Target Design and Deployment for In-Field GeoSAR Calibration

Fugro-EarthData
GeoSAR Technologies

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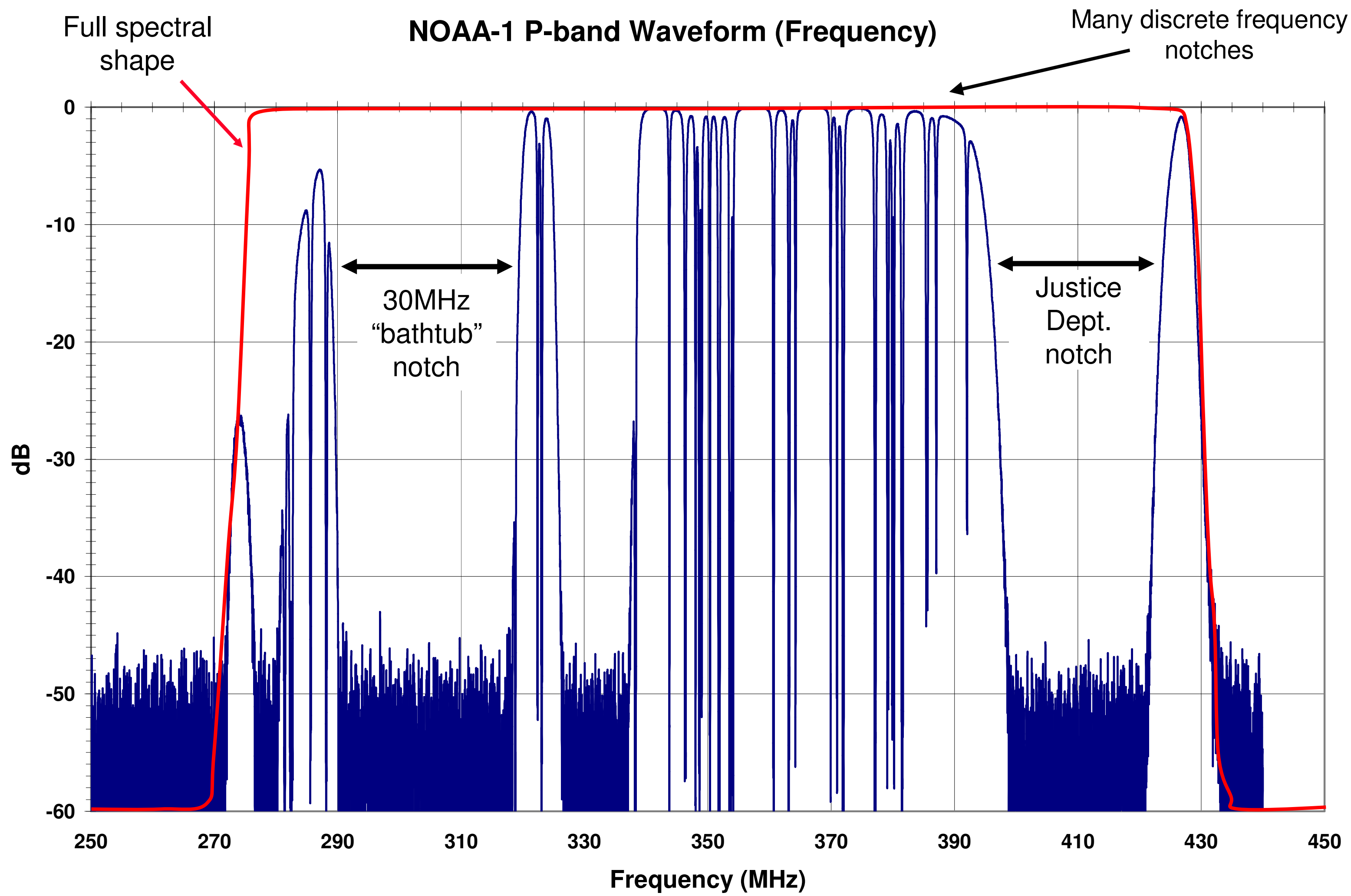
Regulatory Restrictions

- The UHF band is fully assigned to licensed users.
- GeoSAR must not cause interference to licensed users.
- On behalf of NGA, the NTIA coordinates GeoSAR access:
  - Provides list of licensed frequencies and bandwidth.
  - Communicates with local frequency coordinators to verify critical no-interference channels.
  - Provides GeoSAR with operational times.
- Old rules: must notch for transmitters within 20nmi of nadir, unless granted exemption.
- New rules: must notch if within “receiver” range of transmitter (300nmi!).

NOAA-1 P-band Transmit Waveform (Frequency Domain)



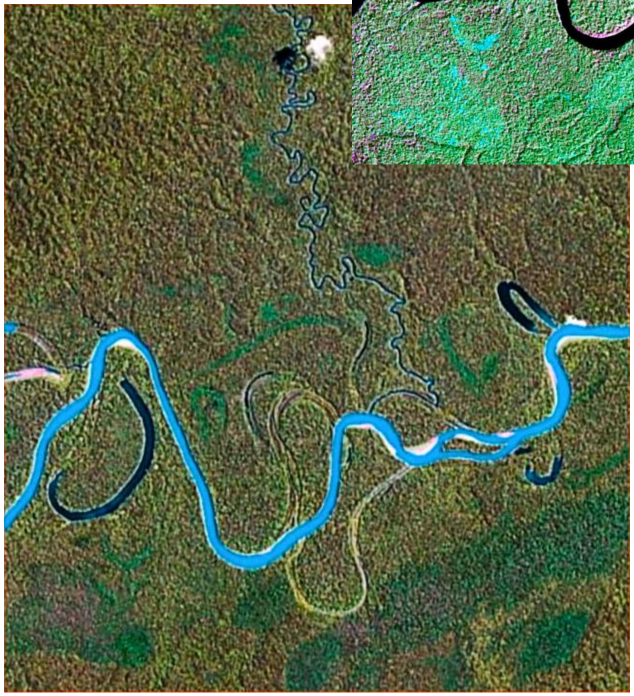
Calibration

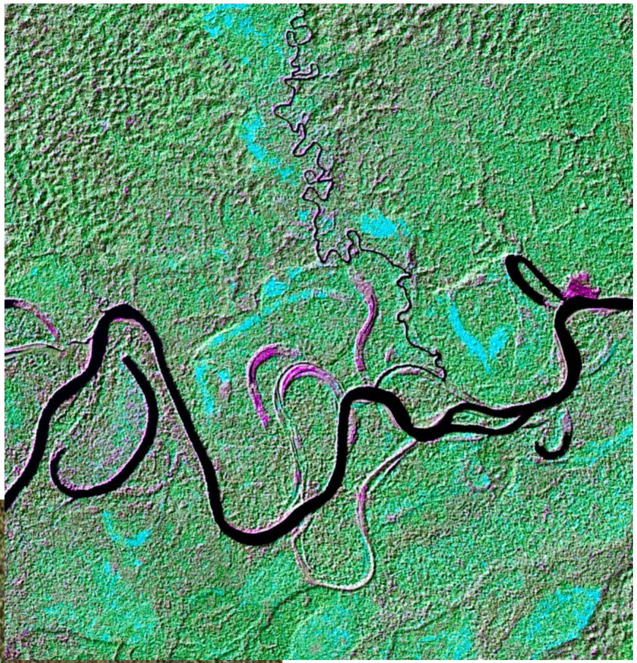
- Permanent calibration site in California.
- Use in notched environment? Calibrate in notched environment.
- Full UHF bandwidth is often available in tropical areas.
- Options:
  - Find a site in the continental US where we aren't required to notch.
  - Find a site overseas where we aren't required to notch.
  - Calculate the effects of notching and compensate for them when notching changes significantly.
- Interferometric calibration
  - requires an accurate, predominantly flat DEM.
- Radiometric (and polarimetric) calibration
  - can be done *in-field* if we have targets available.

Rationale for *In-field* Radiometric Calibration

- System changes don't require return to permanent calibration site.
- Possible to monitor radiometric calibration solution to determine system stability.
- On mapping campaigns we deploy reference targets anyway.
- Contemporaneous calibration solution.

Google image

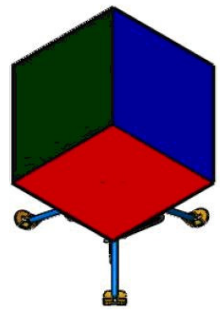


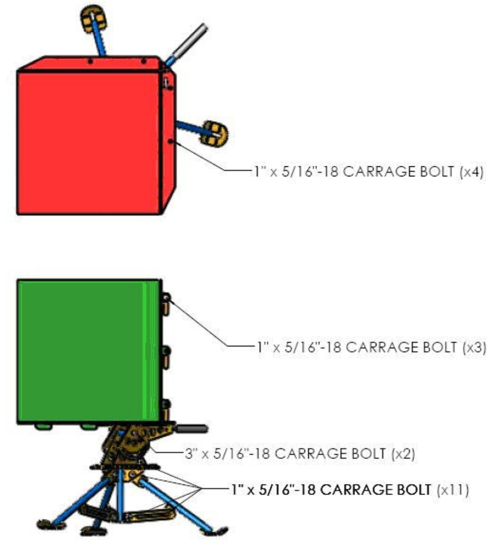


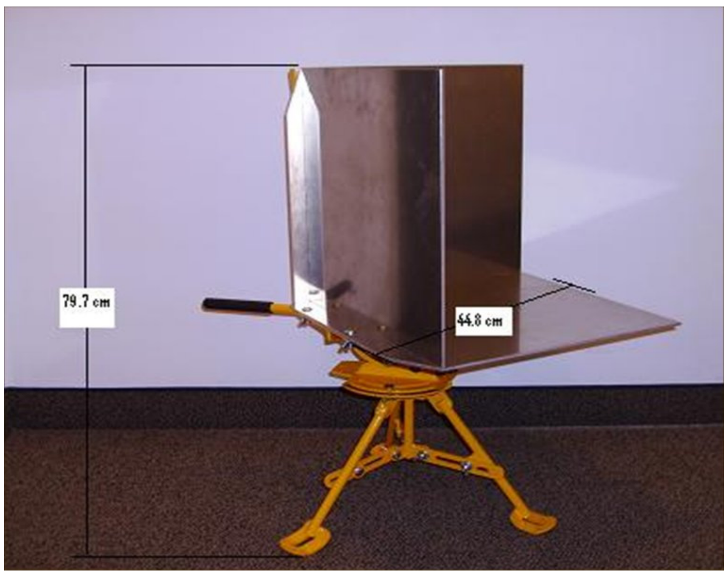
GeoSAR (unsupervised classification on X-band)

X-band Targets

- Small and “easily” deployed.
- Current design consists of a tripod base and a set of three, interlocking plates.
- ~30dBm^2 pk RCS.







P-band Targets

- Large: 2.2m internal face side length. Heavy: ~100lbs
- Simple construction: in-country fabrication – templates ensure regularization.
- Placement strategy! Optimal locations not always available.

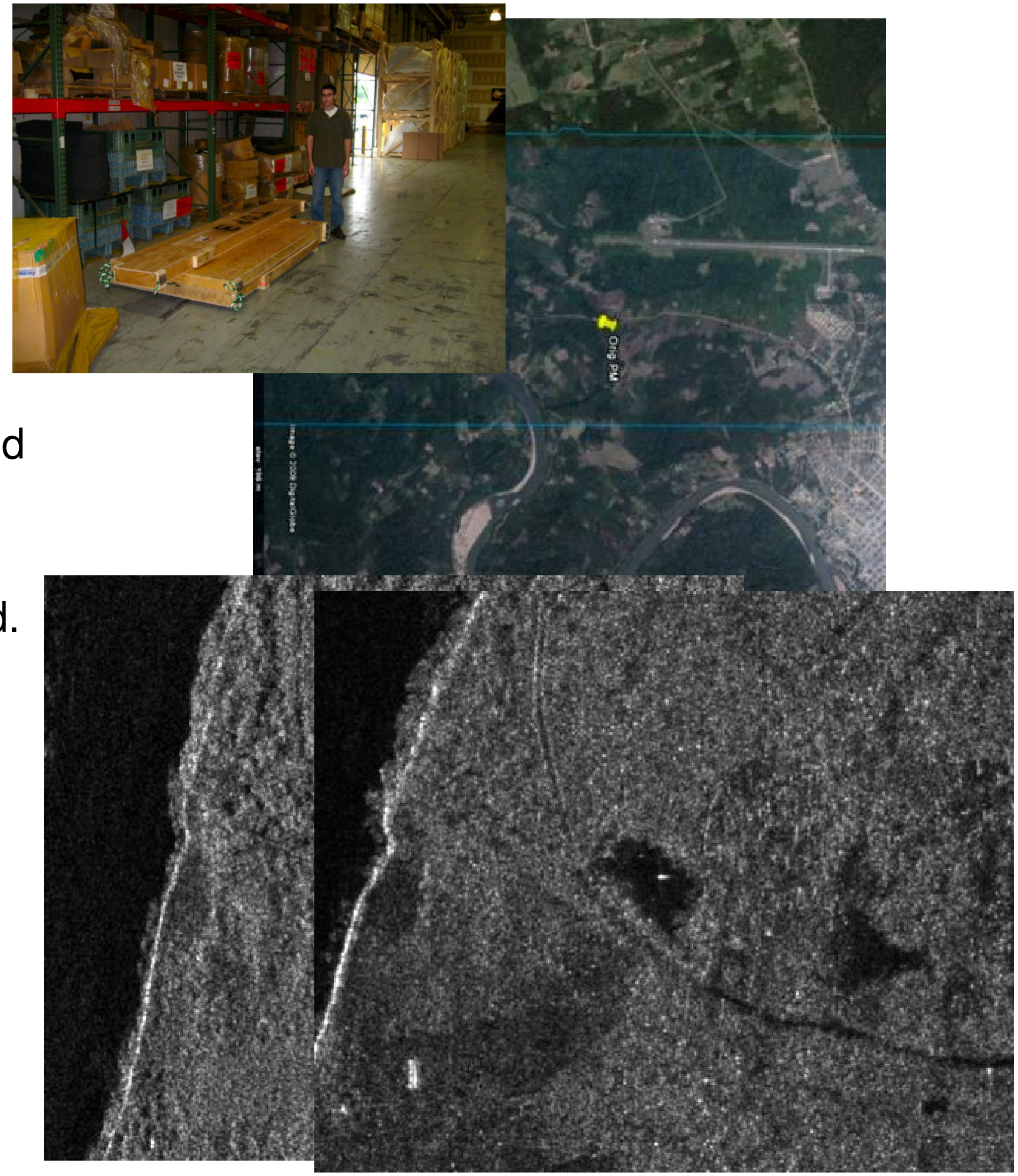
~ 26 dBm^2

Deployment Strategy

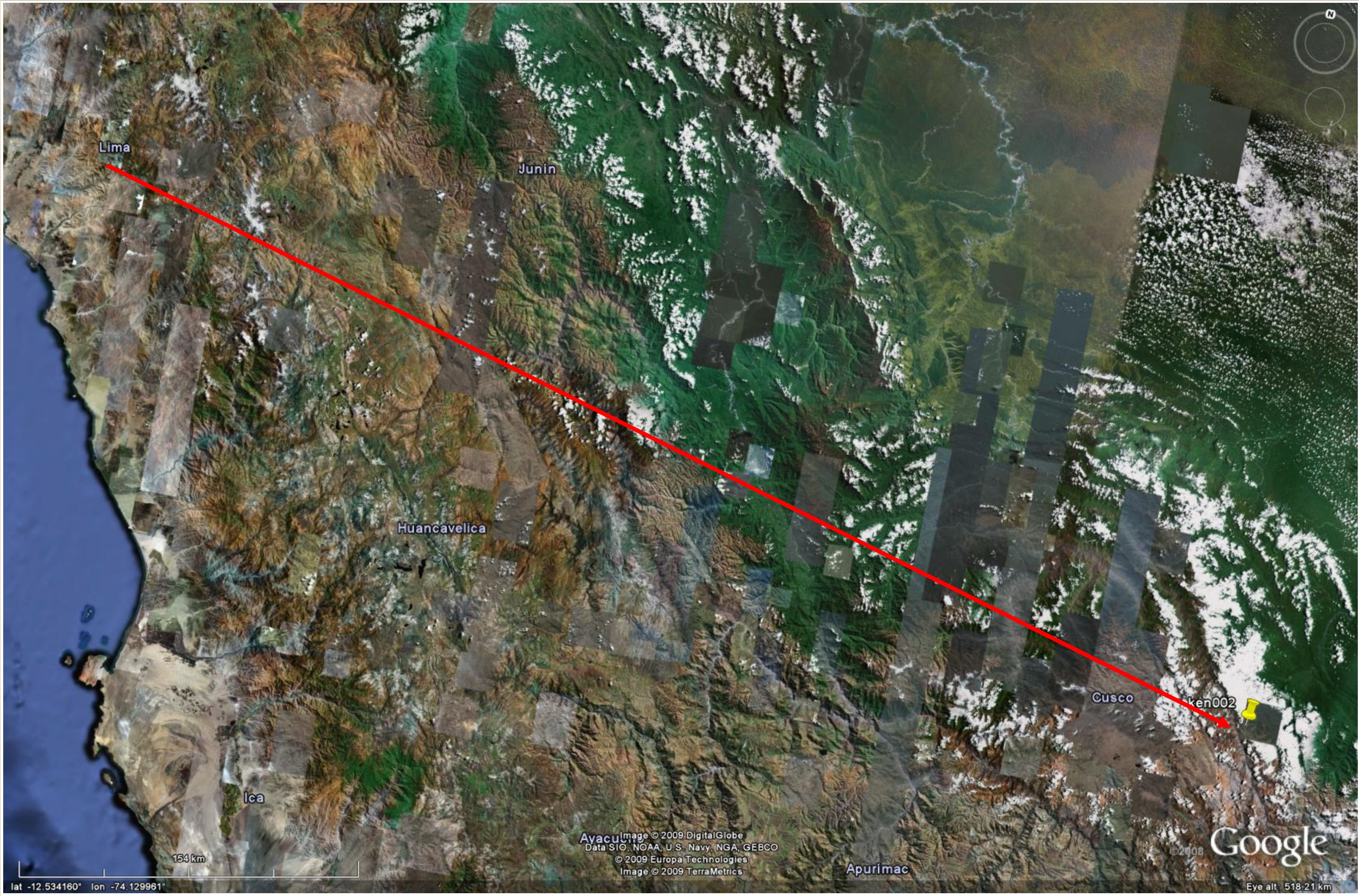
- Flight plan.
- Site identification.
- Surveyor choice.
- Site survey, base and rover GPS setup. Base run for +-15 mins around rover acquisition. Survey nail marks reflector location.
- Field location recorded and communicated.
- Target alignment calculated based on flight path, and field location.
- Targets constructed and deployed.
- Target phase centre recorded
- Targets secured.

Successful Deployment Example: Peru

- Example of target deployment.
- Crated targets to Lima.
- Trucked to survey site.
- Erected at site and GPS locations provided.
- Target alignments calculated and communicated to field-team.
- Targets aligned and imaged.
- Focused targets appear in the imagery and can be used for radiometric calibration …

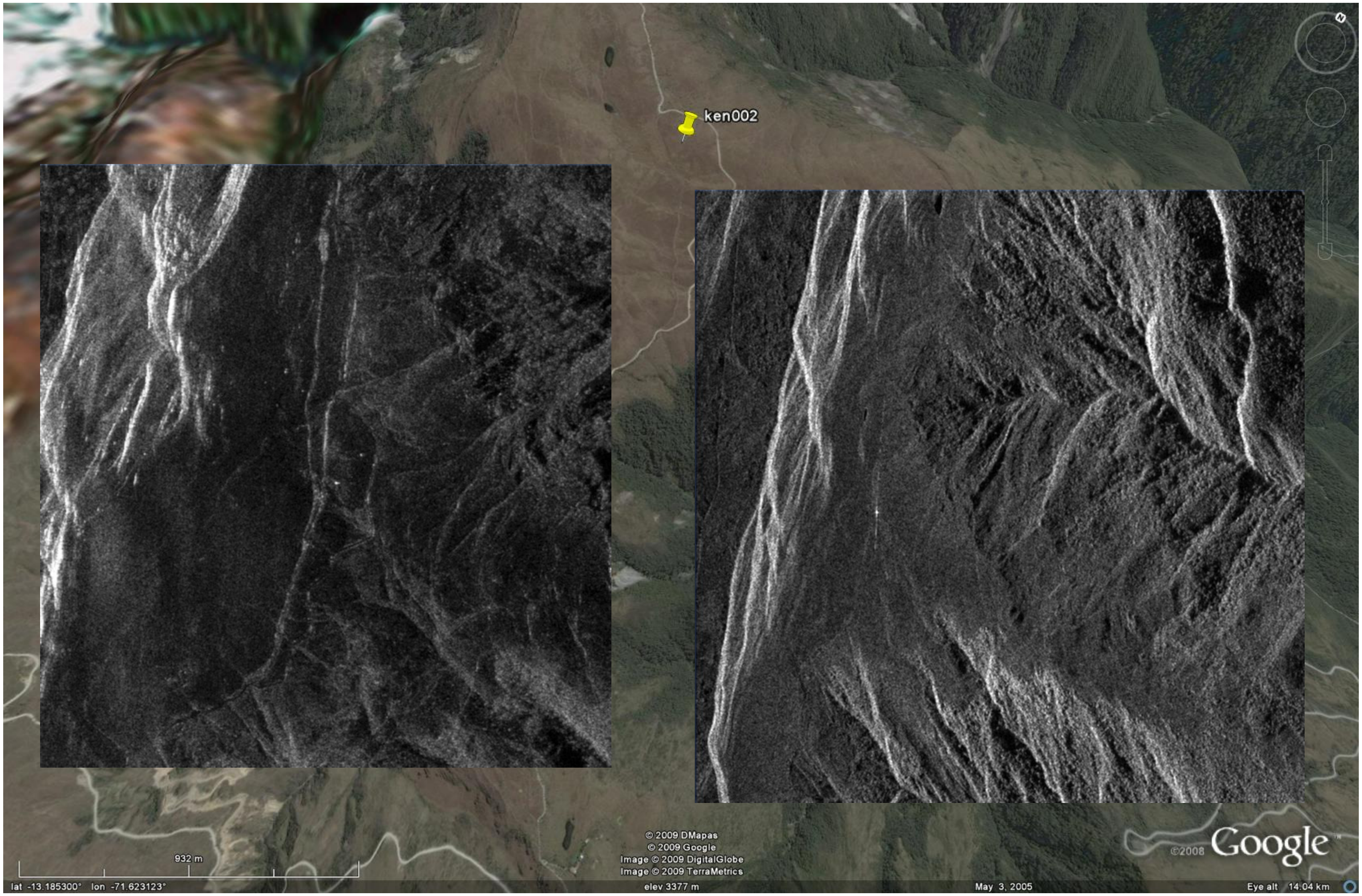


Successful Deployment Example: Peru



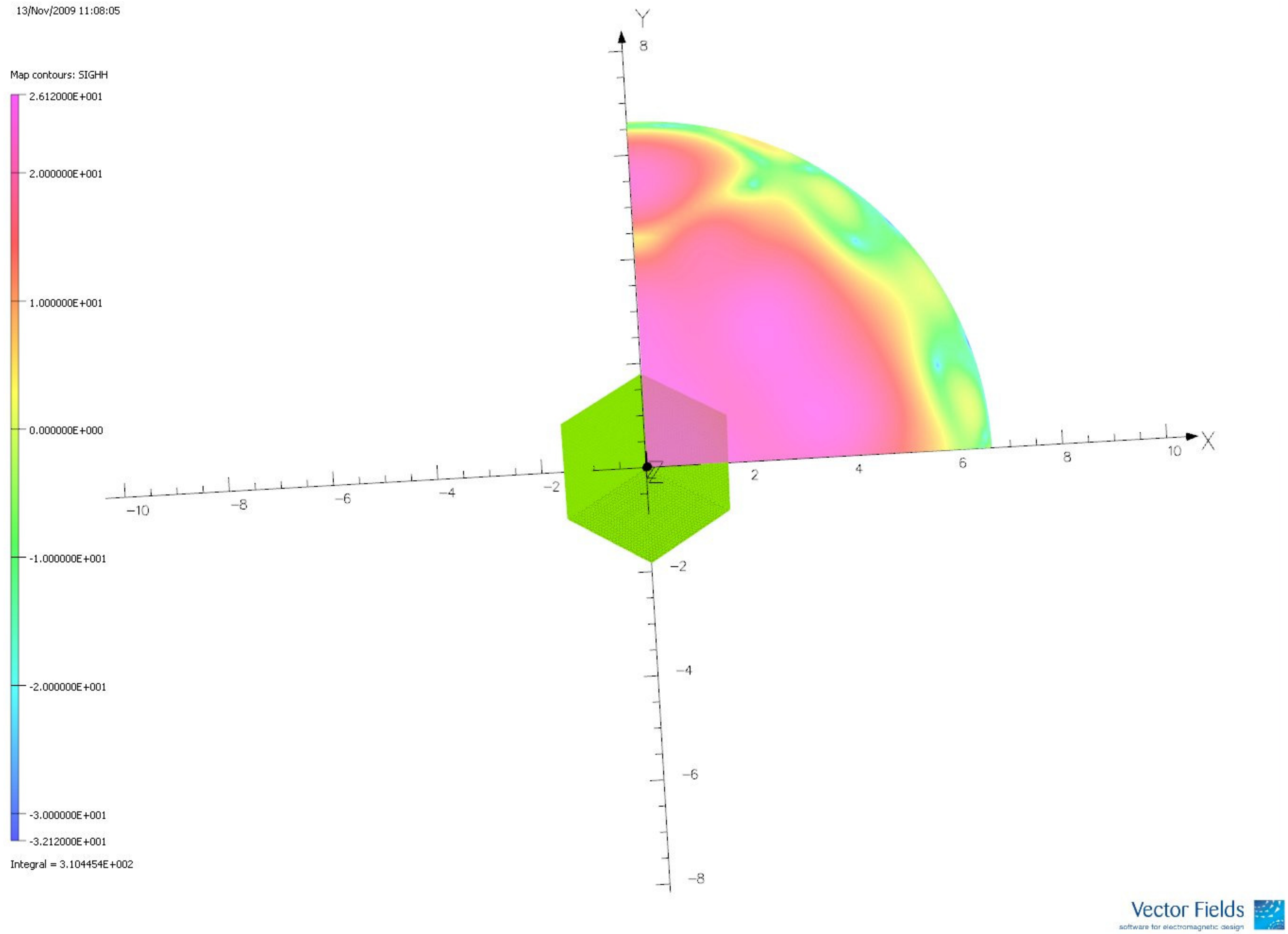
Target site some 370 miles from Lima as the Condor flies …

Deployment Example: Peru



… over 3000m above sea level. Images are SLC.

P-band Target RCS Calculation



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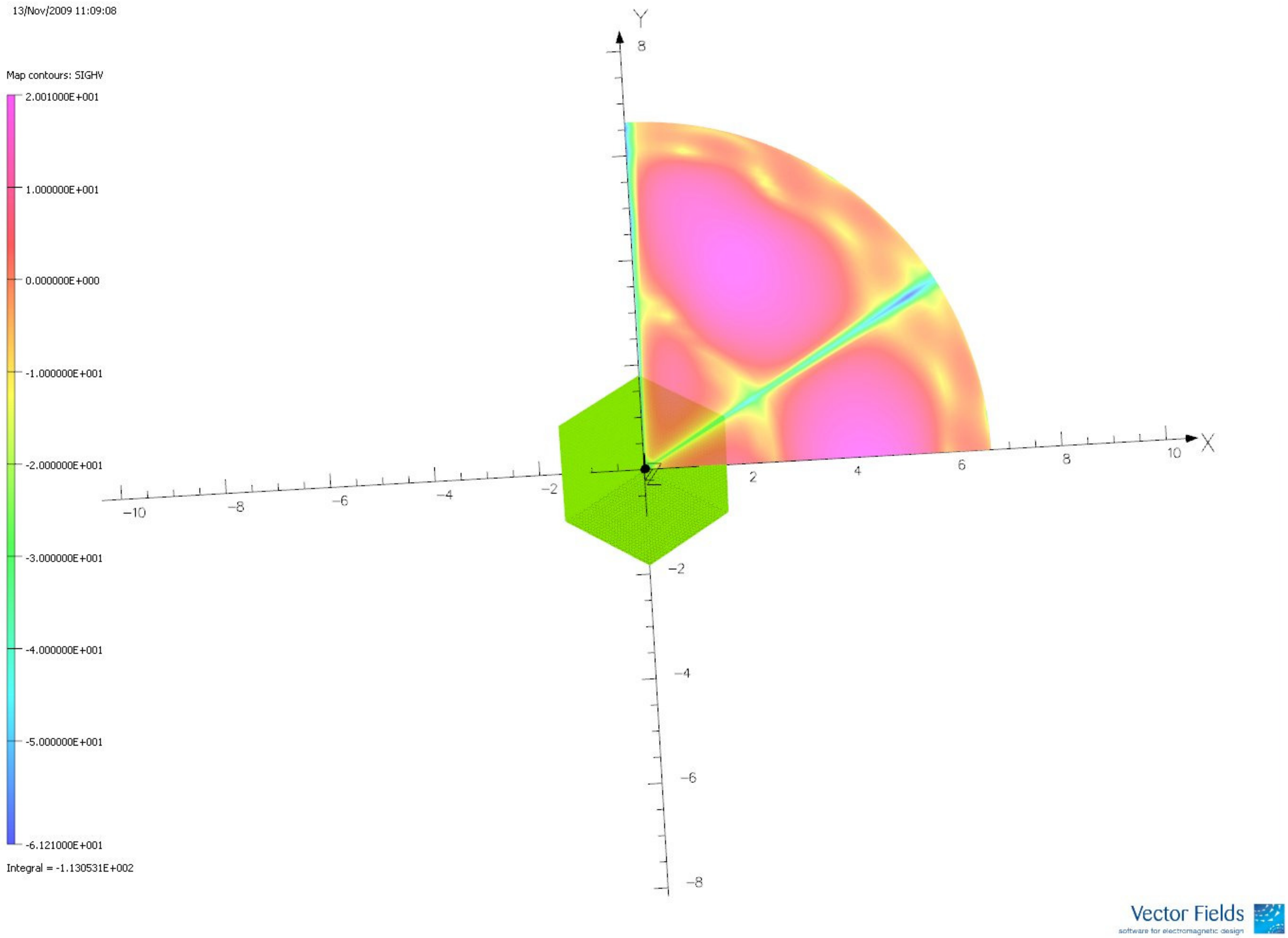
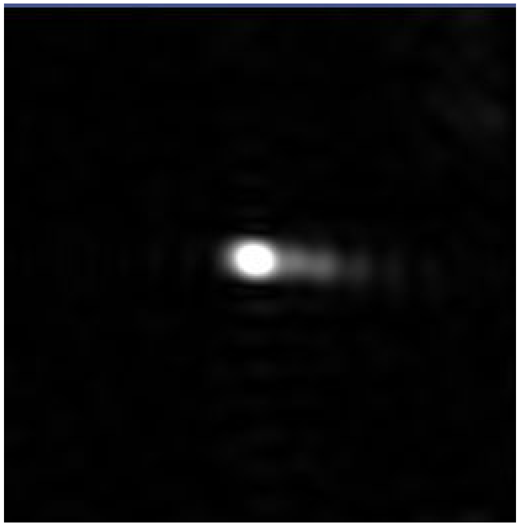
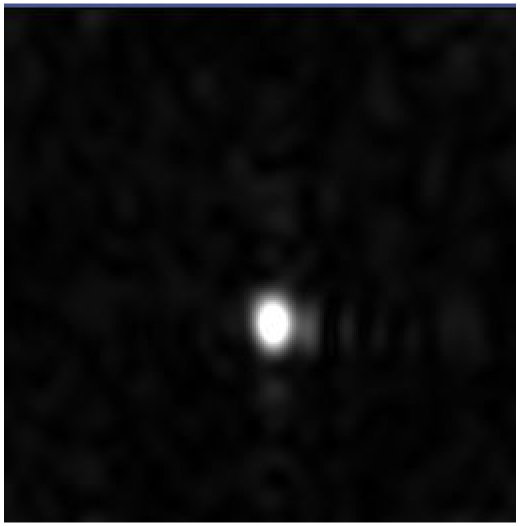


Use of Target RCS in Calibration

- Planned process:
  - MoM full complex scattering matrix calculations.
  - Waypoints on the *flown* flight path + knowledge of target location and orientation.
  - Antenna pattern, orientation, gain, range info. yield scattering amplitudes.
  - Antenna frame HH,HV response of the target recovered from the scattering matrix by basis rotation about LOS.
  - The along-track target responses can be integrated.
  - Several targets can be used to yield a calibration constant.
  - Approach mirrors that used by ONERA (Laurette Pastore, PhD Thesis, *Imagerie Radar par Synthese d'Ouverture en Basse Frequence*, 2002)
  - Frequency dependence of target response can be used to understand range response.

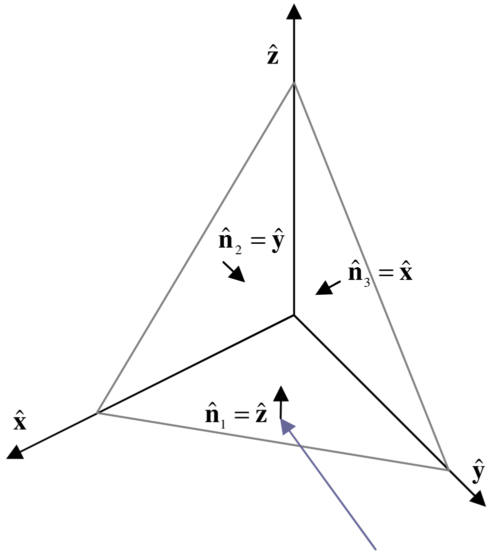


P-band



X-band

Depolarizing Trihedrals



$\hat{\mathbf{k}}_i = -\sin\theta\cos\phi\,\hat{\mathbf{x}} - \sin\theta\sin\phi\,\hat{\mathbf{y}} - \cos\theta\,\hat{\mathbf{z}}$

- High-frequency model.
- For a traditional (PEC) corner reflector we would have

$$R_{v3} = 1$$

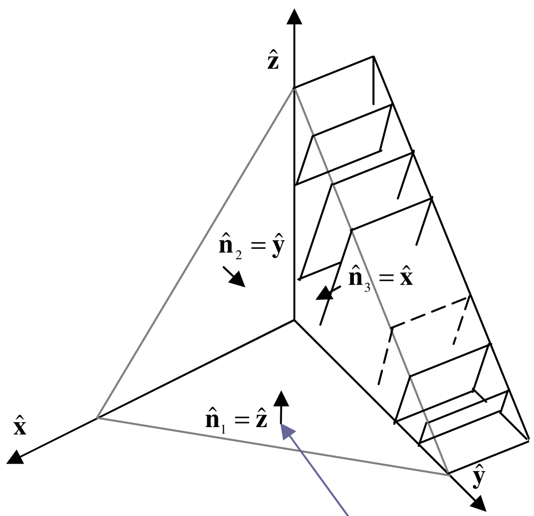
- and

$$R_{h3} = -1$$

- and the cross-polar scattering amplitude would be zero.

$$S_{hh} = \gamma_{i3}^2\,\gamma_{i2}^2\left[1 - \sin^2\theta\sin^2\phi\right]\left(R_{h3}\cos^2\theta\cos^2\phi - R_{v3}\sin^2\phi\right)$$

$$S_{vh} = \left(R_{v3} + R_{h3}\right)\gamma_{i3}^2\,\gamma_{i2}^2\left[1 - \sin^2\theta\sin^2\phi\right]\cos\theta\sin\phi\cos\phi$$



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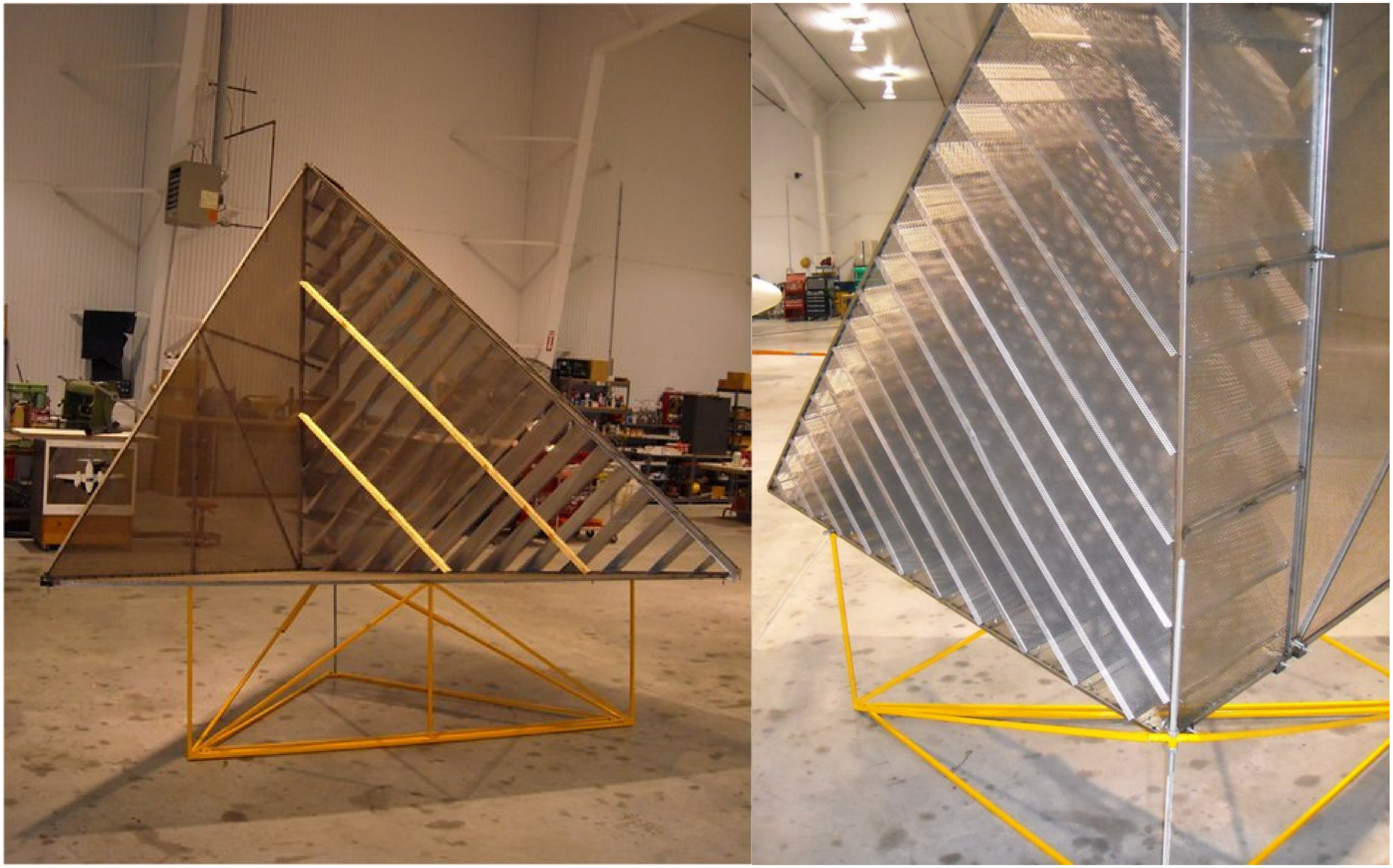
- Replace a reflecting surface with a wave-guide that reflects one polarization preferentially and S_{hv} is no longer zero …

$$\hat{\mathbf{h}}_{i3} = \gamma_{i3}\left(-\cos\theta\,\hat{\mathbf{y}} + \sin\theta\sin\phi\,\hat{\mathbf{z}}\right)$$

$$\gamma_{i3} = \left[\cos^2\theta + \sin^2\theta\sin^2\phi\right]^{-1/2}$$

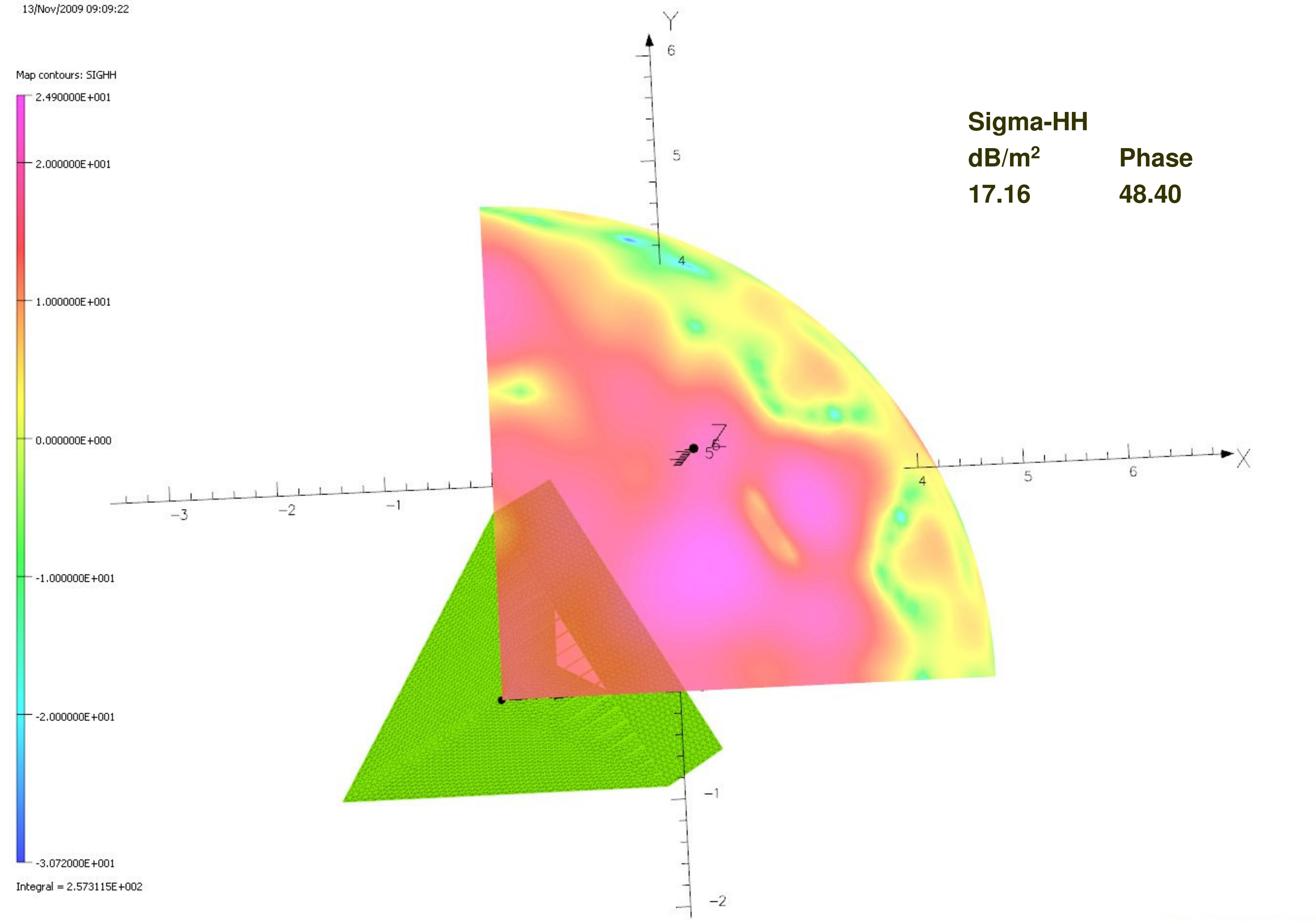
The Gridded Trihedral: A New Polarimetric SAR Calibration Reflector, D R Sheen, et al, IEEE TGRS, Nov, 1992.

P-band Depolarizing Trihedral



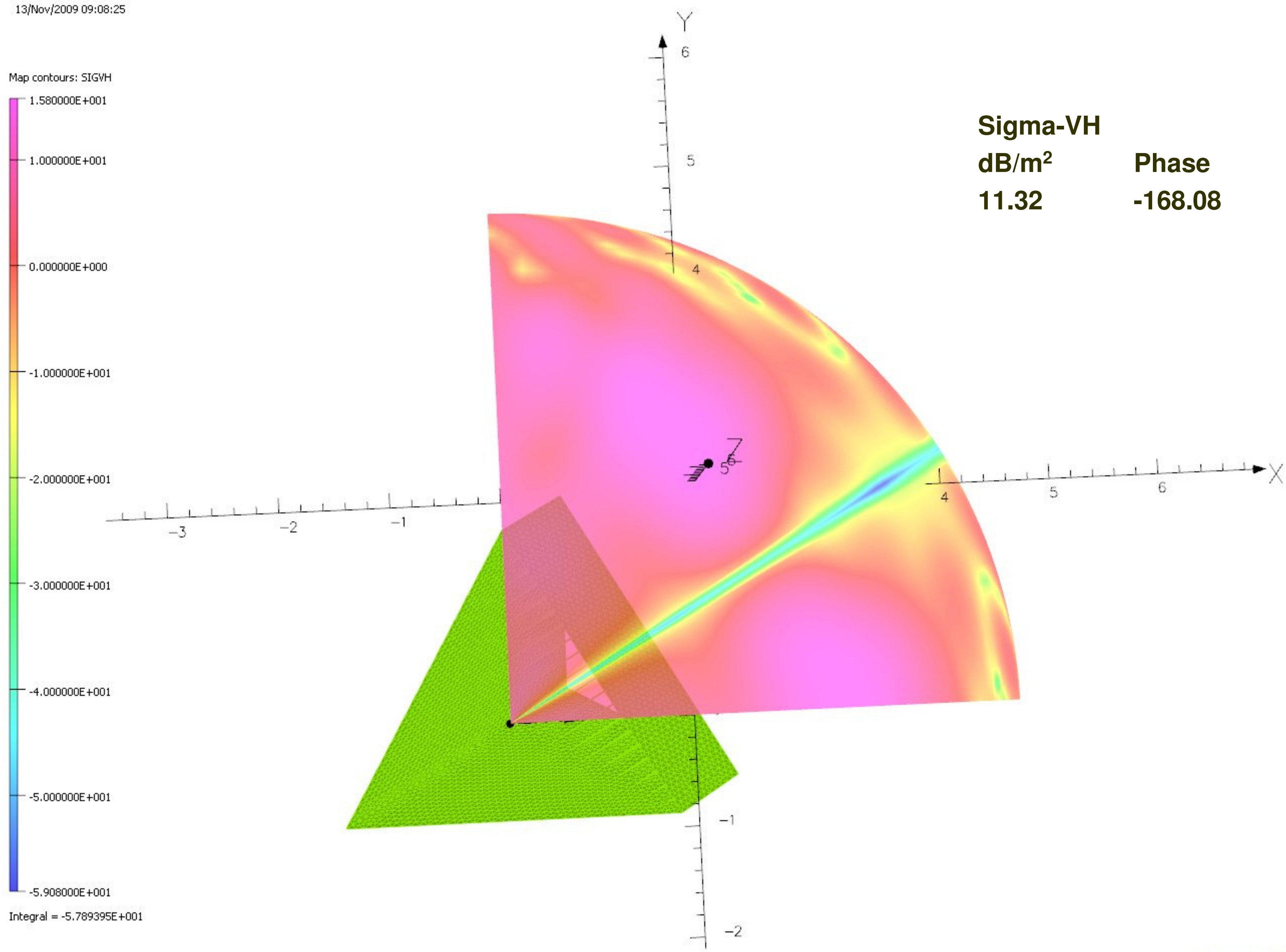
- Prototype P-band depolarizing corner reflector in hangar.

P-band Depolarizing Corner RCS Calculation



Sigma-HH	
dB/m^2	Phase
17.16	48.40

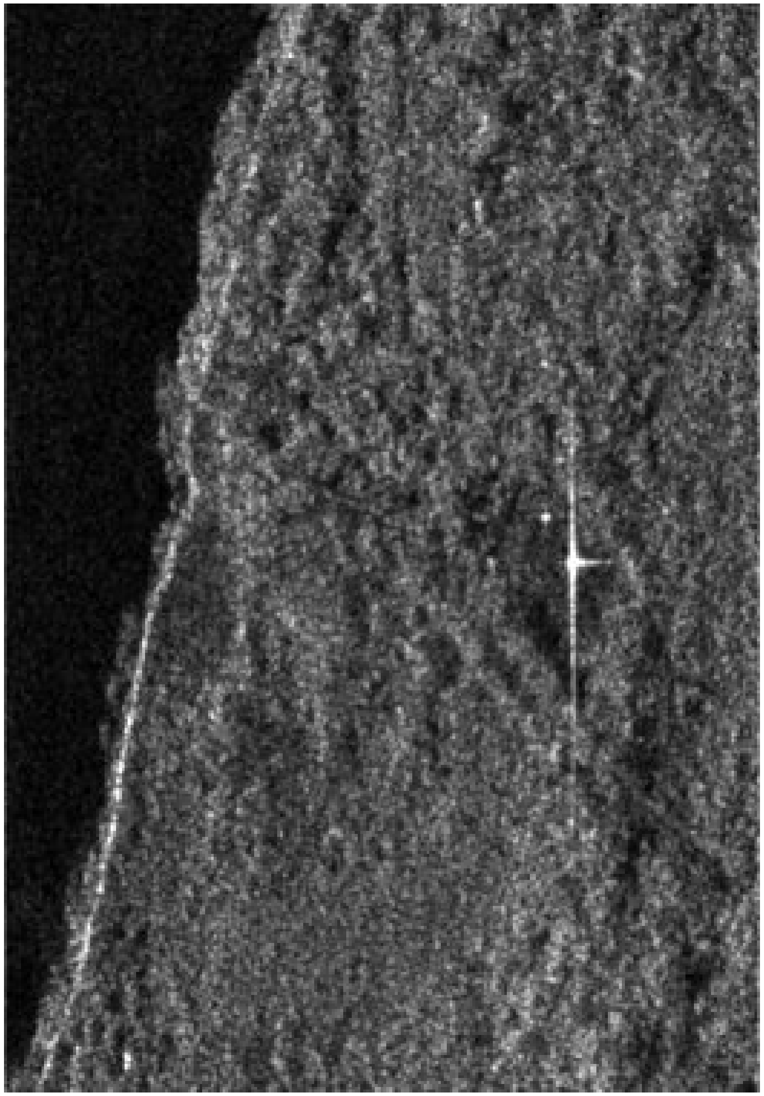
P-band Depolarizing Corner RCS Calculation



Vector Fields
software for electromagnetic design

Summary

- Notching requirements at UHF imply a need to calibrate outside the USA.
- We have designed new targets for radiometric and polarimetric calibration and are investigating their responses (GeoSAR quad-pol upgrade is in progress).
- We have designed a process for deployment of targets during campaigns and tested the process in an overseas deployment.
- We will continue to improve the *in-field* calibration process by incorporating the target scattering pattern and flight path information.
- Thank you!



X-band and P-band targets visible in the X-band image