Synthetic Aperture Radar (SAR) Imaging using the MIT IAP 2011 Laptop Based Radar*

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Gregory L. Charvat, PhD
MIT Lincoln Laboratory

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Outline

• Aperture, Antennas, and Arrays
  • Synthetic Aperture Radar (SAR)
  • Airborne SAR
  • Rail SAR
  • SAR using the MIT IAP Radar
• Homework
Similar to a camera, larger the aperture the more energy collected
For a parabolic antenna, the ‘dish’ is the aperture
Larger the ‘dish’ the greater the gain compared to isotropic (ideal point radiator) providing increased signal-to-noise (SNR).
Larger the dish the narrower the half-power beamwidth providing greater angular resolution.
Plan Position Indicator (PPI)

- Contemporary radar system
- Rotate a large aperture for a PPI (angle vs. range) image
  - angular resolution depends on aperture size
  - gain depends on aperture size

(targets)
Cloudy skies above western Europe
RAF bombing at night complicating navigation
H2S ground mapping radar solved problem [1]
  navigation and bomb laying
  could map out where cities were located
  later versions could map out cities
Antenna Aperture and Arrays

Array Factor: \[ AF(\theta) = \sum_{n=1}^{N} A_n e^{j\beta x_n (\sin \theta - \sin \theta_s)} \]

- Longer the array the more elements
- More elements provides more gain providing greater SNR
- More elements reduces 3 dB beamwidth providing higher resolution
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Synthetic Aperture Radar (SAR)

- Small antenna on aircraft illuminates large swaths of ground
- Range profiles recorded along flight path
- SAR algorithm processes data into image of ground [2]
  - *thereby synthesizing an aperture the length of the aircraft flight path*
  - *narrow beamwidth, high resolution and gain*
Real-Time Imaging SAR Algorithm

- Range Migration Algorithm (RMA) [2]
- Used for stripmap SAR imaging
- Accounts for wave front curvature
  - the synthesized aperture is large compared to target scene

Flight Path vs. Range Data → Hilbert Transform → Calibration Matrix → Matched Filter → Stolt Transform → 2D IDFT → Resulting image
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LiMIT Ultra-Wideband X-Band SAR
2.5 in × 2.5 in Resolution (3.0 GHz)

Sierra Vista, AZ, August 18, 2005

Lincoln Multi-mission ISR Testbed (LiMIT)

Phased-Array Antenna

160 m Range cutout (400 m swath)

260 m Cross Range cutout (2 km swath)

Sierra Vista, AZ, August 18, 2005

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Sierra Vista, AZ, August 18, 2005

(Aerial Photo)

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Linear Rail SAR

- FMCW Radar moved down linear rail
- Range profiles acquired along rail
- SAR algorithm synthesizes aperture to form high resolution image
Rail SAR example: Backyard SAR

Aircraft Models Placed on Styrofoam Table

Data Acquisition and Rail Control

http://blog.makezine.com/archive/2010/06/how-to_build_a_synthetic_aperture_r.html
http://hardware.slashdot.org/story/10/06/18/1350259/ DIY-Synthetic-Aperture-Radar


Backyard SAR Imagery

Imagery of aircraft placed on Styrofoam table

1:48 Scale B52

1:32 Scale F14

20 cm
Backyard SAR Imagery

5.0 Mustang on radar

Cannondale M300
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• implement rail SAR by manually moving radar down straight path

• record range profiles incrementally every 2”

• process with SAR_image.m
Example: SAR image of Back of Warehouse using IAP ‘11 Radar
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• Use the MIT IAP radar to make SAR imagery of one or more interesting target scenes of your choice

• Discussion of your imagery during final class on 1/28/11

References


