J1 CrIIS Noise Performance & Impulse-Noise/Bit-Trim Mask Optimization

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Outline

- Excellent CrIS NEdN performance
- NEdN subtle issues
  - NEdN dependency on photon flux sometimes not as expected
  - Differences in electrical side 1 to side 2
- Optimizing bit-trim mask
- Impulse mask considerations
  - Radiation causes spikes in interferograms
  - Detecting/correcting spikes in FIR filtered interferograms
Extensive J1 NEdN Measurements During TVAC

- NEdN from both operational and staring mode
- Three sensor plateaus
  - (PFL) Proto Flight Low (ICT at about 262 K)
  - (MN) Mission Nominal (ICT at about 278 K)
  - (PFH) Proto Flight high (ICT at about 314 K)
- Both electronic sides
- Different power supply voltages
- With induced vibration
Example Staring MN NEdN

- MW FOV9 out of family with other FOVs
- MW FOV9 slightly above spec value
- MN (Mission Nominal) plateau staring mode
Operational Mode MN NEdN

- Staring and operational mode NEdN nearly identical
- MN 287 K ECT, side 1
Allan Deviation

Alternative way to characterize noise behavior

Standard deviation of sets with increased averaging

Single spectral channel per band (868, 1234, 2528 cm\(^{-1}\))

MN, 287 K ECT, operational mode, side 1

Bottom trace is Matlab random noise

http://www.allanstime.com/AllanVariance/
PFL (Proto Flight High) temperature plateau

Operational mode, 287 K ECT, side 1
PFH (Proto Flight High) temperature plateau
Slightly higher NEdN
Operational mode, 287 K ECT, side 1
NEdN Verses Photon Flux

- NEdN expected to increase with photon flux
- Band averaged NEdN of operational mode data
  - LWIR 680-1020 cm\(^{-1}\), MWIR 1220-1600 cm\(^{-1}\), SWIR 2160 – 2400 cm\(^{-1}\)
- In general NEdN increases with photon flux as expected
- Exception for large contrast between ECT and CrIS sensor
- Excess noise seen in PFL and PFH
- Behavior may be due to ground testing vibration issue
- Vibration issues also seen during SNPP CrIS TVAC
Average NEDN goes up with photon flux

MW FOV9 NEDN consistently increases with photon flux

Component of NEDN difference between sensor and ECT
MWIR Expanded Scale

- Average NEdN goes up with photon flux
- Component of NEdN difference between sensor and ECT
Average NEdN goes up with temperature
Component of NEdN difference between sensor and ECT
Possible indication of vibration effects
Staring mode data didn’t show as large effect
Spectrally correlated noise is insignificant
Spectrally correlated noise dominates random noise
Allan Deviation Also Show Non-Ideal Behavior

- Same cases as previous two slides
- In 310 K case noise increased and character changed
- Bottom plot Matlab random number generator
Electronic Side 1 Side 2 NEdN Differences

- Differences in NEdN between side 1 and side 2 have been observed
- Actual differences or random measurement error?
- Operational data more representative of on-orbit operation
- LTR (Long Term Repeatability) data set
  - Consists of 36 collections 2 hours each
- Averaged over spectral band to produce one NEdN point for each FOV per 2 hour measurement
  - Removed LWIR NEdN tail (band averaged over 750 – 1050 cm⁻¹)
  - Only real data shown, imaginary results are similar
- Concatenated measurements into one time series
- First half side 1, second half side 2
NEdN Trend for MWIR LTR

- FOV9 is out of family
- FOV 8 has positive side 1 to side 2 jump
- FOV 7 has negative jump
Bar chart gives alternative view of data

Bars are the standard deviation of data for side 1, side 2, and combined side 1 and side 2

Shows if differences are statically significant
MW FOV8 shows large side 1 side 2 difference

SW side 1 to 2 differences are not statistically significant
Bit-Trim Mask Optimization

- Number of bits needed to define an interferogram depends on interferogram position
- Larger number of bits needed near center, less in wings
- Lut Desert Iran, 6/21/2015
Bit-Trim Mask Optimization

- Bit-Trim is a lossless data compression technique.
- Needs to be optimized for best performance.
  - Bit-Trim too conservative waste bandwidth.
  - Too aggressive corrupt bright scene data.
- J1 can benefit from SNPP data.
- Compare largest interferogram amplitude for each interferogram point of a scene with bit-Trim mask.
- Pick SNPP scenes with high dynamic range.
  - Australia February 23, 2012 (orbit 01671).
  - Andes Mountains March 12, 2013 (orbit 07113).
  - Lut Desert, Iran July 14, 2012 (orbit 03689).
- Use same bit-Trim mask for J1 as presently used for SNPP.
Absolute value of maximum interferogram at each interferogram position is plotted with positive part of bit-trim mask.

SNPP interferograms are always below bit-trim mask.
MWIR and SWIR Bit-Trim Masks

MWIR

Interferogram Amplitude bits

Interferogram Samples

SWIR

Interferogram Amplitude bits

Interferogram Samples
Interferogram Spikes

- Radiation can cause spikes in interferograms
- Impulse mask designed to zero out interferogram spikes
- SWIR is most affected (smallest detector current)
- Impulse mask operates on interferograms before FIR filter
- Electrical offsets and low frequency signals cause false triggers
- Impulse mask must be set high to avoid false triggers
- Small spikes are not presently being detected/corrected
- Many more small spikes than large spikes
- A method of detecting spikes is through interferogram asymmetry
- Small spikes can be detected/corrected on the ground
Geographical Distribution of Interferograms with Spikes

Medium sized SW spike January to May 2015
Low Earth Orbit Radiation Distribution

From NASA/SAMPEX satellite
Can’t Use Scaled Bit-Trim Mask for Impulse Mask

- Diagnostic mode allows view of raw interferograms
- Bit-trim mask scaled to raw interferogram levels
- Electronic offset about 95 counts for LW and MW
- Beginning of scan transient can be around 200 counts
Example of Spike in SW Interferogram

- Filtered interferogram is absolute value
- Many SW interferogram have small amplitudes
  - High dynamic range in the SW scenes
- Xin Jin estimated 123 spikes/day for side (less than 0.07%)
Detecting Interferogram Spikes

- A simple amplitude mask isn’t very effective to detect spikes
  - Bright scenes can be larger than spikes
- Interferograms should be symmetric
- Interferogram phase makes direct left side to right side comparisons difficult
- Absolute value of interferogram plotted
Interferograms can be binned to make side to side comparisons
Example is for 6 interferogram points/bin and skip ZPD area
Right side of interferogram has been flipped
Difference clearly show spike
Spikes Are Not Single Sample Events

- Raw diagnostic mode data
- Data points indicated by “x” connected by straight lines
- Shape similar to that of a damped oscillator
- Least-squares fit to spike
- Subtract modeled spike from interferogram
Affect of Filtering and Decimating on a Spike

- Modeled spike
- SW band
- Fit uses real and imaginary component
Example of Spike Removed from Interferoogram

- Correction though subtracting modeled spike from original interferogram
- No residual error visible
- FOR 27, FOV6, 2/18/2015 18:11:11.367
Expanded Vertical Scale

- Fit to spike is very good
- Residual error not visible in expanded view of interferogram
Expanded View of Corrected Interferogram

- Spike residual error not visible
- Quantization noise clearly visible
Conclusions

- CrIS J1 has excellent NEdN performance
- Evidence for vibration effects in ground testing
  - Not an issue for MN
  - Noticeable for PFL and PFH
- Some FOVs show consistent differences in side 1 to side 2 NEdN
- Bit-trim mask optimization for CrIS SNPP can be applied to J1
- Impulse mask needs to be set high to avoid false triggers
- Number of interferogram affected by spikes is low with respect to operability requirement of 99%
- Radiation spikes can be detected and removed through ground processing