

Wide Angle, Staring Synthetic Aperture Radar

Feb 2012



Ed Zelnio
Sensors Directorate
Air Force Research Laboratory



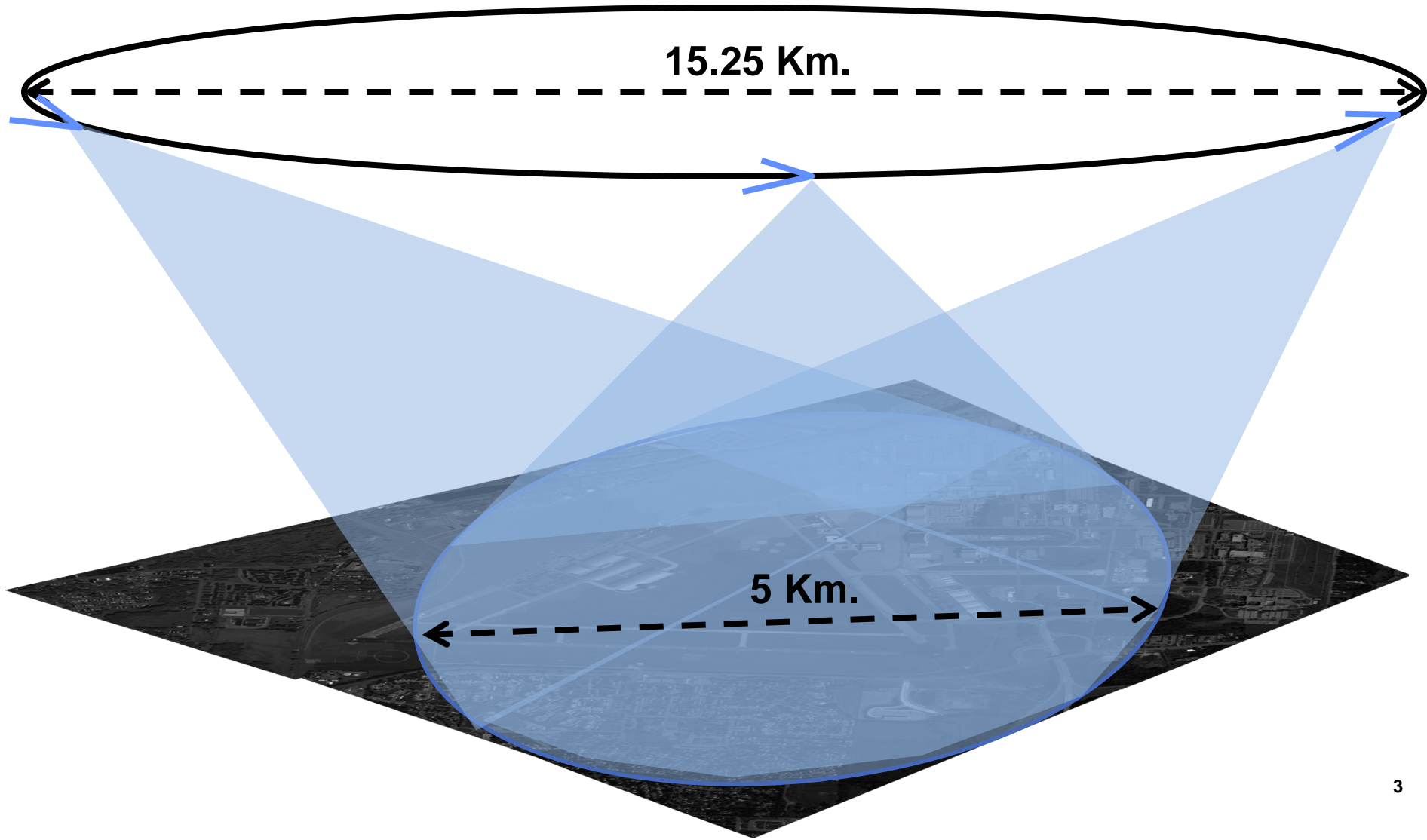
Outline



- **Review SAR – Focus on Wide Angle, Staring SAR (90%)**
- **Technology Challenges (10%)**



Wide Angle, Staring Synthetic Aperture Radar





Gotcha Radar Program
Michael Minardi, et al
Processing and Data Products
June 2008 (Oral Presentation)



Synthetic Aperture Radar



- **Geometry**
 - SAR Projection
 - Layover v Parallax v Shadow
- **Energy Scattering**
 - Diffuse v Specular v Scintillation / Speckle
 - Man-made v Natural
 - Military v Civilian
 - Scalar v Polarization
 - High Frequency v Low Frequency
 - Modulus v Phase
 - Standard v Wide Angle
- **Tomography / Aperture**
 - Range (Frequency) v Azimuth v Elevation (Angle)
 - Far Field v Near Field
 - Image v Phase History
 - Coherent v Incoherent
 - Stationary v Moving

SAR v Visible v CAT



SAR / Visible / CAT Comparison



	SAR	Visible	CAT (e.g., X-ray)
Elemental Projection	<ul style="list-style-type: none">• 1D• Orthogonal to Line of Sight• Ranging (Time / Frequency)	<ul style="list-style-type: none">• 2D• Along line of Sight• Angle / Angle	<ul style="list-style-type: none">• 2D• Along line of Sight• Angle / Angle
Energy / Scattering	<ul style="list-style-type: none">• Active (Waveform)• Diffuse Scattering<ul style="list-style-type: none">• Natural• Specular Scattering<ul style="list-style-type: none">• Man-made	<ul style="list-style-type: none">• Passive• Diffuse Scattering	<ul style="list-style-type: none">• Active• Diffuse Transmission
Tomography \ Aperture	<ul style="list-style-type: none">• Coherent (t, angle)• Frequency / Azimuth / Sparse Elevation• Phase History• Carrier Frequency	<ul style="list-style-type: none">• Non-Coherent• 2D Angle / Azimuth / Elevation• Image• Base band	<ul style="list-style-type: none">• Non- Coherent• 2D Angle / Azimuth / Elevation• Image• Base band

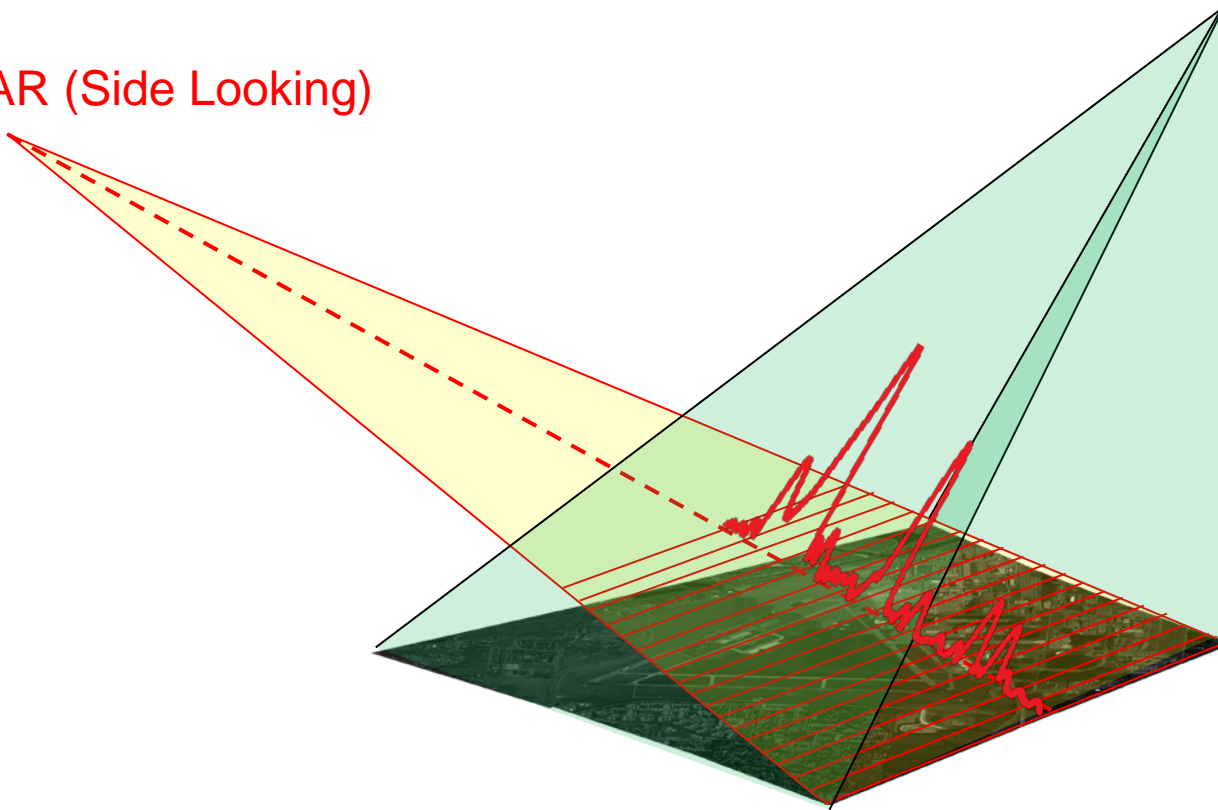


Geometric Projection SAR v Photo



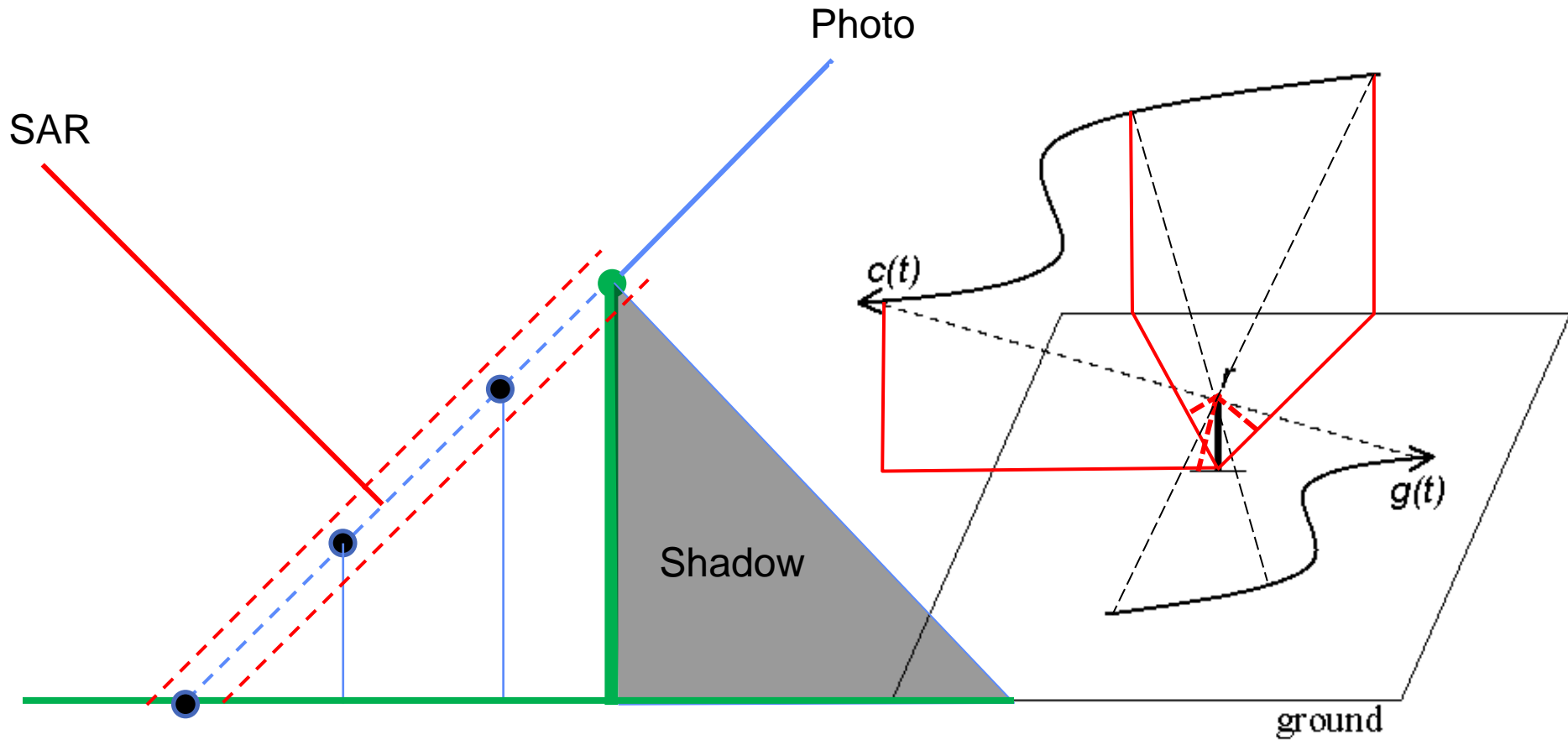
Photo (Downward Looking)

SAR (Side Looking)



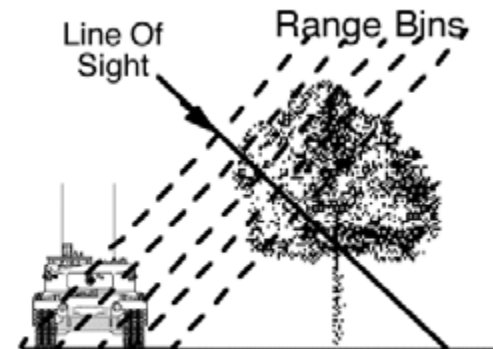
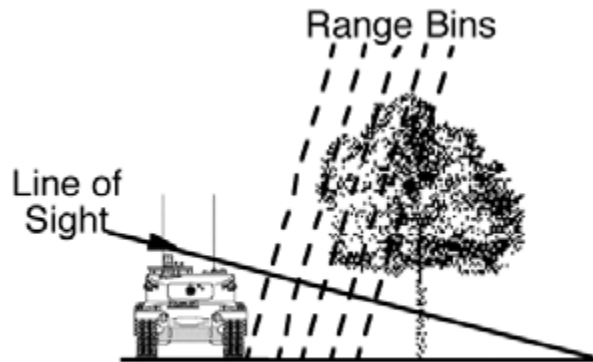


Projections (Layover v Parallax v Shadow)



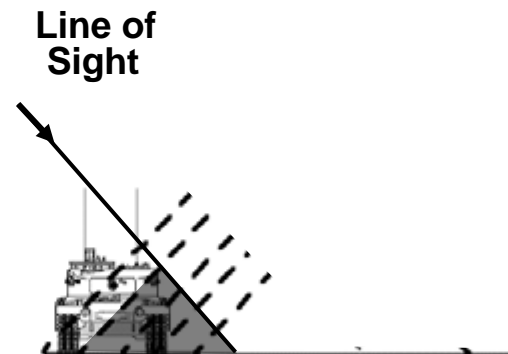
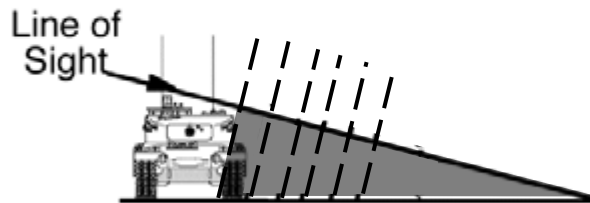


Layover and Shadow



Foliage Return Contaminates Target Signature Range Bins

LAYOVER



SHADOW

Fourier Processed Flat Plane Projection



Future Air Force Sensing Challenges
Ed Zelnio

Compressive Sensing Workshop
Feb 2009, Duke, (Oral Presentation)



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June 2008 (Oral Presentation)



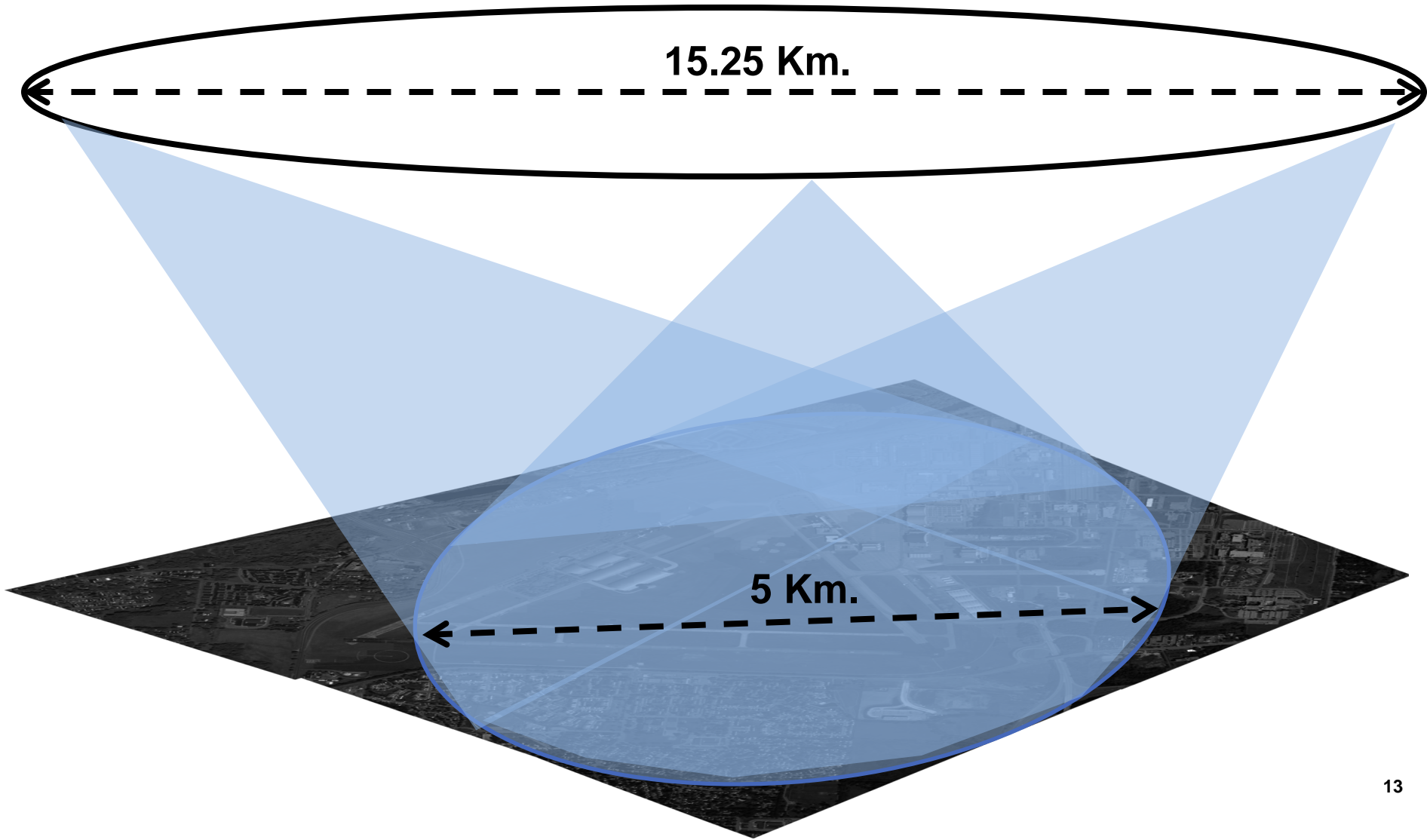
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Wide Angle Synthetic Aperture Radar





Improved Image Quality

Single-Look vs. Multi-Look



Wooden Structure
in trees

Vehicles in Treeline

Speckle Reduction

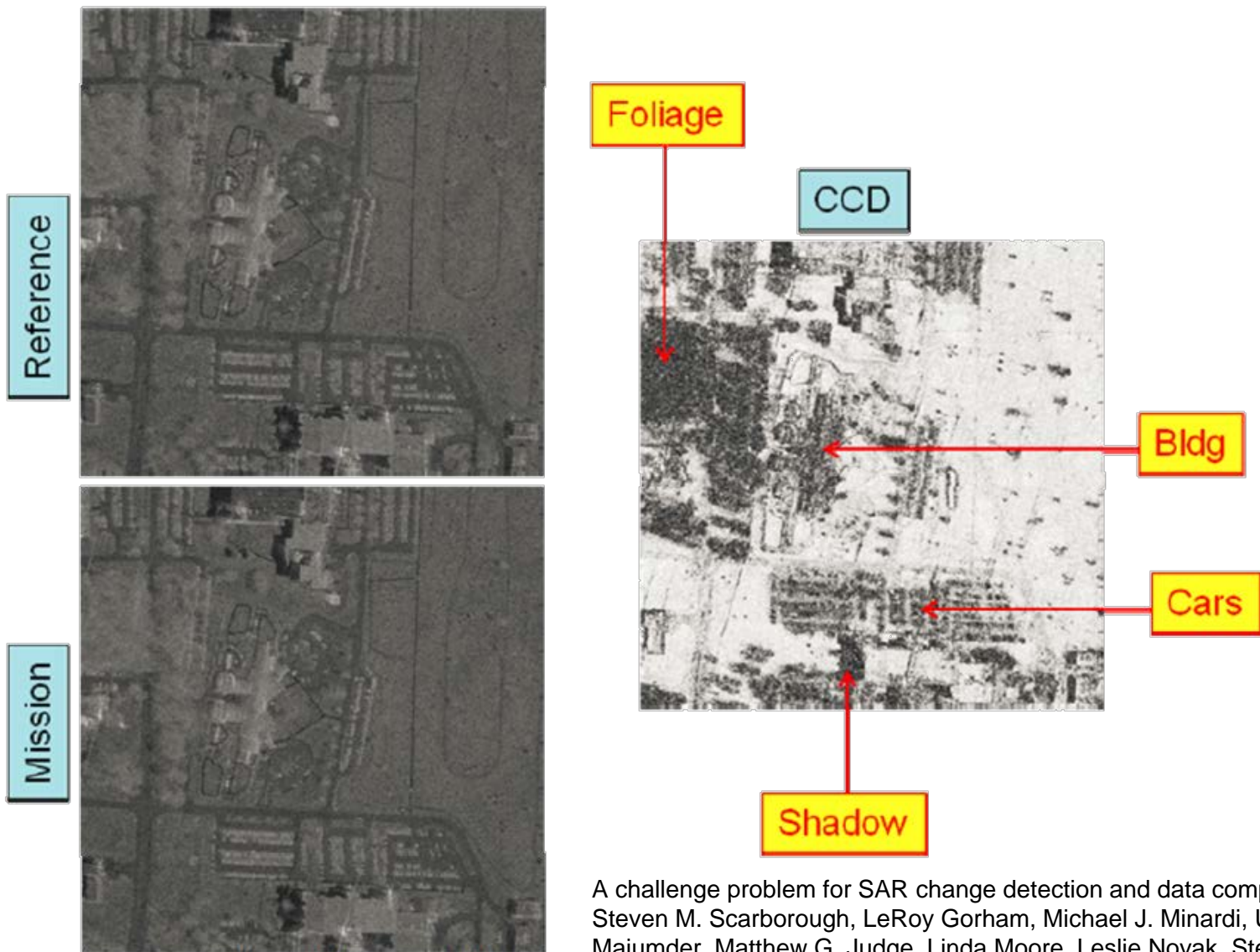


Single-Look SAR

Multi-Look SAR



Coherent Change Detection



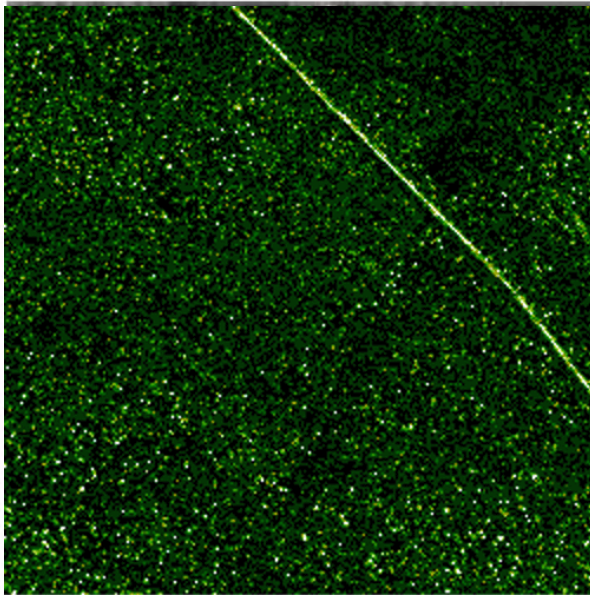
A challenge problem for SAR change detection and data compression
Steven M. Scarborough, LeRoy Gorham, Michael J. Minardi, Uttam K. Majumder, Matthew G. Judge, Linda Moore, Leslie Novak, Steven Jaroszewski, Laura Spoldi, and Alan Pieramico



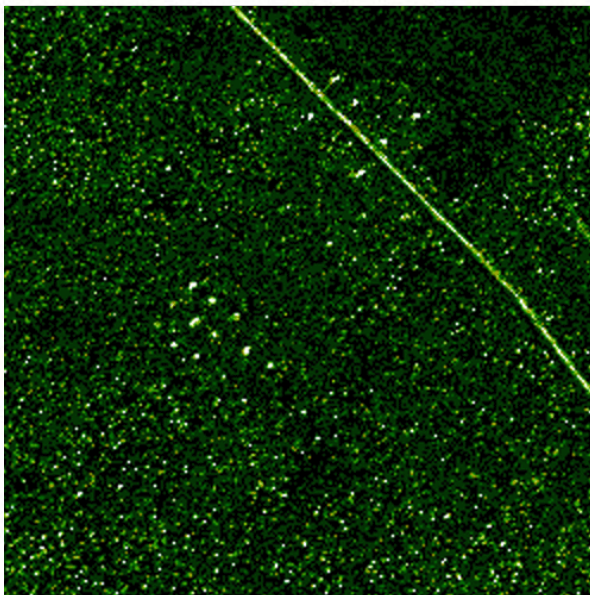
VHF Change Detection in Dense Foliage



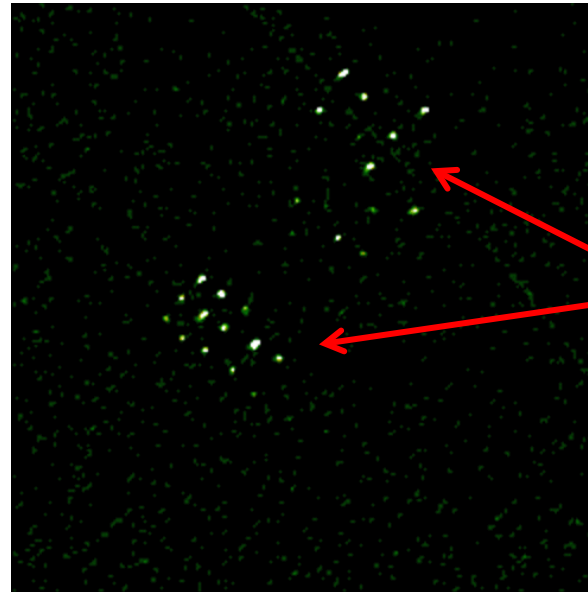
Reference



Mission



NCD



Vehicles

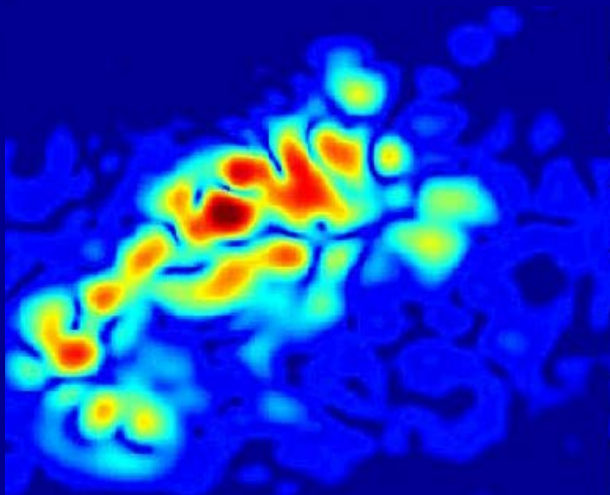


Performance of VHF-band SAR change detection for wide-area surveillance of concealed ground targets

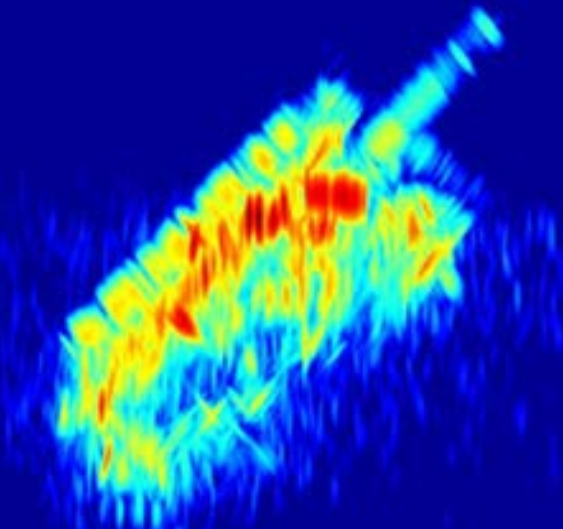
Lars M. Ulander, William E. Pierson, Mikael Lundberg, Peter Follo, Per-Olov Frolind, and Anders Gustavsson
Proc. SPIE 5427, 259 (2004)

Tank v Honda Civic

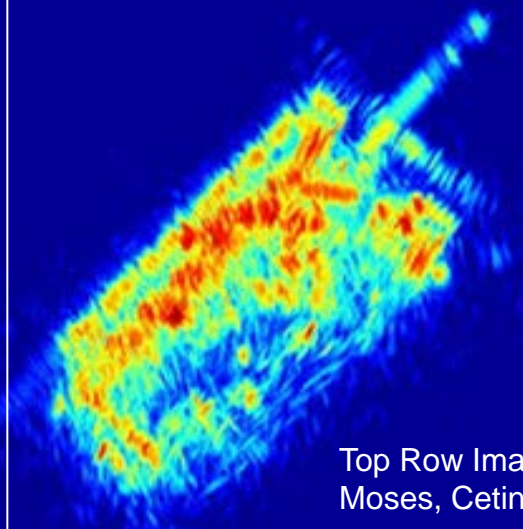
3 Degrees Aperture



110 Degrees Aperture

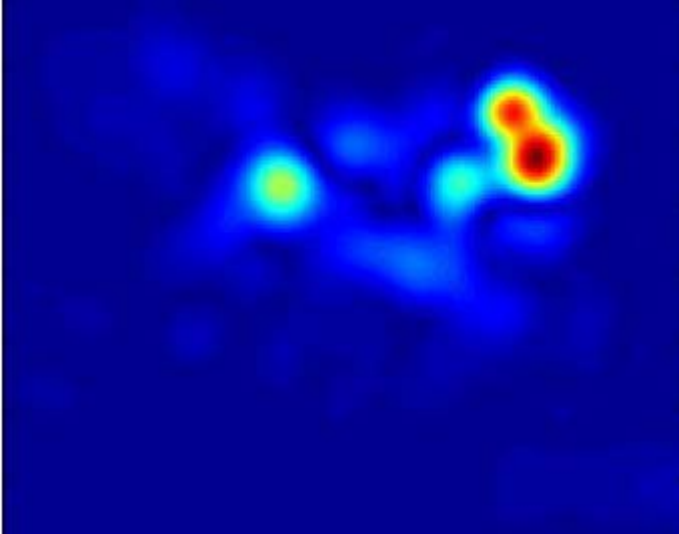


110 Degrees Aperture
(Enhanced)

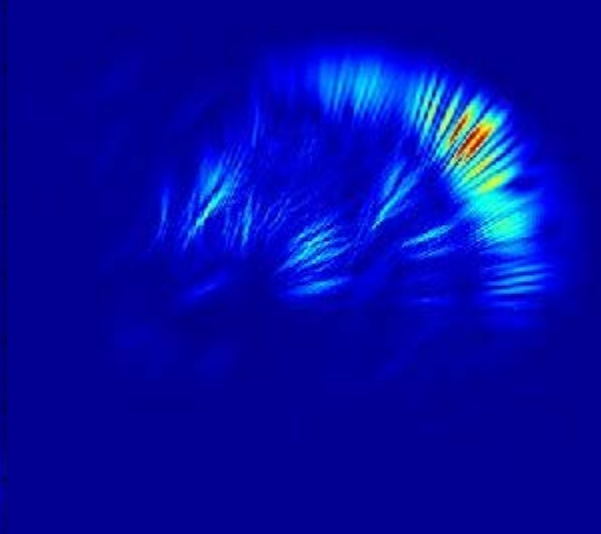


Top Row Images by
Moses, Cetin

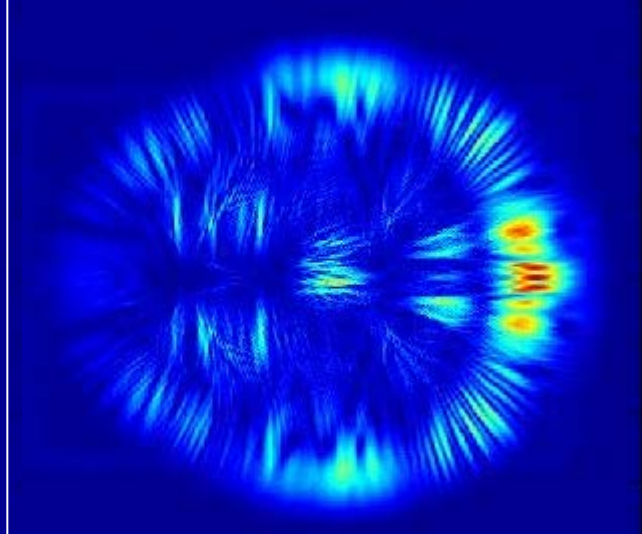
5 Degree Aperture



110 Degrees Aperture



360 Degrees Aperture





Deconvolution + Angle Diversity



- 110 Degree Angle Change, 20 Degree Coherent Aperture
- Center Every 5 degrees and Map Max Value to Corresponding Angle Color

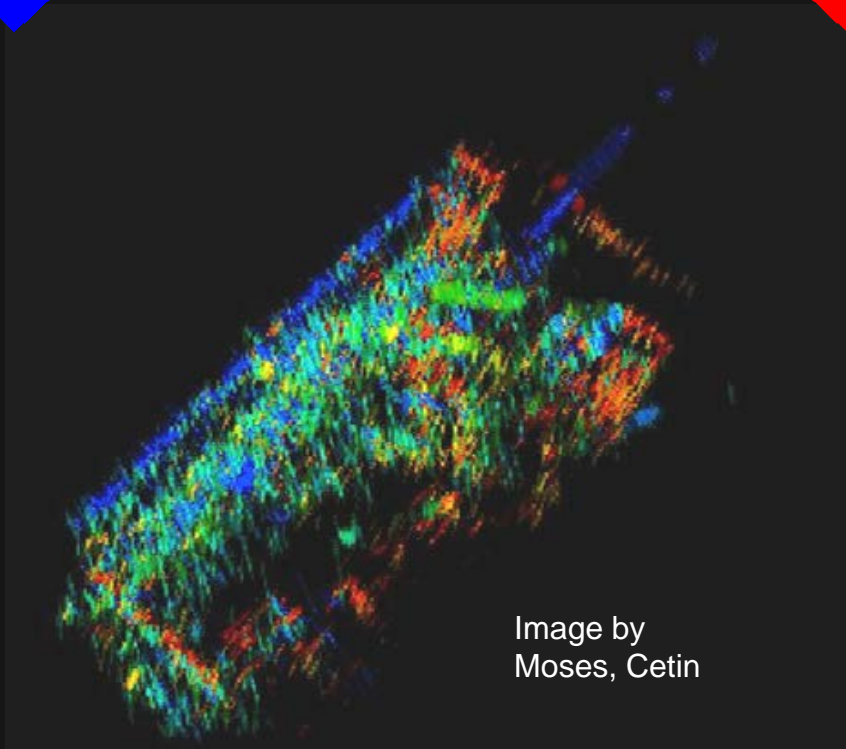
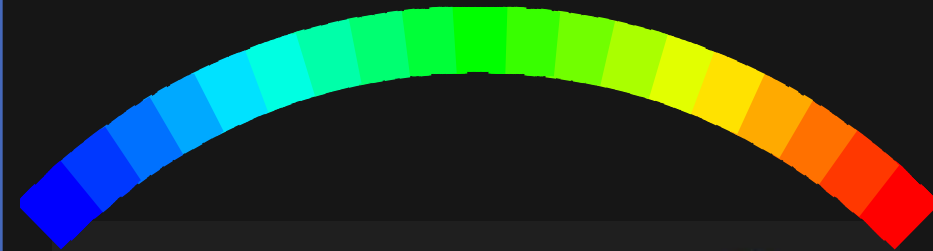
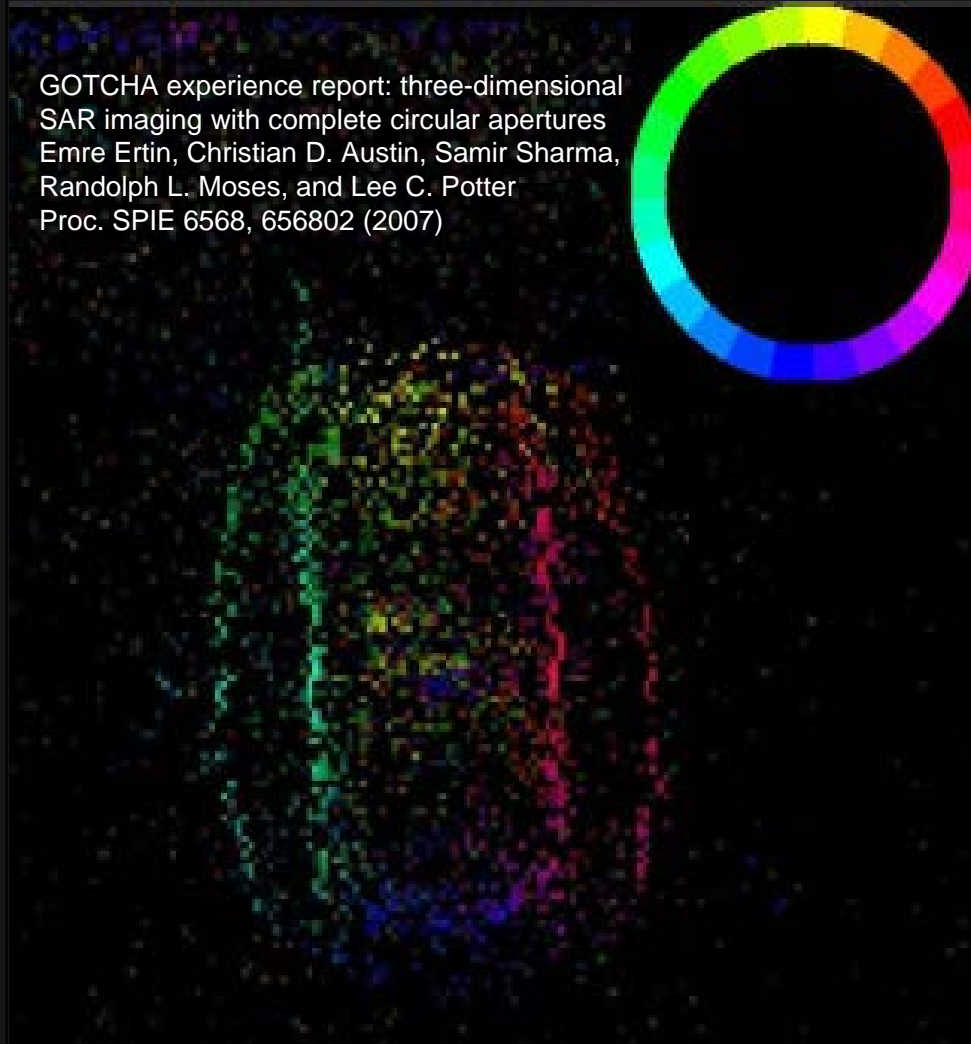


Image by
Moses, Cetin

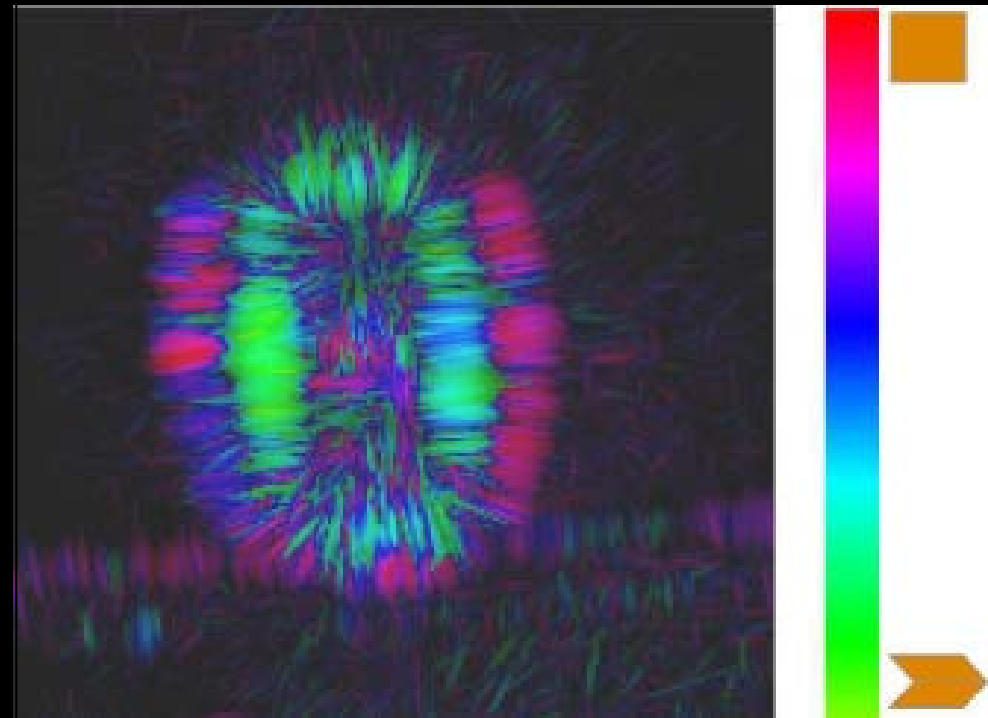
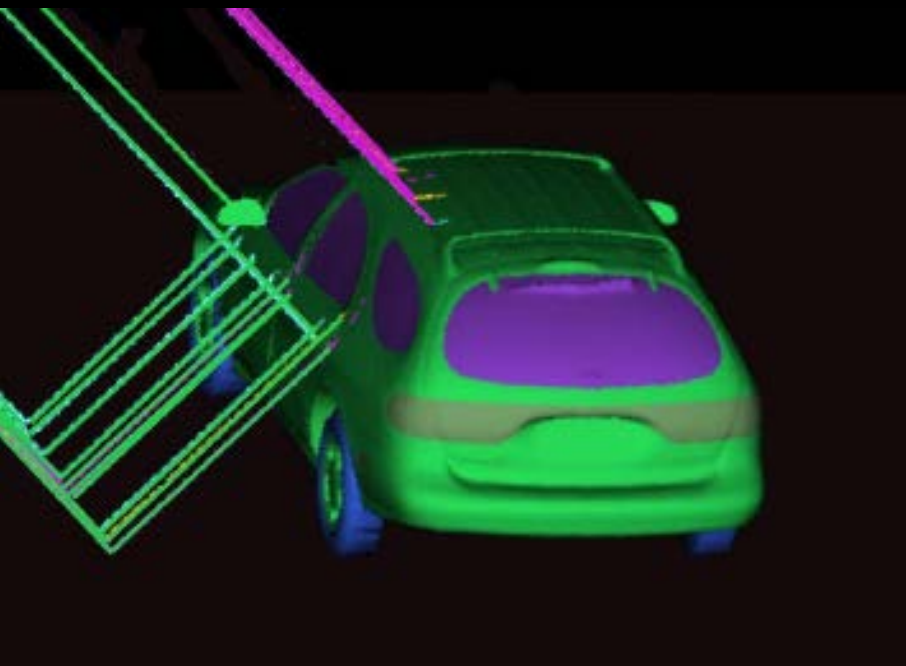


GOTCHA experience report: three-dimensional SAR imaging with complete circular apertures
Emre Ertin, Christian D. Austin, Samir Sharma, Randolph L. Moses, and Lee C. Potter
Proc. SPIE 6568, 656802 (2007)





Use of Polarization



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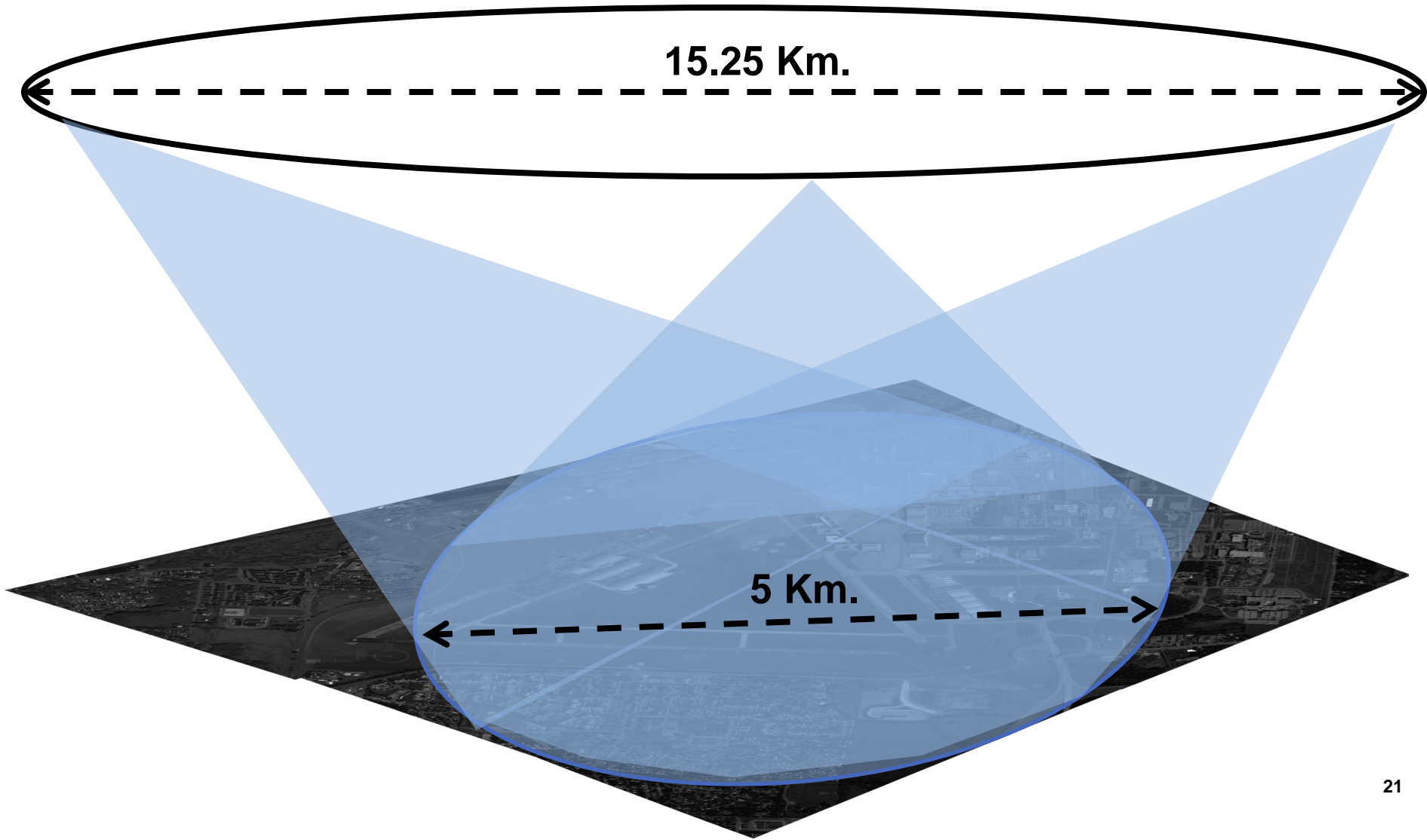
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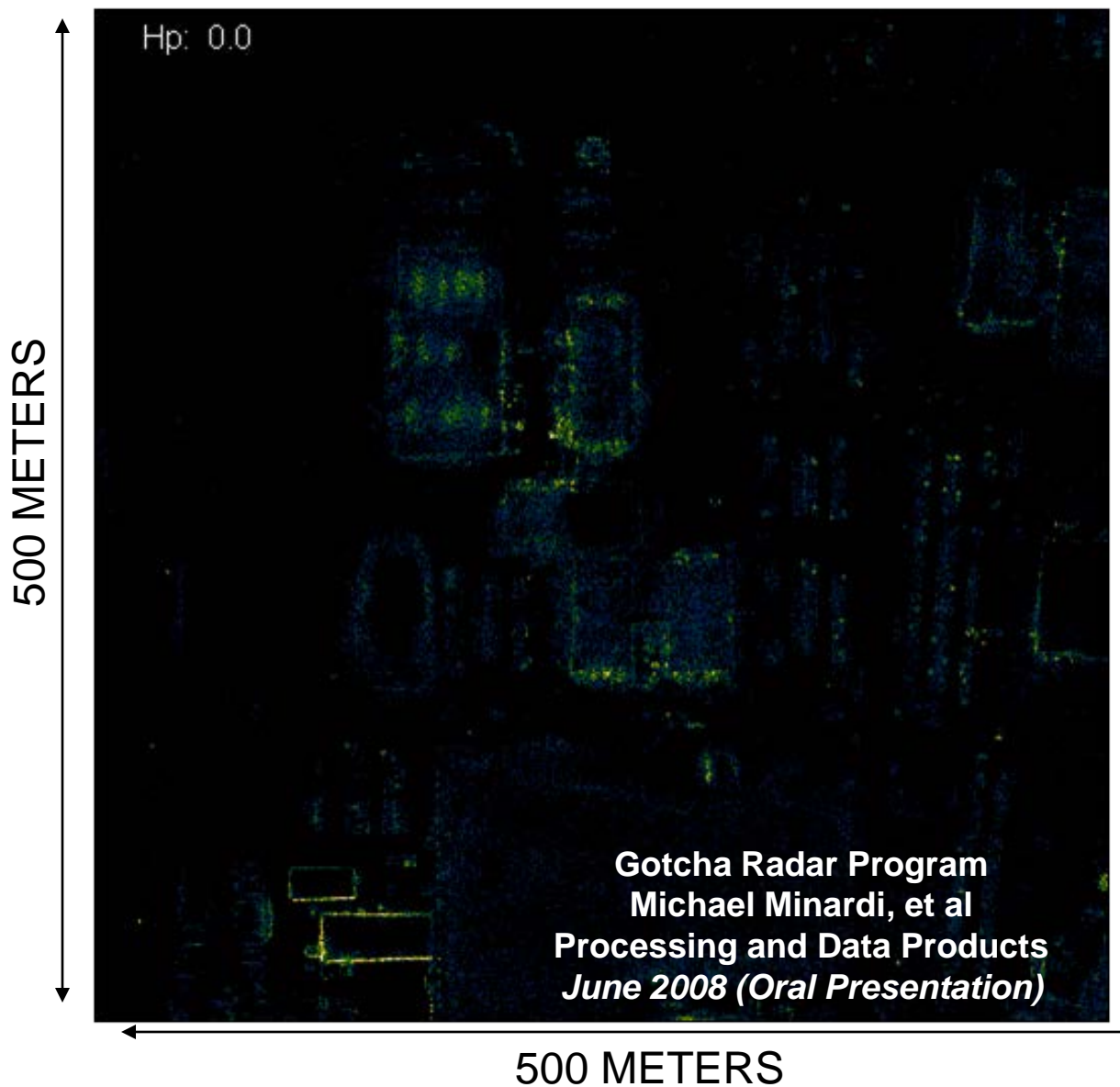


Wide Angle Synthetic Aperture Radar





Depth from Focus





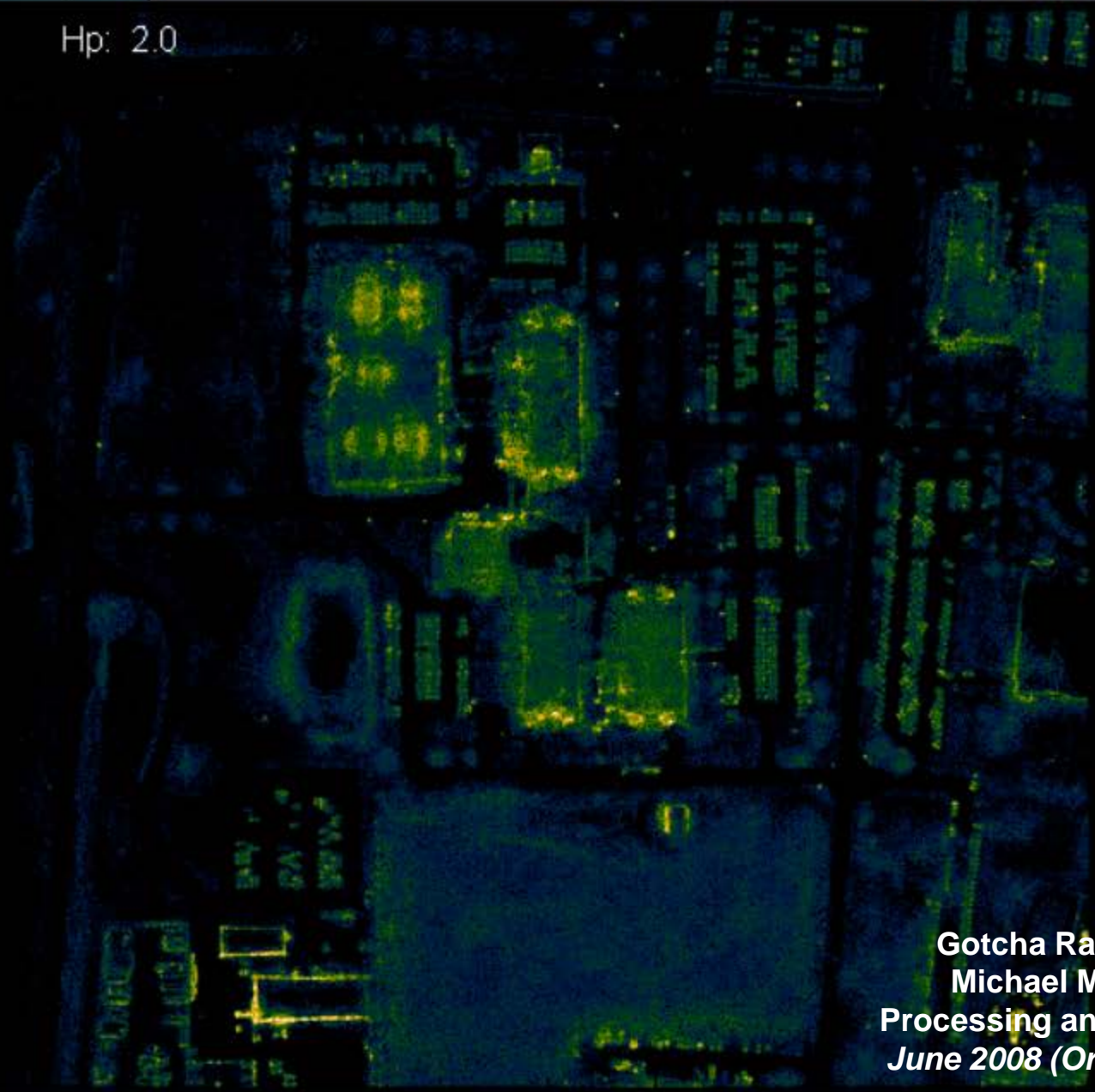
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Gotcha Radar Program
Michael Minardi, et al
Processing and Data Products
June 2008 (Oral Presentation)



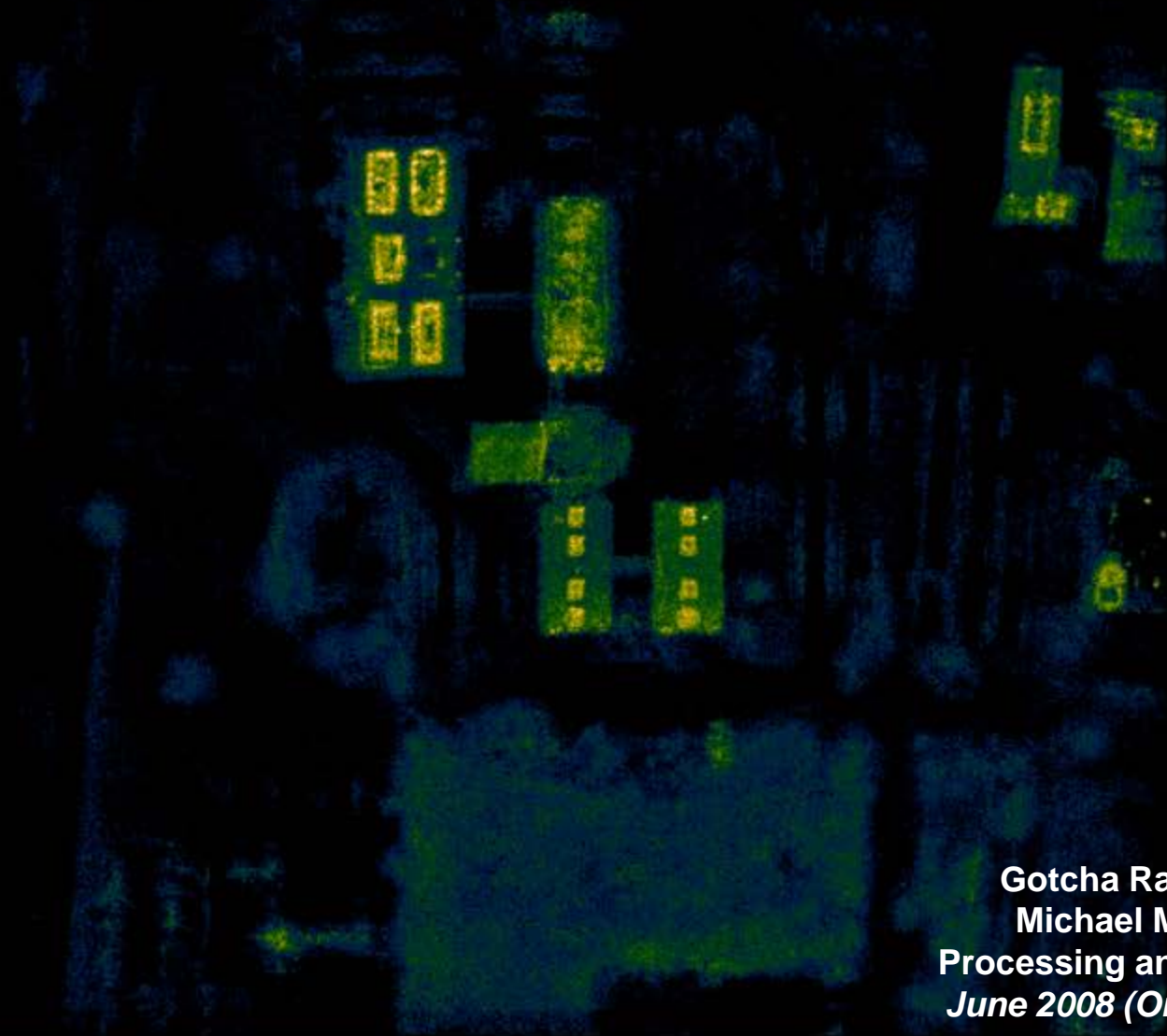
Hp: 2.0



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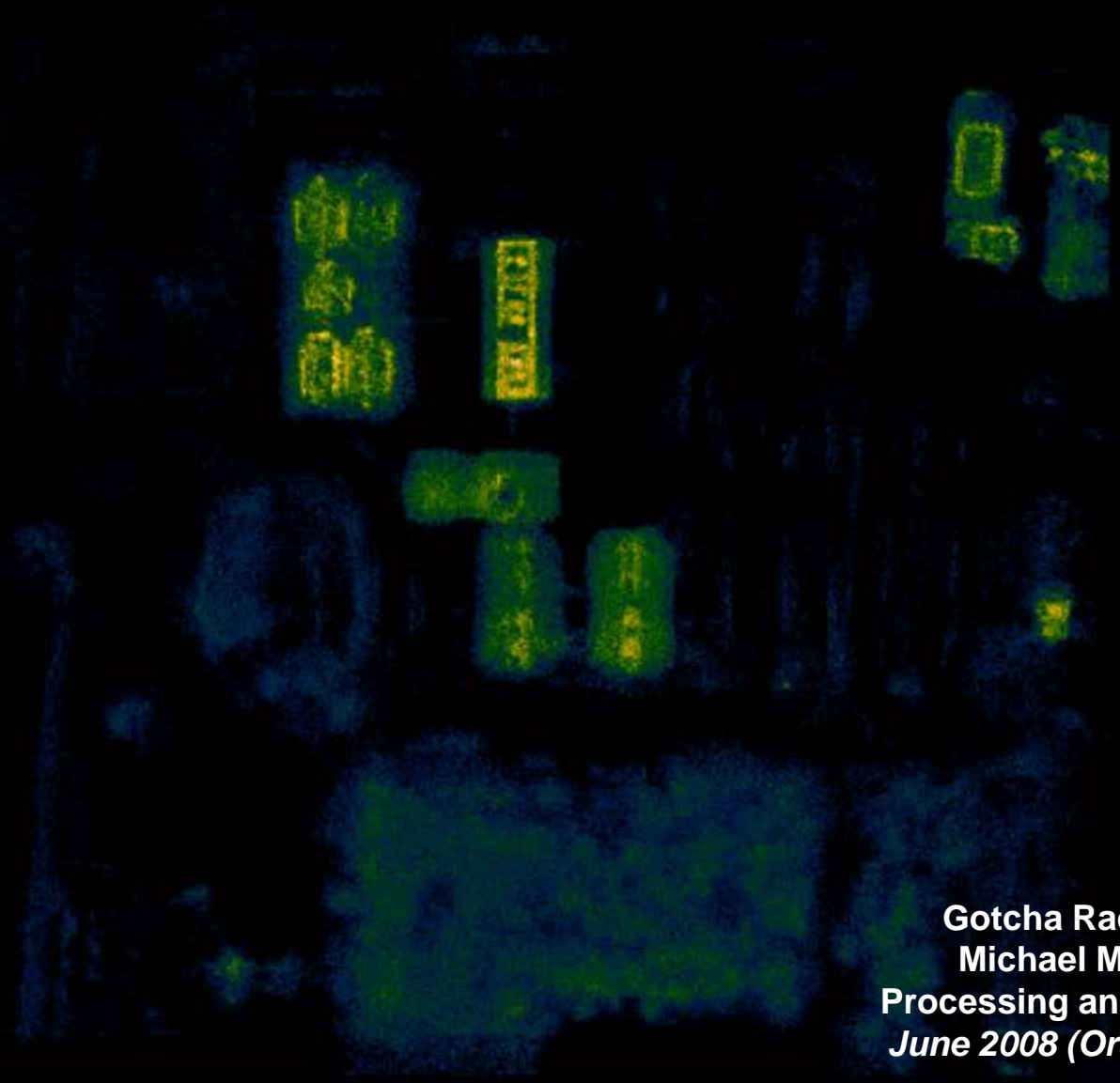


Hp: 12.0



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Hp: 18.0



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Hp: 36.0

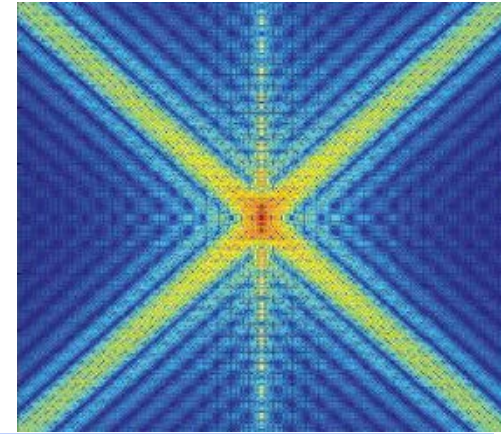
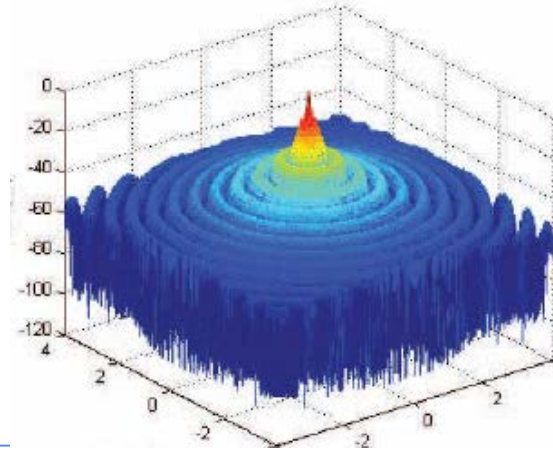
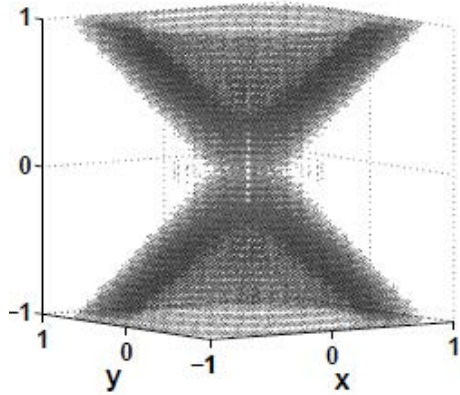


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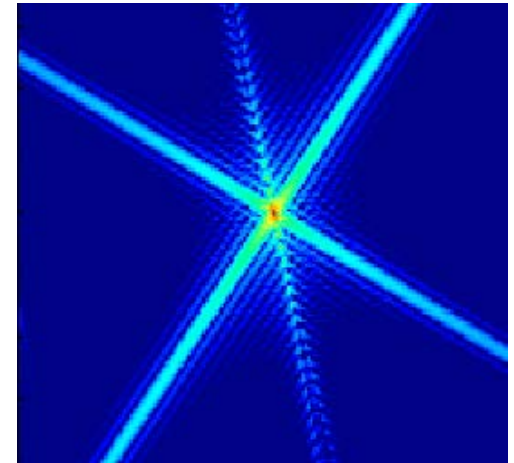
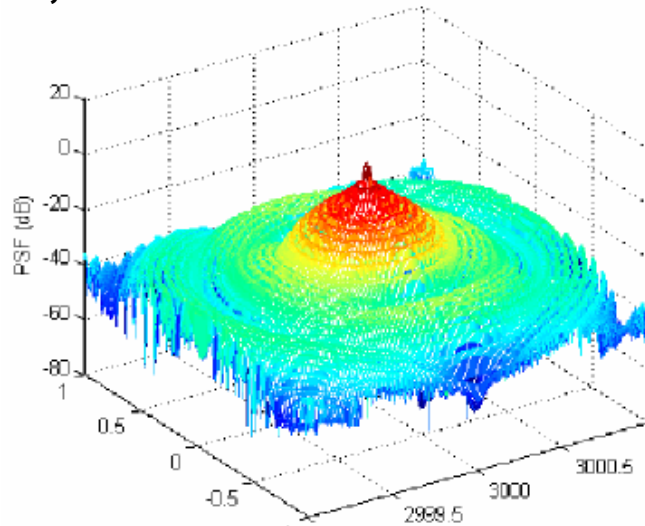
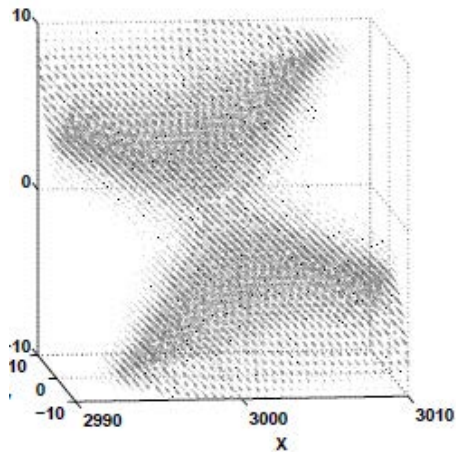




Synthetic Aperture Near Field



3,000 Meters from Scene Center



An analytical expression for the three-dimensional response of a point scatterer for circular synthetic aperture radar

Linda J. Moore and Uttam K. Majumder

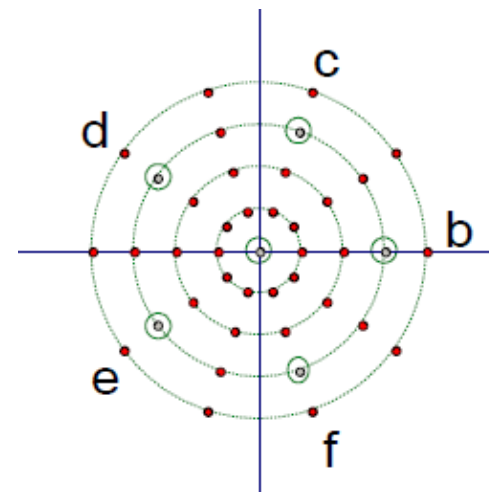
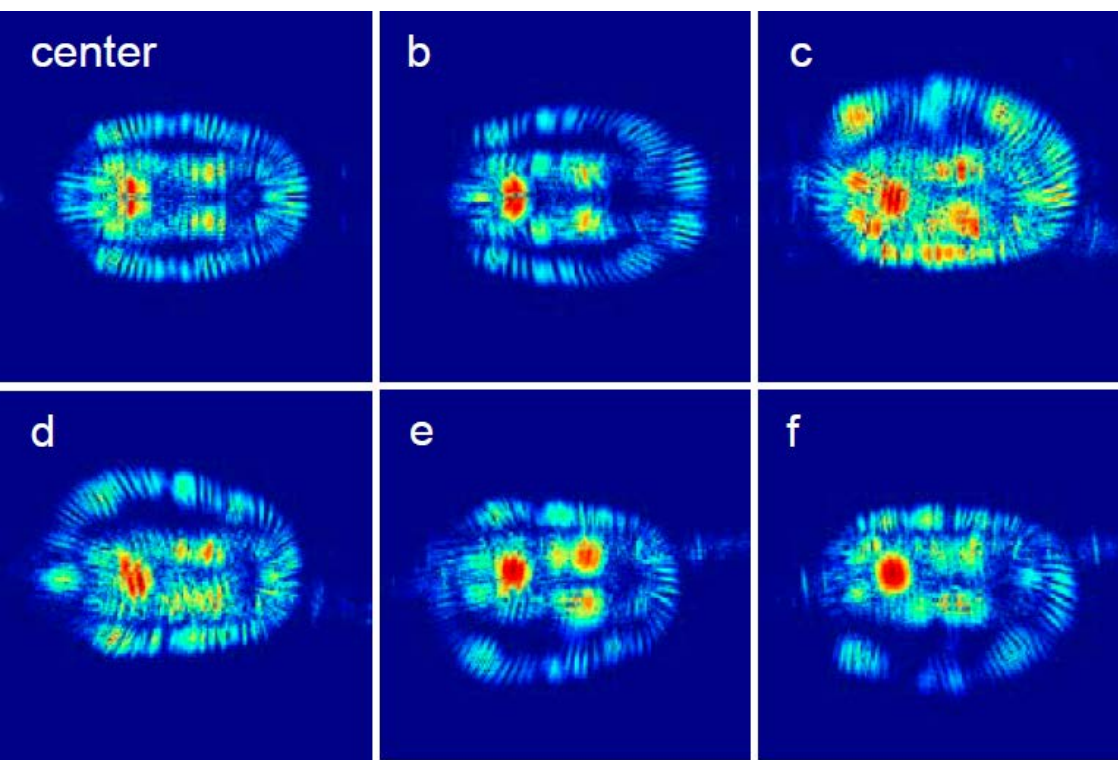
Proc. SPIE 7699, 769907 (2010)



Synthetic Aperture Near Field



.4 * flight path radius = 3000 m from scene center



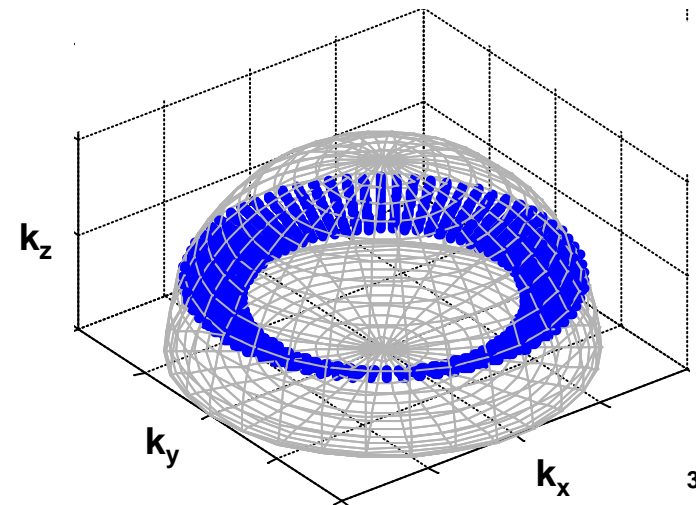
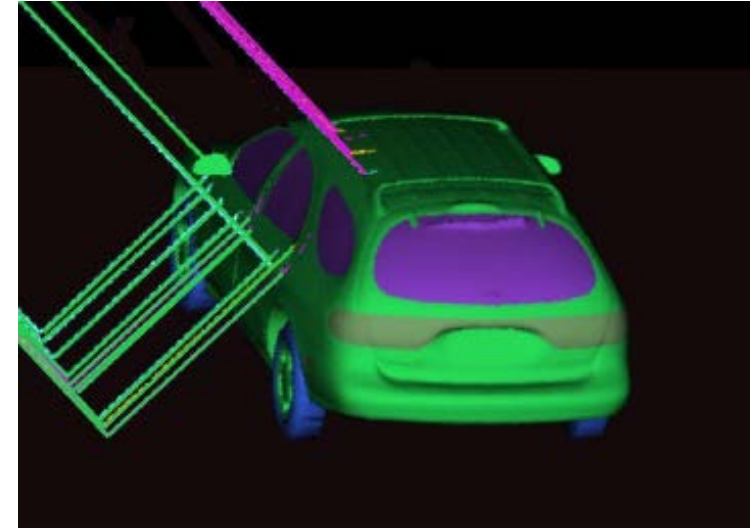
Classifying civilian vehicles using a wide-field circular SAR
Kerry E. Dungan and Lee C. Potter
Proc. SPIE 7337, 73370R (2009)



Range x Elevation x Azimuth (Phase History)



- **Range**
 - Change in λ
 - Very little amplitude and phase center change at high frequency
- **Azimuth**
 - Change in angle
 - Scatterers dense in beam, significant amplitude and phase center change for man-made objects
- **Elevation**
 - Change in angle
 - Gravity \rightarrow Scatterers sparse in beam, many right angles result in little amplitude and phase center change





High-Resolution SAR Image (1 inch vs. 1 foot resolution)



Gesture:
Lat: 39.77935°
Lon: -84.08133°
MGRS: 16SGK49960734

Layer Manager

- Starfield
- Sky Gradient
- Images
- ZoomIt! Data
- Boundaries
- KML Icons
- Waving Flags
- Diamond Touch
- EarthQuake Icons
- Historical EarthQuake Icons
- Videos
- Playback
- SAVig
- GlobalClouds
- Grid lines
- Anaglyph Stereo 3D
- Placenames
- Measure Tool

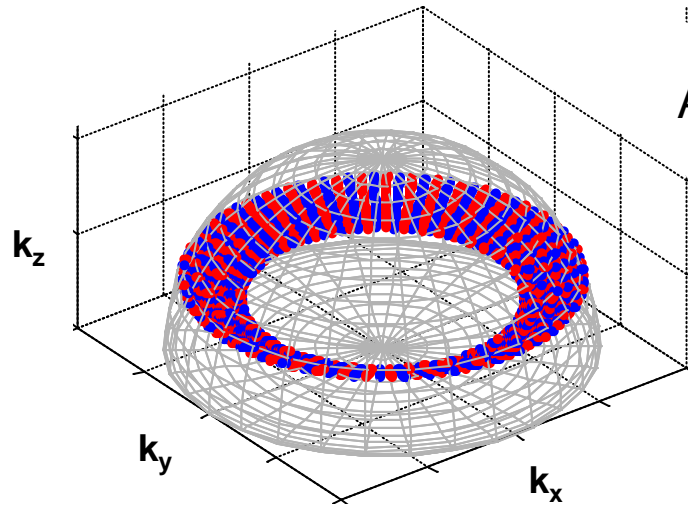
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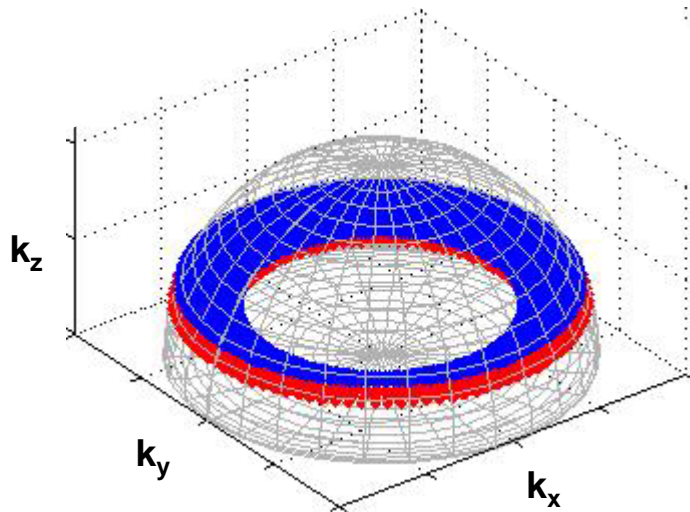
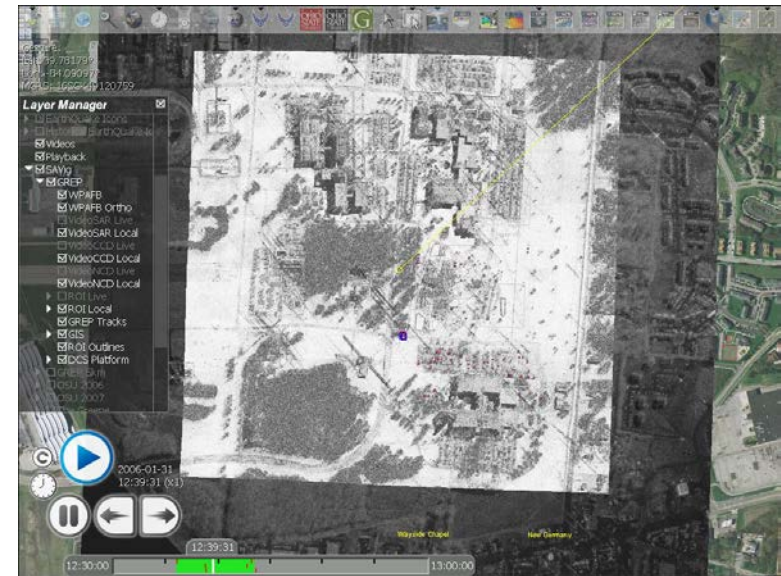
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Coherency



Aperture for Coherent Change Detection



Aperture for Interferometric SAR



Angle / Time / Integration Times (Moving Objects)



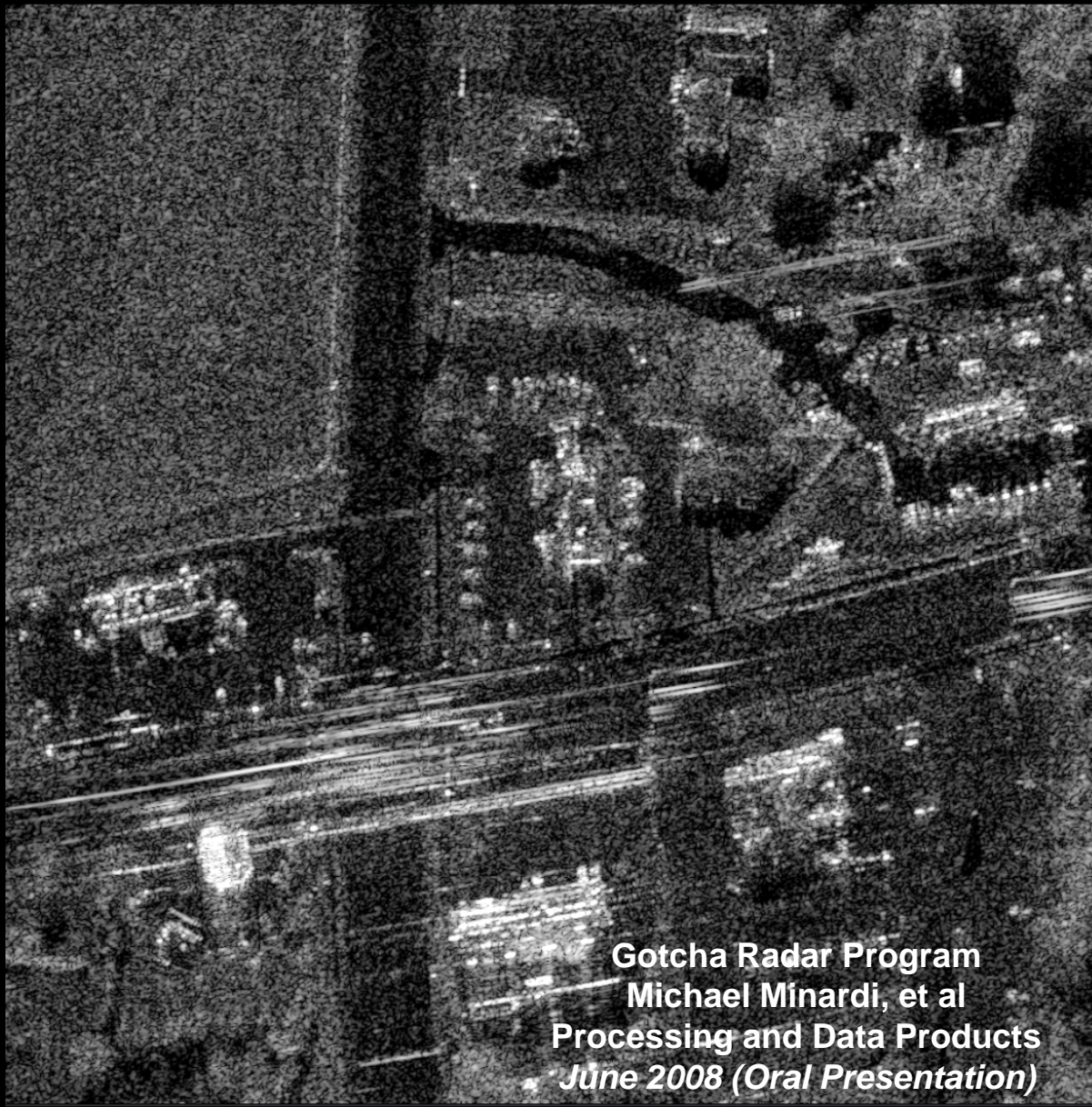
DATA 0217



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Angle / Time / Integration Times (Moving Objects)



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SAR v Visible v CAT



Technology Challenges



- **Application**
 - **Moving object (vehicle, pedestrian) detection, tracking and geolocation**
 - **Computation / Transmission (Phase History Compression) / Storage**
 - **Target Recognition**
- **Underpinning Technology**
 - **Scattering Characterization (Anisotropy, Polarization, Statistical)**
 - **Under-sampled Sensing (Sensing Diversity)**
 - **Forward and Inverse Scattering**