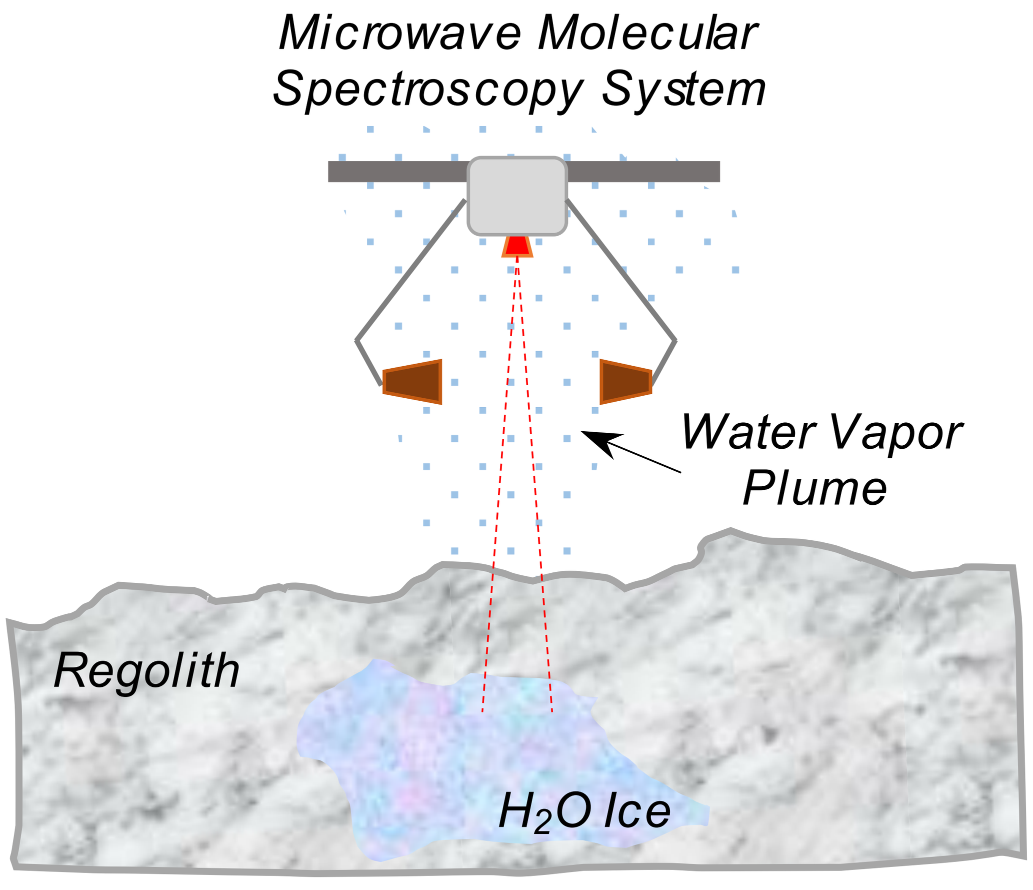
- Wideband (23 -27 GHz)
- 8.5" - 1D Array
- Mono-static (mono-static)

2019

- 8 Arrays (x64 elements)
- Fully multi-static one-sided
- 256 transmitters, 256 receivers
- Aperture Size: 15" x 3.5"
- Frequency: 26.5 – 40 GHz
- Cross-range resolution: ~2.5 mm
- Range Resolution: ~11 mm

2022

Microwave Spectroscopy – Detecting H_2O



Collaboration with Garry "Smitty" Grubbs II, Dept. of Chemistry – MO S&T.