VIDEO SAR

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Outline

- What is Video SAR (ViSAR)?
- Applications
  - *Example 1: Kirtland Airforce Base Solar Array*
  - *Example 2: Kirtland Airforce Base Eubank Gate*
  - *Example 3: Display-Aided Target Tracking*

What is Video SAR?

- The display of sequentially captured SAR images at a rate that is representative of continuous motion.
- SAR can be operating in stripmap or spotlight modes

- Application 1: High resolution video surveillance of one area – **probably spotlight**
  - *High resolution implies high latency / low frame rate acceptable*

- *Application 2:* Low res video feed combined with GMTI for tracking – **probably stripmap**
  - *Lower resolution better lends itself to real time video applications*

Spotlight Mode SAR

- Two scatterers at range R are separated by $\Delta\Theta = \frac{\Delta CR}{R}$
- Doppler difference between them is $\Delta f_D = \frac{2v\Delta\Theta}{\lambda}$
- Radar's Doppler resolution: $\Delta f_D = \frac{1}{T_a}$
- Cross Range Resolution: $\Delta CR = \frac{\lambda}{2\gamma}$
- Aperture Time: $T_a = \frac{\lambda R}{2v\Delta CR} = \frac{R\gamma}{v}$
- Aperture Length: $D_{SAR} = vT_a = R\gamma$ *(small angle approximation)*

- Spotlight data products lend themselves to polar format processing (not discussed)

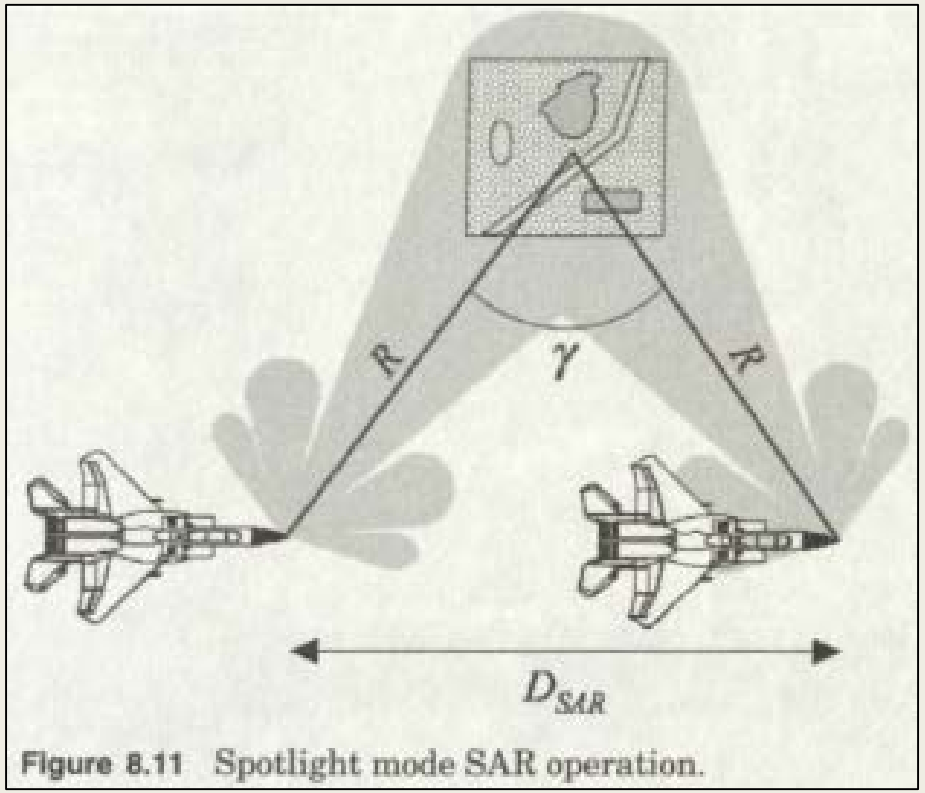


Figure 8.11 Spotlight mode SAR operation.

[Richards]

Some Perspective on Frame Rate

- Frame rate (fps) – number of distinct images shown per second
- Refresh rate (Hz) – number of times the screen content is refreshed per second

- Human requirement for perceiving “continuous” motion is 16 – 20 fps
- Film industry standard is 24 fps

- 24 SAR images per second would require an aperture time of 42 ms
  - *This ignores processing latency & throughput, (T_a smaller if watching real time)*
  - *Shorter T_a means degraded Doppler resolution* $\left(\Delta f_D = {}^{1}/_{T_a}\right)$

[Tarantola]

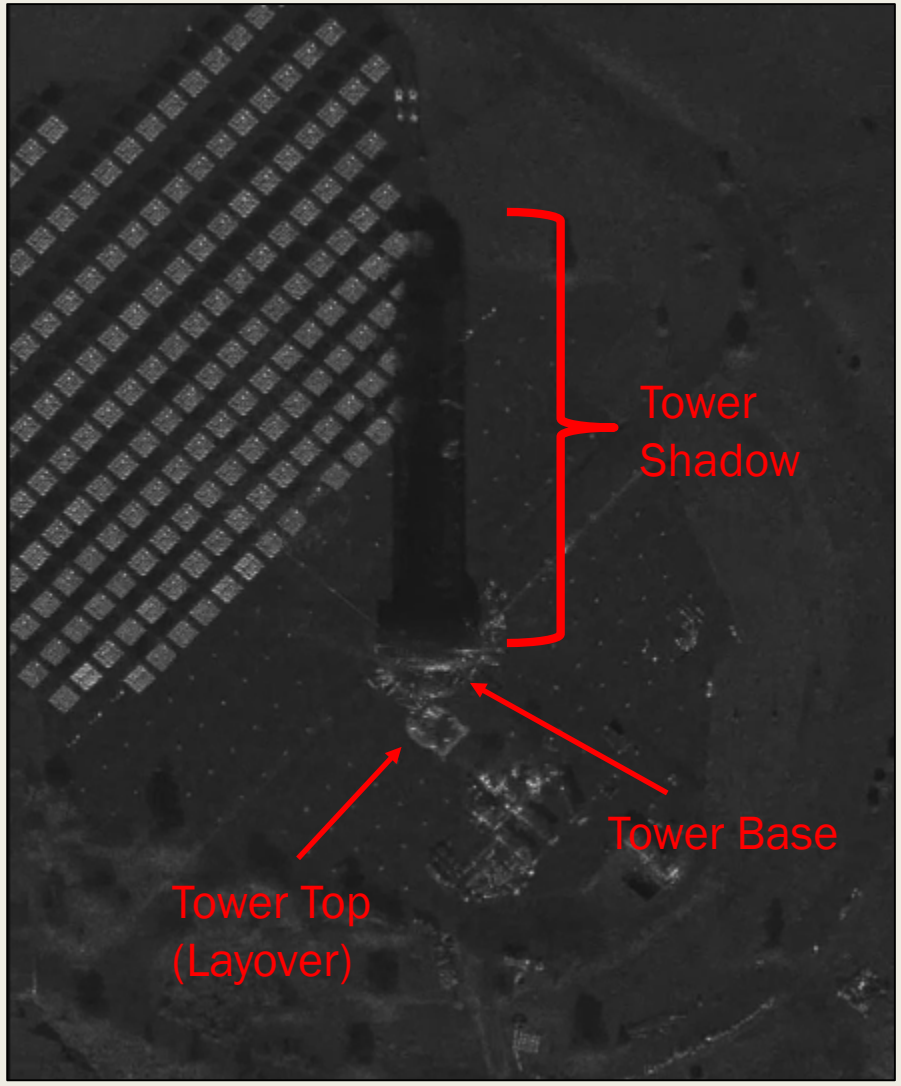
Example High Resolution ViSAR Product

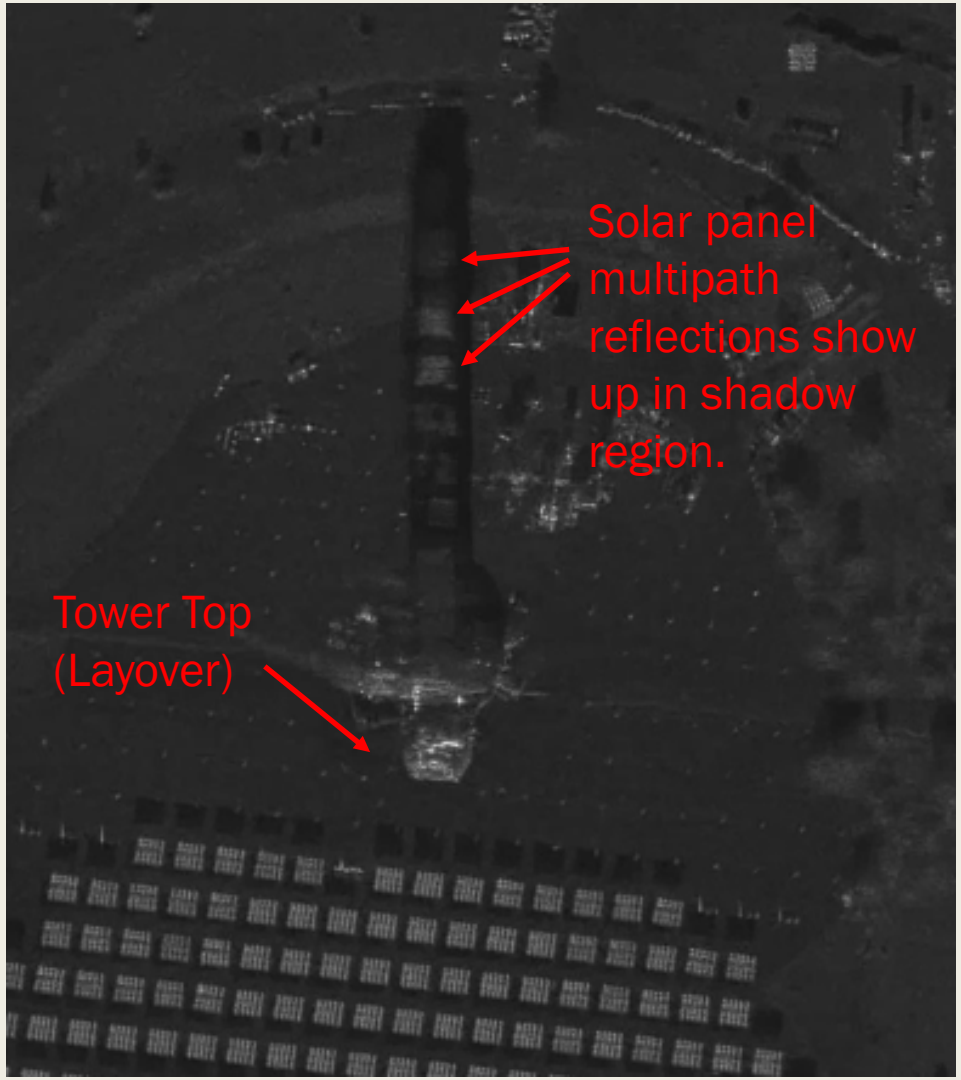
- Kirtland Airforce Base Solar Array, Albuquerque, New Mexico
- Video Captured on April 9, 2010
- Recorded 9:04:36 to 9:08:28 PM
- Radar Platform – undocumented
- Video composed of 761 images
- Video playback length: 30 s
- Video record duration: 232 s

- Record rate: 761/232 = 3.25 fps
- Playback rate: 761/30 = 25 fps

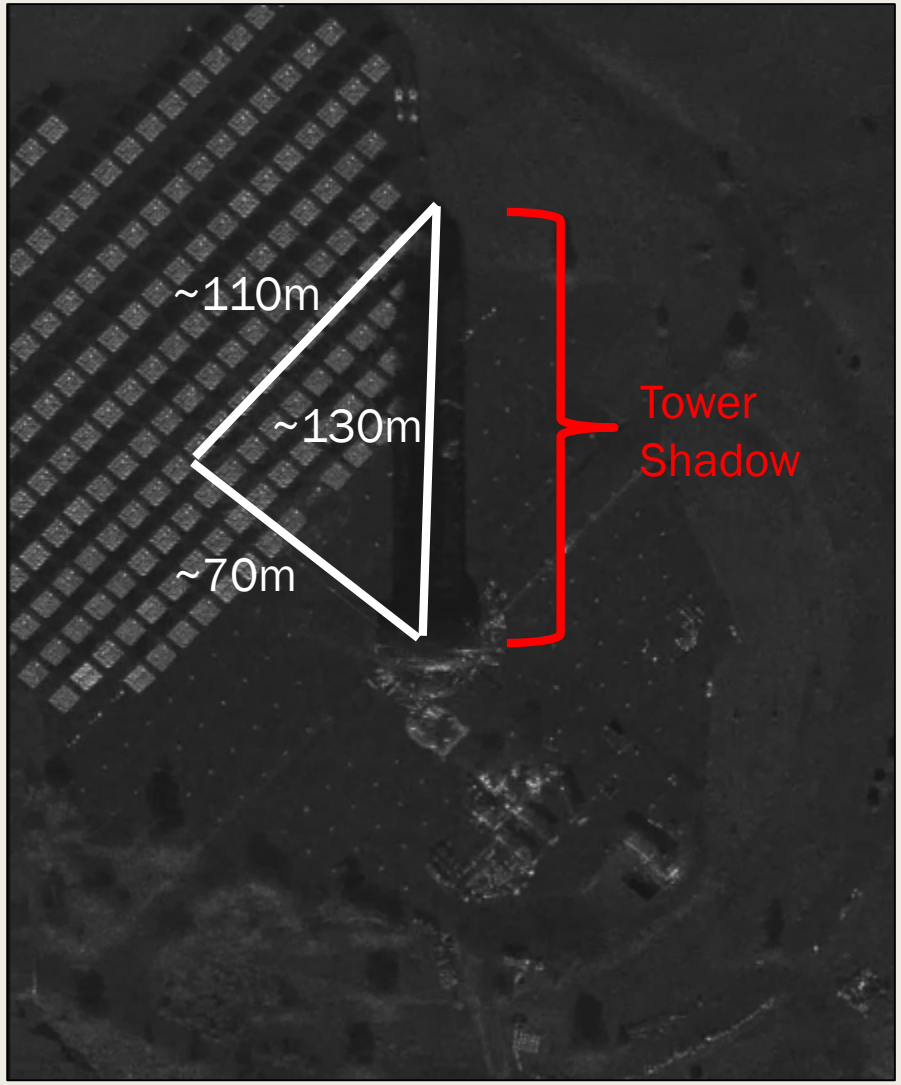
- http://www.sandia.gov/radar/_assets/videos/solartower.mp4

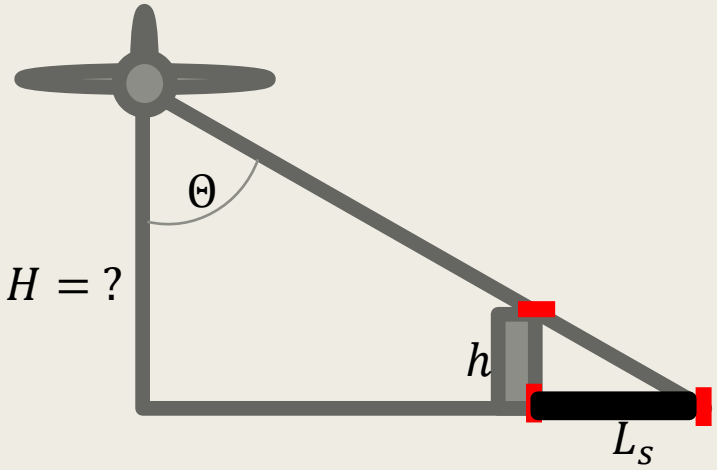
Example High Resolution ViSAR Product





Example High Resolution ViSAR Product



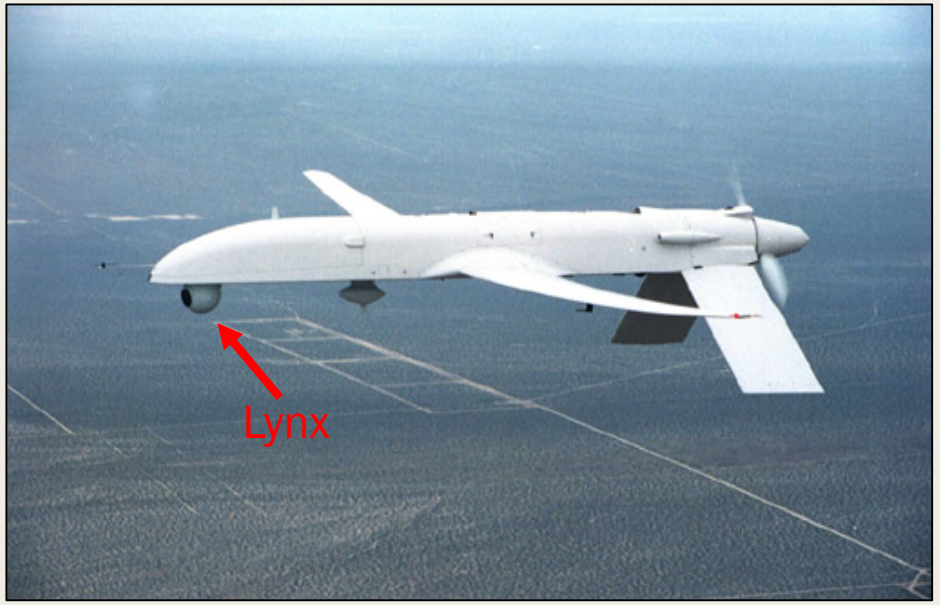


- Solar panels are ~ 6m on a side
- Estimating that the panel posts have 10 m spacing, the tower's shadow length is ~130 m.
- The tower height is 61 m.
- The radar look angle is $\Theta = tan^{-1}\left(\frac{Ls}{h}\right) \approx 65\ deg$

Assumed System (Lynx) Parameters

- Lynx first deployed in 1999, design targeted for large UAV platforms (I-GNAT & others)
- Ku-Band (15.2 GHz to 18.2 GHz, fc = 16.7 GHz), Transmitter Power = 320 W
- Modes: Stripmap/Spotlight SAR, GMTI, CCD, “Zoom and Steer” capability
- I-GNAT: max cruise altitude = 8 km
- Max velocity w/ radar op = 250 km/hr

Lynx Spotlight Mode Specifications (1999)	
Resolution	0.1 m to 3.0 m
Range	4 km to 25 km (+ for low res)
Squint Angle	+/- 50 deg to 130 deg
Patch Size	2 x (640 x 480) pixels



[Tsunoda]

Assumed System (Lynx) Analysis

- Given $\Delta CR = 0.1$, $\gamma = \frac{\lambda}{2\Delta CR} = \mathbf{0.0898\ deg}$
- Video suggests, $\gamma = \frac{\gamma_{tot}}{\#im} = 0.263\ deg$ (3x larger)
- This contradiction suggests more images * may have been formed and averaged ($3\#im = 2283$)
- Therefore, aperture time $T_a = \frac{t_{rec}}{3*\#im} = \mathbf{0.102\ s}$
  - *Allows ~100 pulses per image with PRF = 1 kHz*
- If $\mathrm{H} = 2\ km$, $\mathrm{R} = \frac{cos(\Theta)}{H} = \frac{cos(65)}{2000} = 4.73\ km$ *
- $\mathrm{v} = \frac{R}{\gamma T_a} = 245\ km/hr$ *

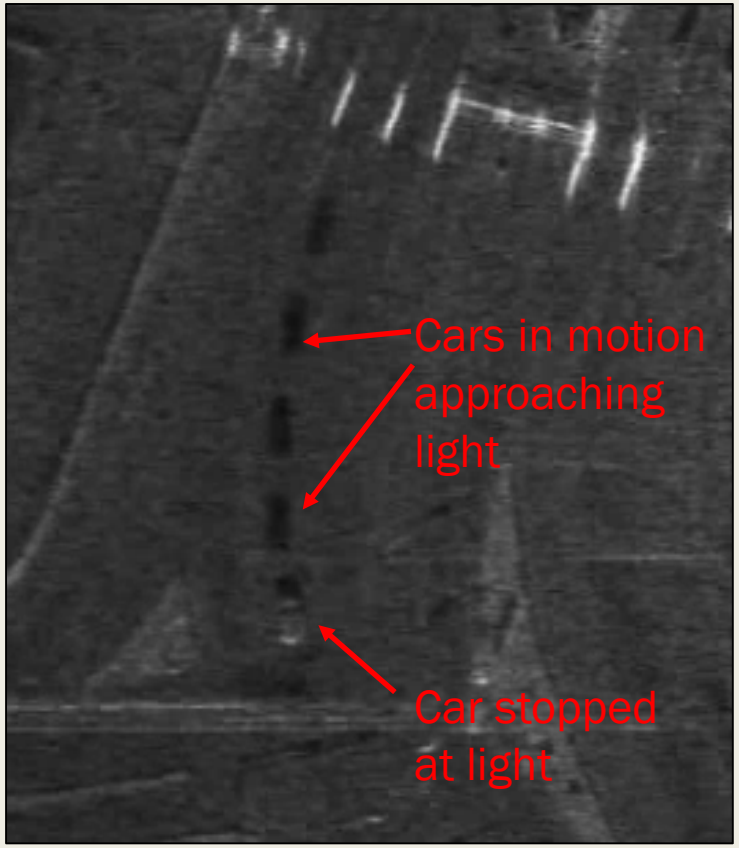
Assumptions	
Cross Range Res (ΔCR)	0.1 m
Tx Frequency	16.7 GHz
Tx Wavelength (λ)	1.8 cm
**PRF*	*1 kHz*
Number of Images ($\#im$)	761
Total Record Time (t_{rec})	232 s
Total Rotation Angle (γ_{tot})	200 deg
**Height (H)*	*2 km*
Incidence Angle (Θ)	65 deg

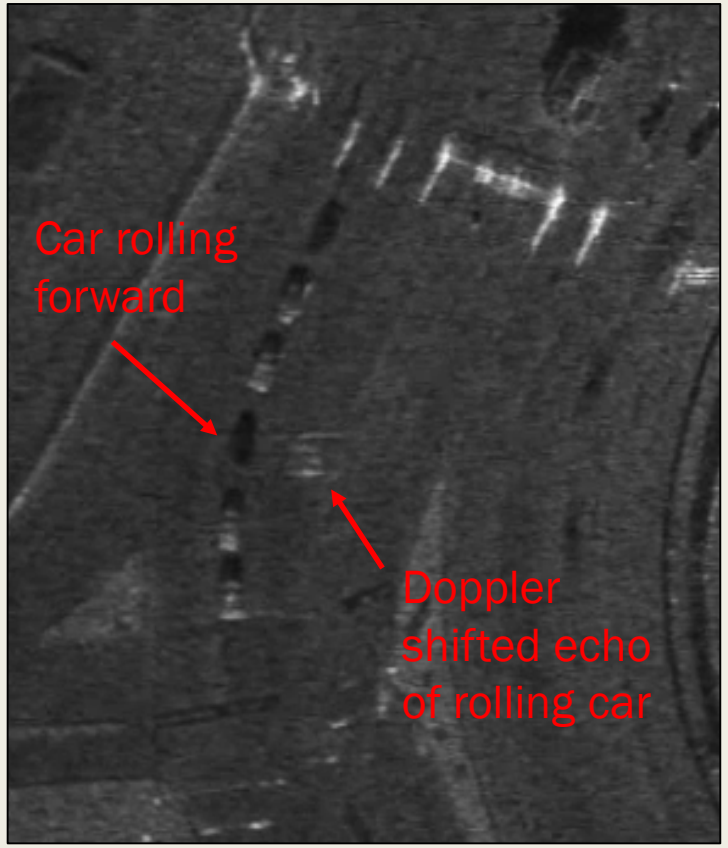
** Numbers or statements based purely on conjecture to complete example.*

Example High Resolution ViSAR Product

- Eubank entrance to Sandia National Laboratories, Albuquerque, NM
- Motion effects clearly visible as cars start and stop
  - *Initially, vehicle motion normal to radar motion.*
  - *End of video, vehicle motion parallel to radar motion.*
- http://www.sandia.gov/radar/_assets/videos/eubankgateandtrafficvideosar.mp4

Example High Resolution ViSAR Product Motion Effects



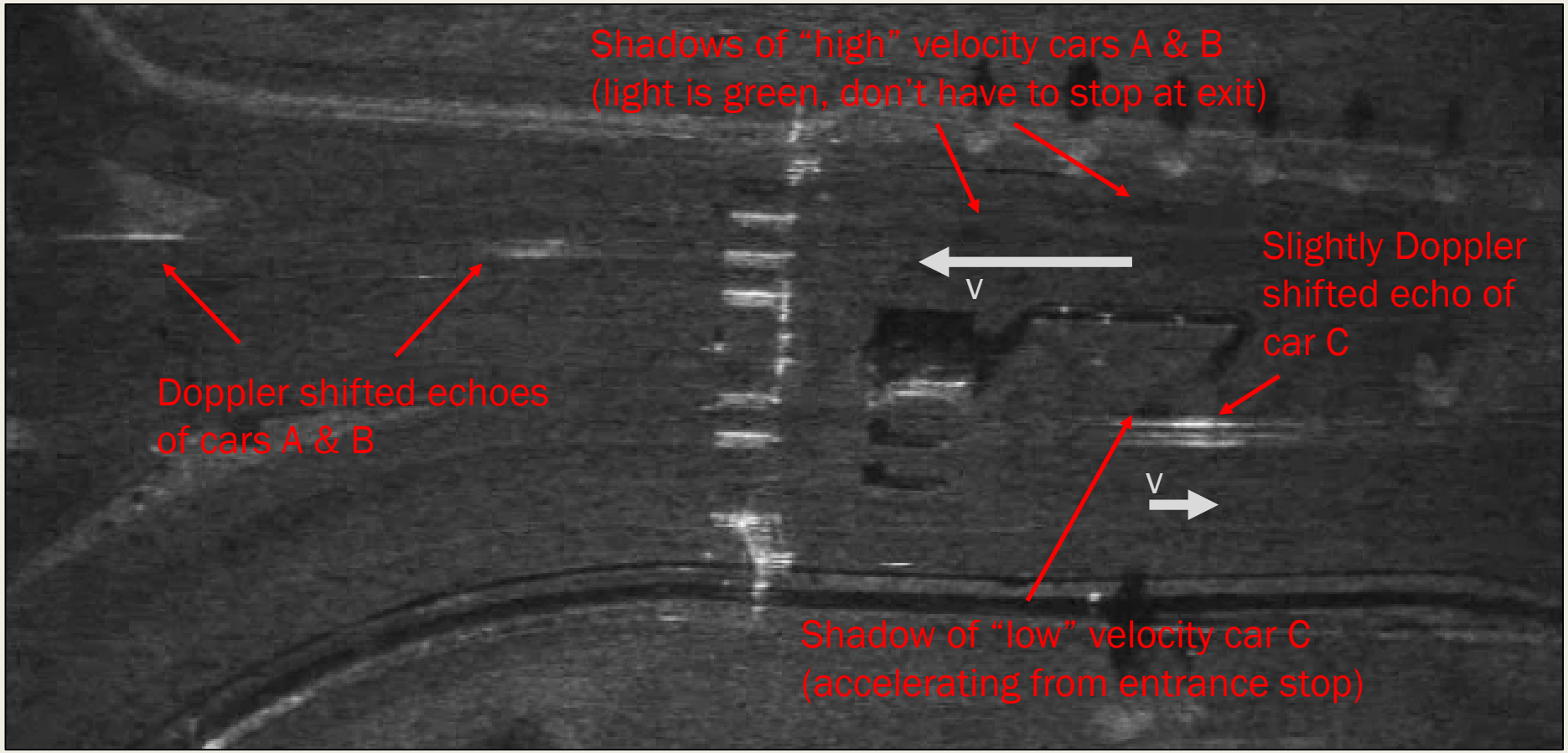


Doppler shifted echoes aren't dramatic in these scenes because the vehicle motion is mostly normal to the radar platform motion

$$f_D = \frac{-2v\cos(\Theta)}{\lambda}$$

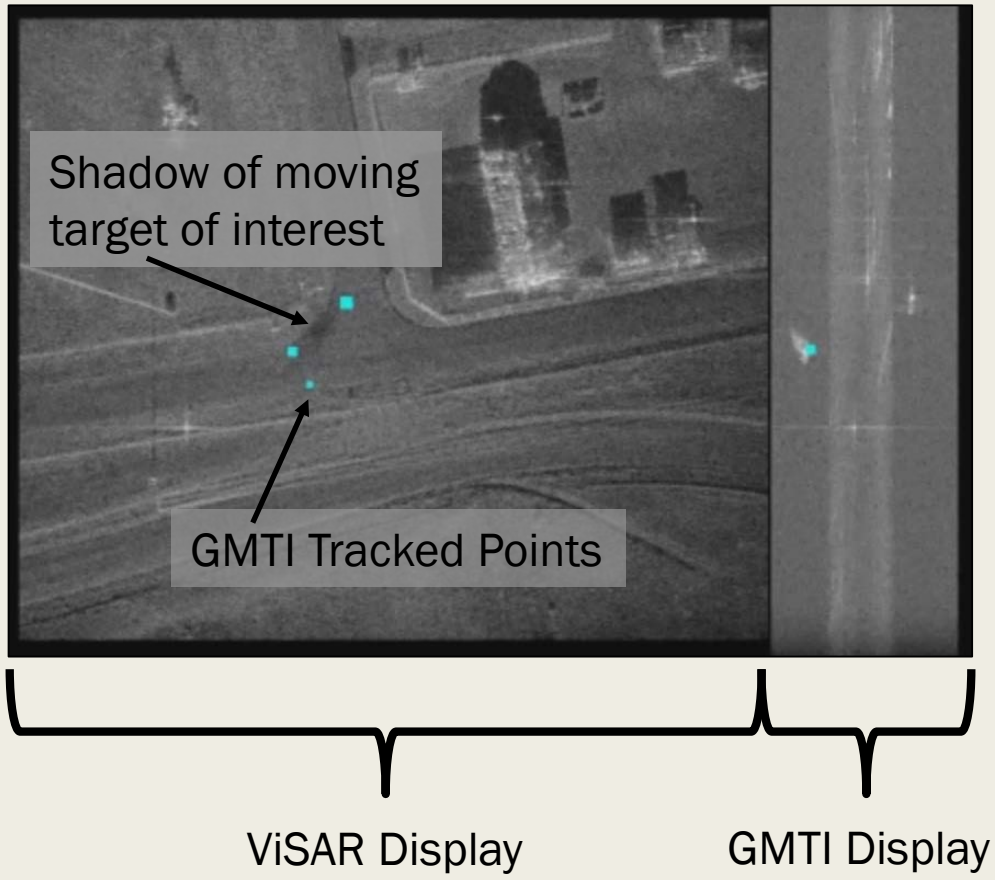
Direction of radar platform motion

Example High Resolution ViSAR Product Motion Effects



Direction of radar platform motion

Example Low Resolution ViSAR Product



- Velocity Independent Continuous Tracking Radar mode
- Side by side ViSAR / GMTI display
- GMTI tracker specifies region of interest for ViSAR
- Significant zoom and scan evident in ViSAR data product
- Hard to identify radar platform motion from the video, generally seems to move in the direction of the tracked object.

- http://www.sandia.gov/radar/_assets/videos/victr.mp4

References

- Richards, M. (2005). *Fundamentals of radar signal processing*. New York: McGraw-Hill.
- SNL National Solar Thermal Test Facility: http://energy.sandia.gov/energy/renewable-energy/solar-energy/csp-2/nsttf/
- SNL Radar Modes: http://www.sandia.gov/radar/areas_of_expertise/radar_modes.html
- SNL Radar Video Index: http://www.sandia.gov/radar/video/index.html
- Tarantola, A. (2015, Jan. 14). *Why Frame Rate Matters*. Retrieved from http://gizmodo.com/why-frame-rate-matters-1675153198.
- Tsunoda et. al. 1999. Lynx: A high-resolution synthetic aperture radar. *SPIE Aerosense, 3704.* Retrieved From *http://www.sandia.gov/radar/files/spie_lynx.pdf*.