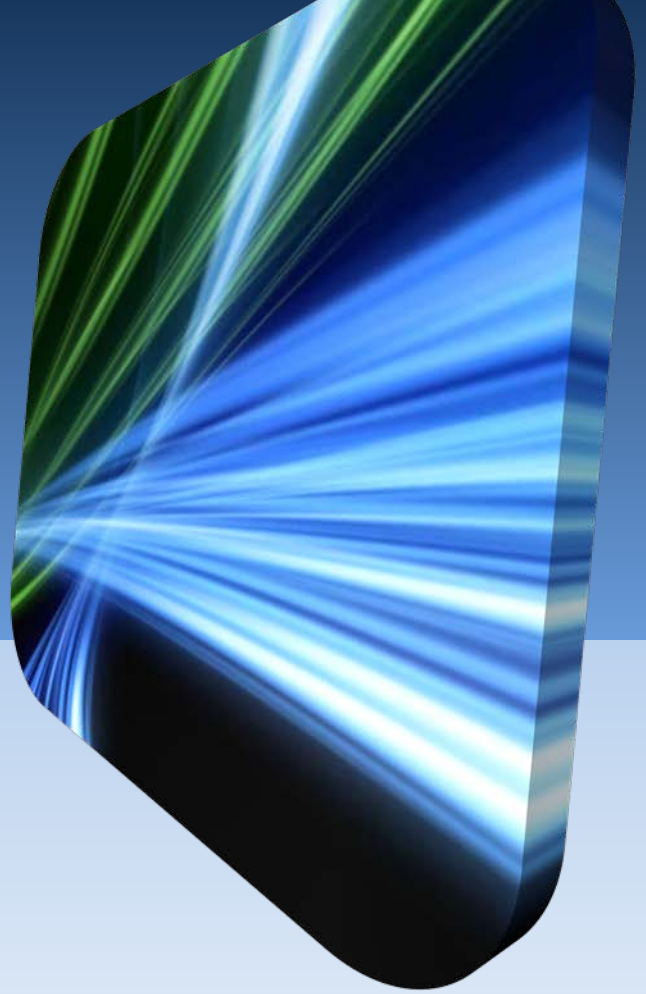
True CrIS ILS - Consequences of Unapodized SDR Processing



Joe Predina
Perry Falk

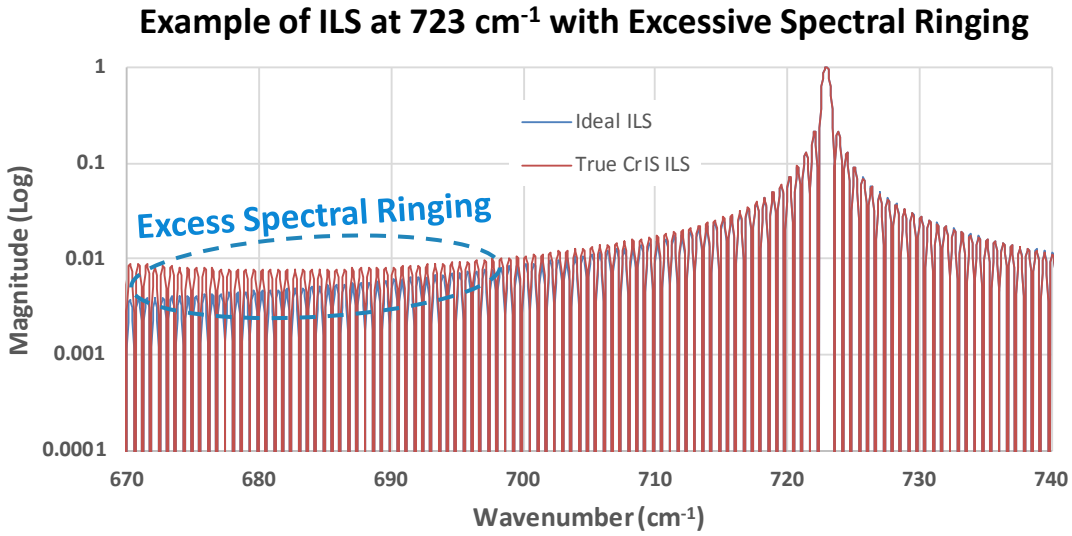
Logistikos Engineering LLC, Fort Wayne, IN

STAR JPSS Science Team Annual Meeting
Session 4, Part 1: CrIS SDR
August 8-12, 2016
College Park, MD

LOGISTIKOS ENGINEERING LLC. AEROSPACE SYSTEM ENGINEERING SERVICES

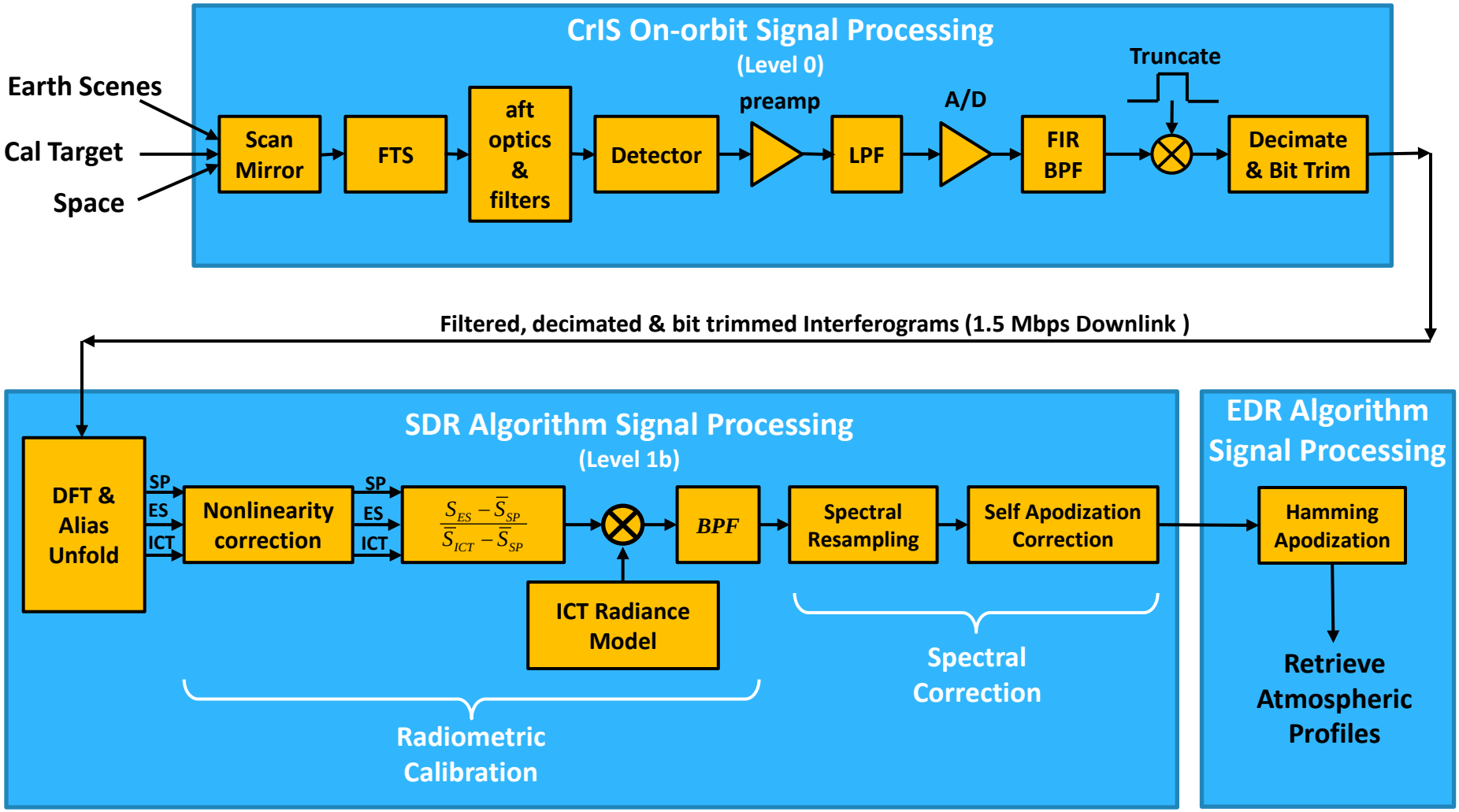
Introduction – True CrIS ILS

- It is desirable for interferometer systems to produce an unapodized ideal Sinc ILS after completion of all SDR calibration operations
- Deviation from ideal Sinc ILS (excess spectral ringing) is common in FTS systems
- Spectral Ringing can be caused by many factors
- Suppression of Sinc ILS sidelobes & other forms of spectral ringing is commonly achieved by applying an external apodization function such as Hamming or Blackman-Harris



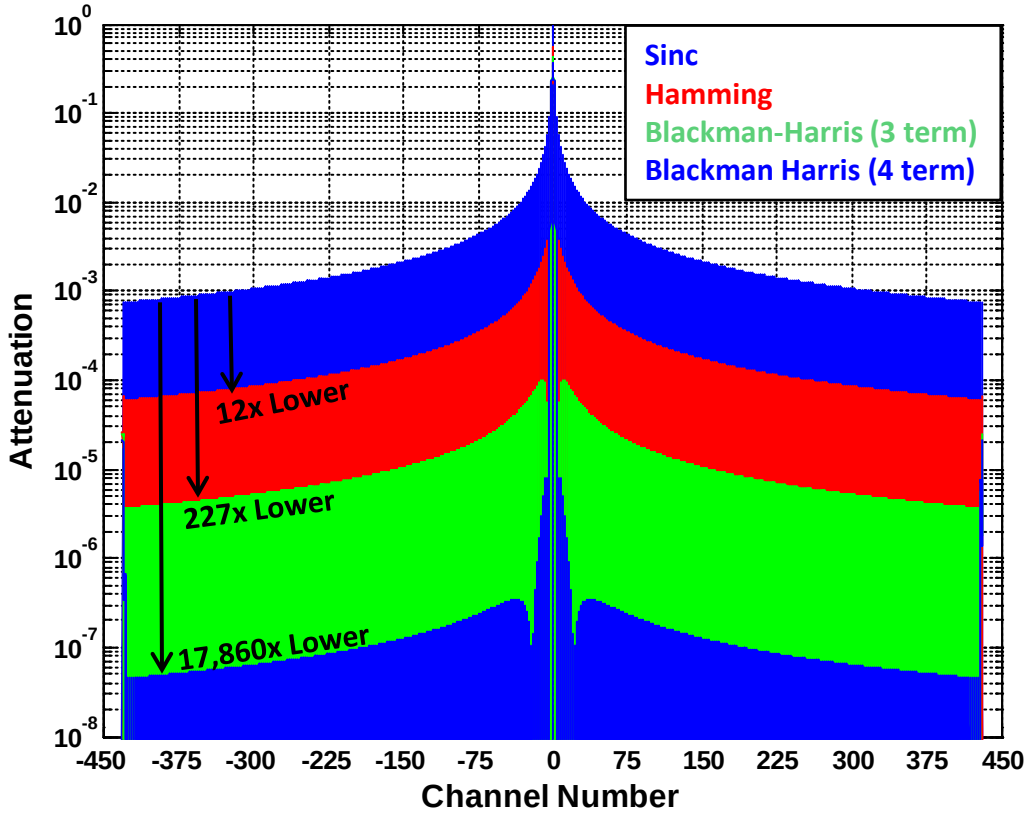
NPP SDR Processing

Radiometric Calibration Precedes Spectral Correction – Hamming Applied in EDR

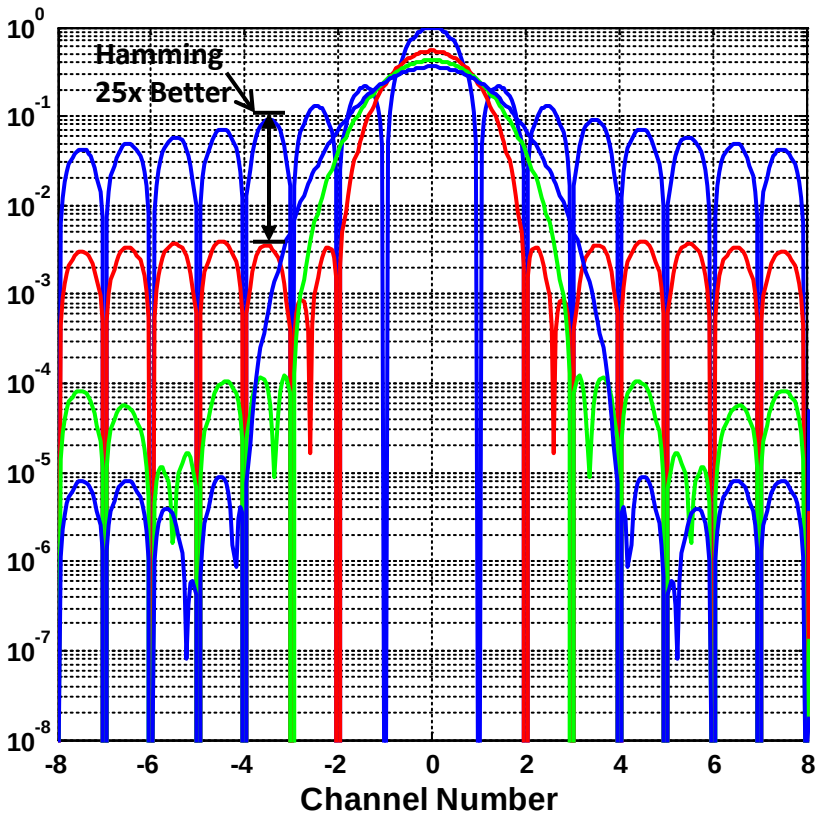


Sidelobe Spectral Ringing Typically Suppressed with Apodization Function

Sidelobe Magnitude for Various Apodizations



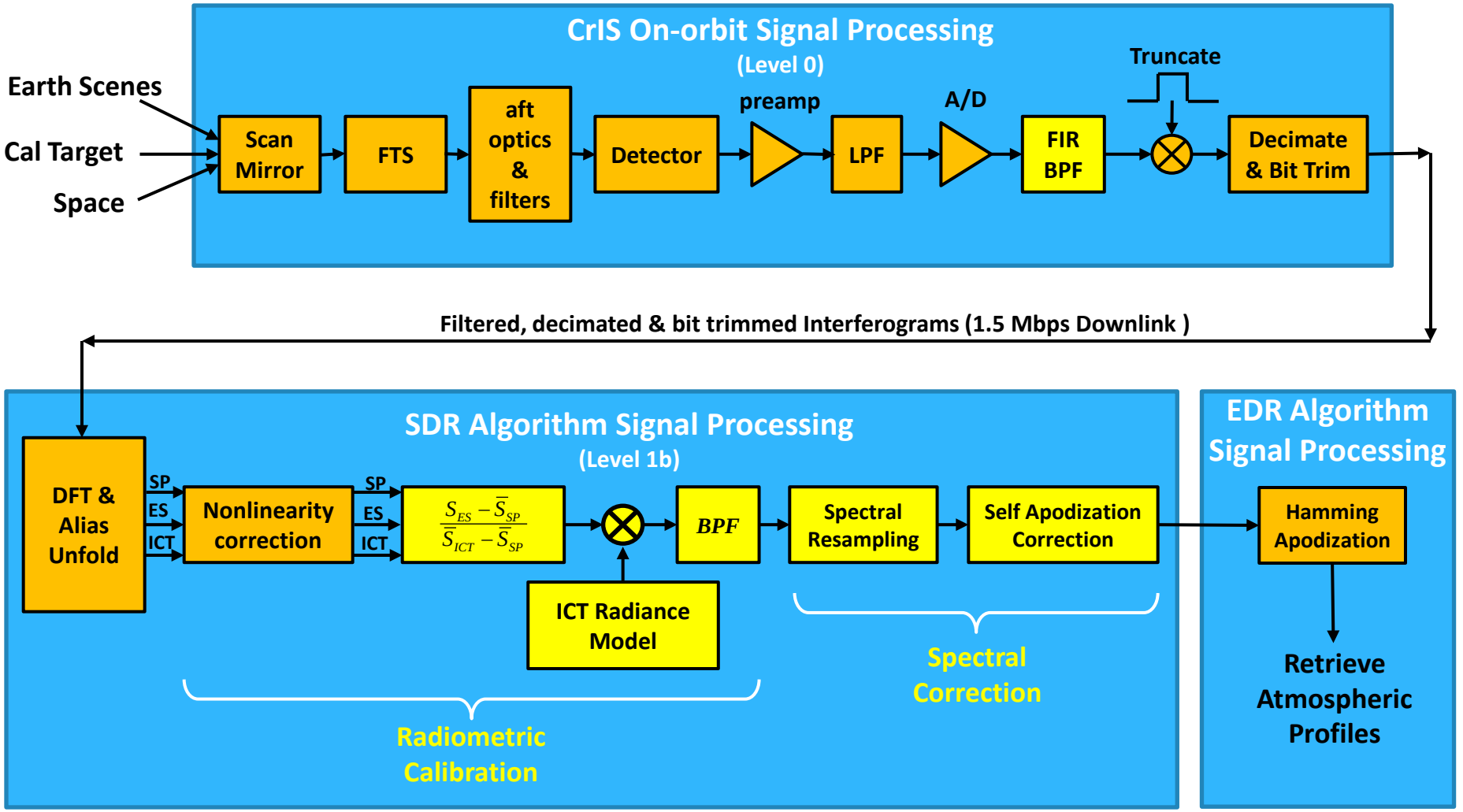
Main Lobe Resolution for Various Apodizations



ILS Sidelobe Uncertainty Also Reduced when Using Apodization Functions

Can Current Hamming Apodization Be Eliminated?

CrIS CAL/VAL Team Focus Areas for Reducing Spectral Ringing & Improving ILS Knowledge



Key CAL/VAL Team Findings

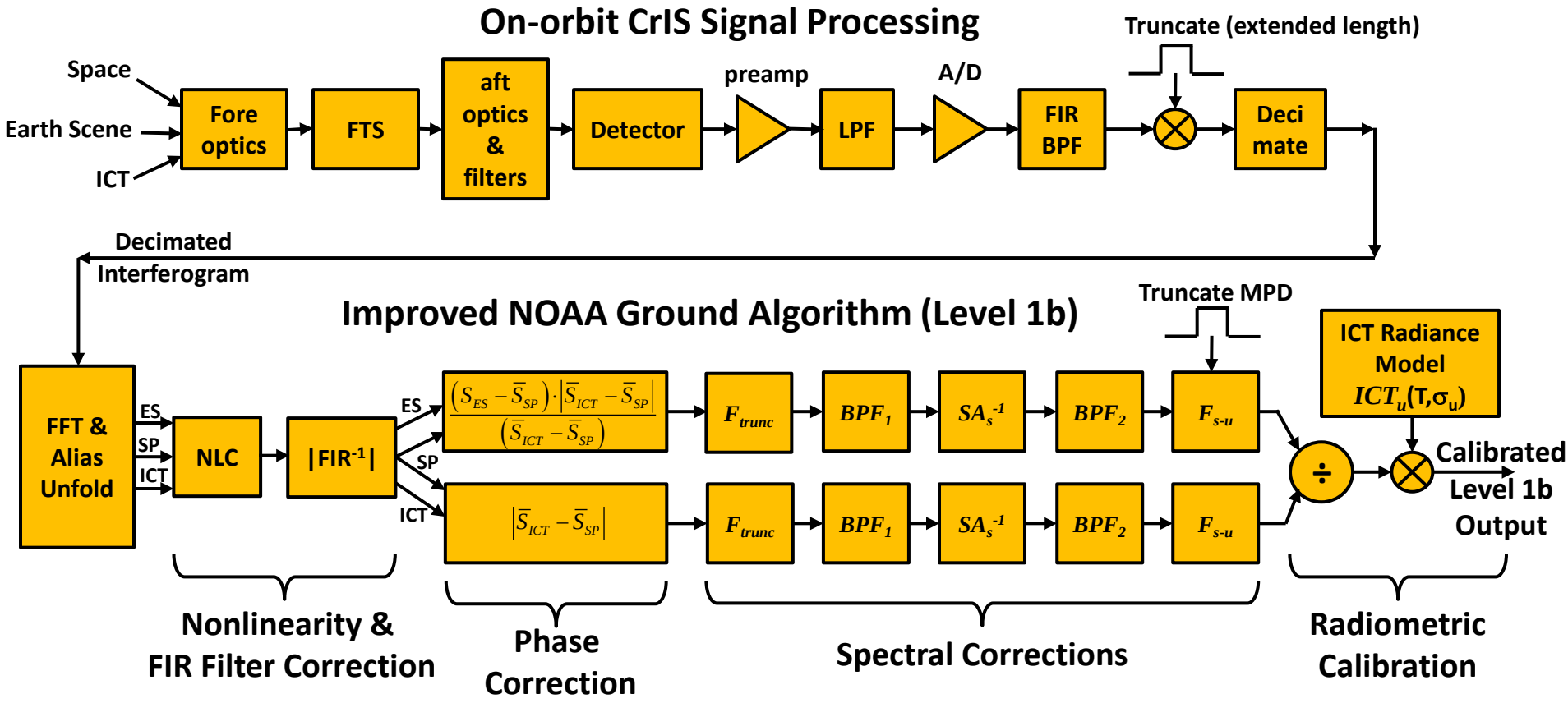
Reordering of NPP CrIS SDR Calibration Operations Will Improve ILS Knowledge for J1 Instrument

- Self Apodization correction should <u>precede</u> Radiometric Calibration
- Self-apodization (SA^{-1}) correction should <u>precede</u> Spectral resampling ($F_{s\text{-}u}$)
- Spectral resampling function must use large number of samples "N_0" in computation
- Processing of extended length interferograms through full calibration and with truncation to shorter MPD as a last step helps
- Truth Spectrum must include the effect of instrument optical responsivity

Other Consequences of Suggested Changes

- Must compensate for CrIS FIR filter (FIR^{-1}) prior to spectral correction
  - In-band amplitude ripple
  - ZPD centering or delay
- Must phase correct spectrum prior to spectral correction

Improved Level 1b Algorithm Performs Spectral Correction on Extended Length Interferogram Prior to Radiometric Calibration



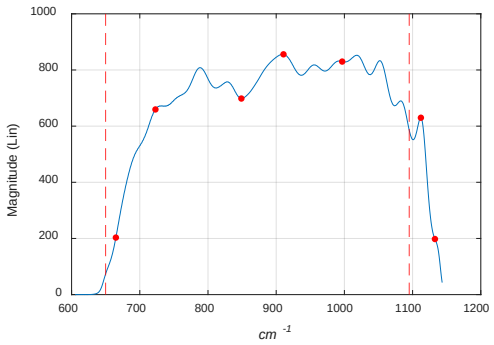
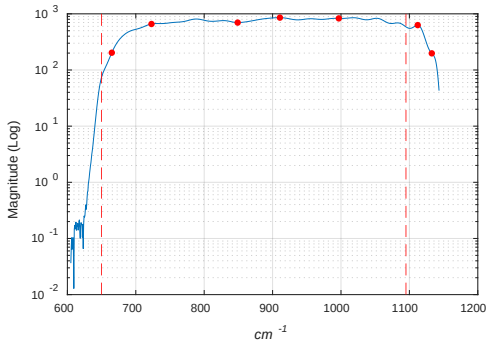
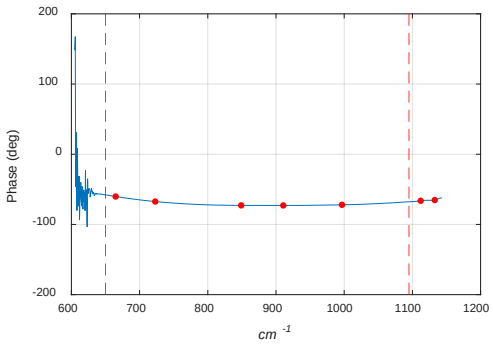
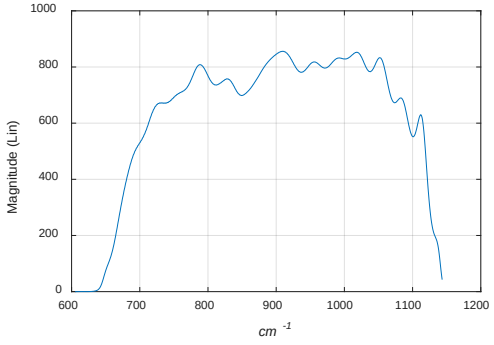
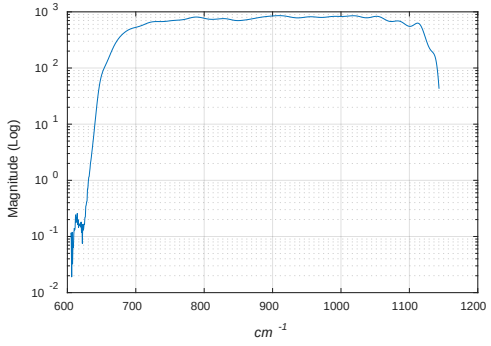
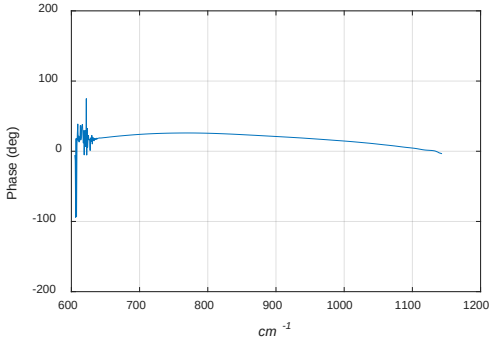
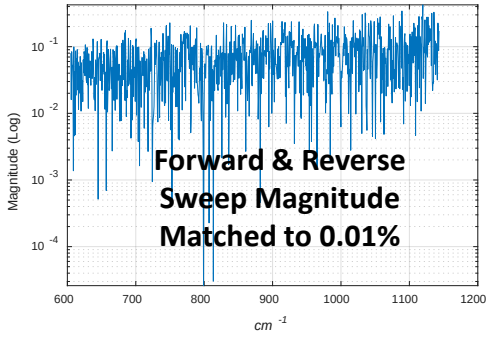
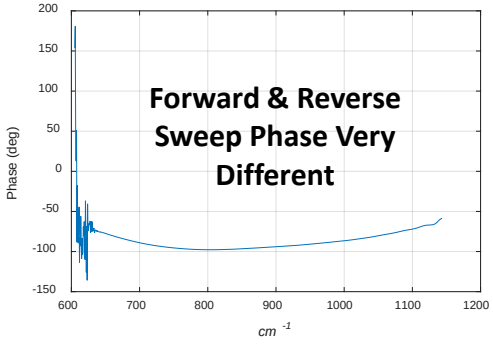
$$L_{ES} = ICT_u \cdot \frac{F_{s\to u}\cdot f_{BPF2}\cdot SA_s^{-1}\cdot f_{BPF1}\cdot F_{trunc}\cdot\left[\frac{(S_{ES}-\bar{S}_{SP})\cdot|\bar{S}_{ICT}-\bar{S}_{SP}|}{(\bar{S}_{ICT}-\bar{S}_{SP})}\right]}{F_{s\to u}\cdot f_{BPF2}\cdot SA_s^{-1}\cdot f_{BPF1}\cdot F_{trunc}\cdot|\bar{S}_{ICT}-\bar{S}_{SP}|}$$

$$S_{ES} = |FIR^{-1}|\cdot NLC\cdot CRIGHT\left[FFT\left(CRIGHT\left[I_{ES},\frac{N_{Eb}}{2}\right]\right),N_{unwrap}\right]$$

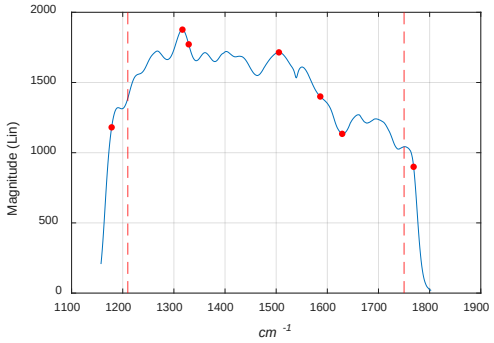
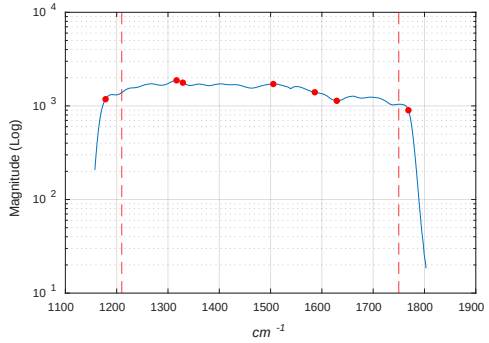
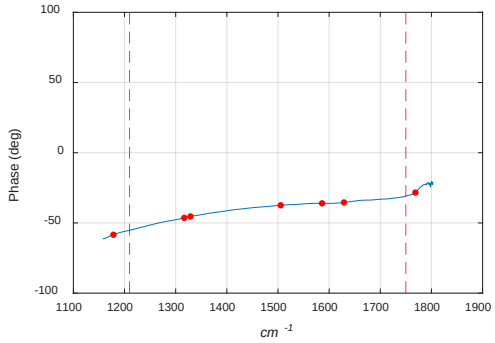
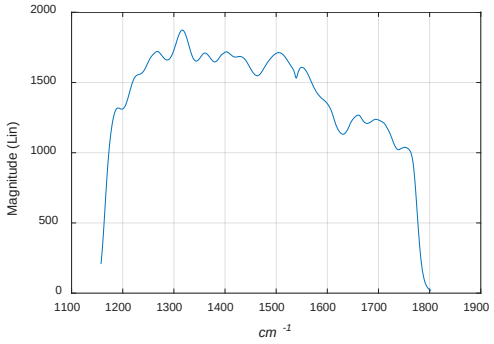
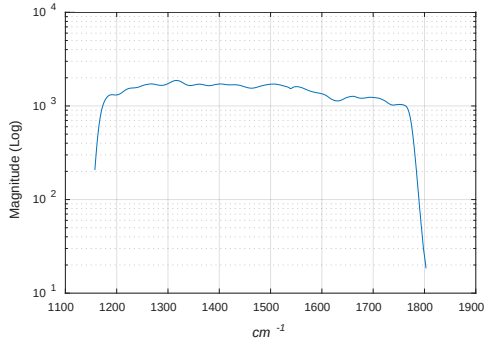
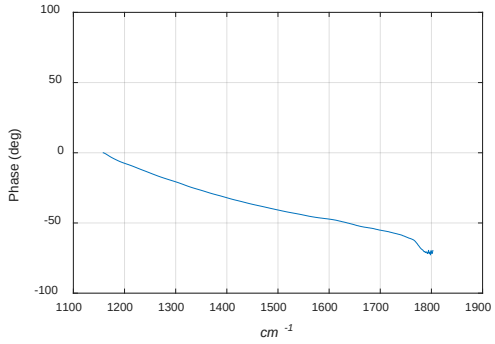
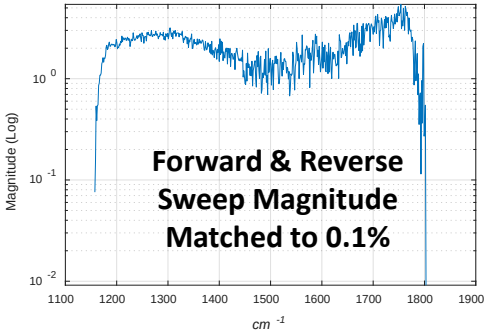
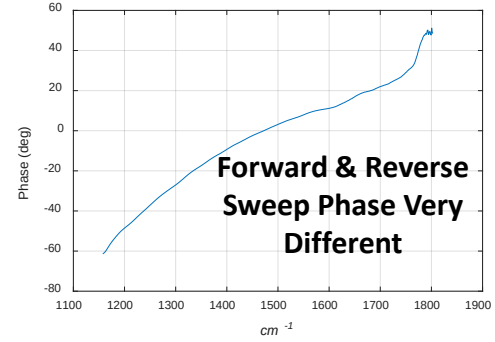
$$S_{ICT} = |FIR^{-1}|\cdot NLC\cdot CRIGHT\left[FFT\left(CRIGHT\left[I_{ICT},\frac{N_{Eb}}{2}\right]\right),N_{unwrap}\right]$$

$$S_{SP} = |FIR^{-1}|\cdot NLC\cdot CRIGHT\left[FFT\left(CRIGHT\left[I_{SP},\frac{N_{Eb}}{2}\right]\right),N_{unwrap}\right]$$

LWIR Optical/Electrical Responsivity

	Linear Magnitude	Log Magnitude	Phase
Interferometer Sweep Direction 0			
Interferometer Sweep Direction 1			
Interferometer Sweep Direction Difference			

MWIR Optical/Electrical Responsivity

	Linear Magnitude	Log Magnitude	Phase
Interferometer Sweep Direction 0			
Interferometer Sweep Direction 1			
Interferometer Sweep Direction Difference			

SWIR Optical/Electrical Responsivity

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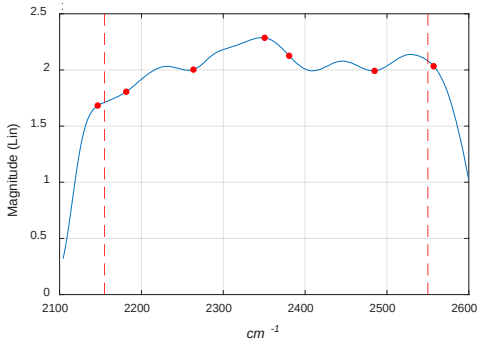
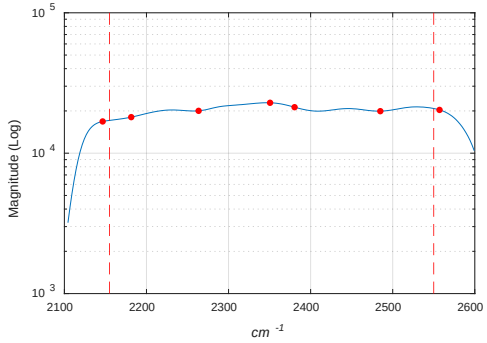
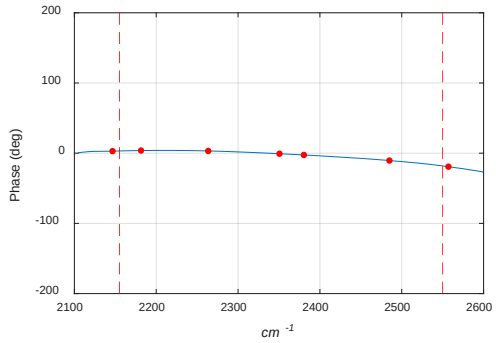
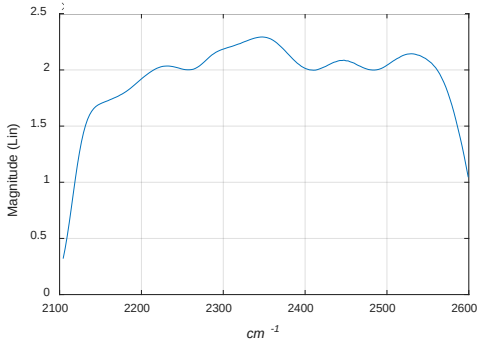
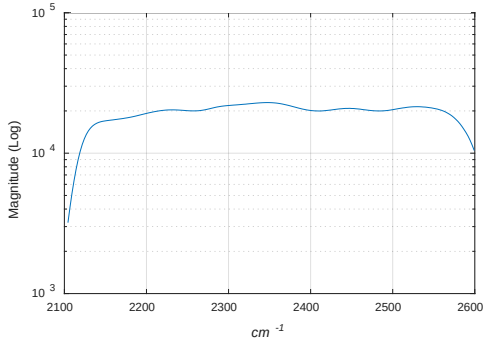
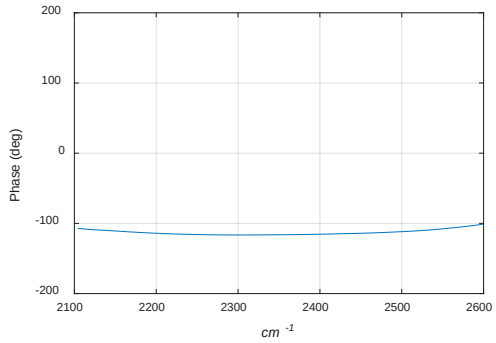
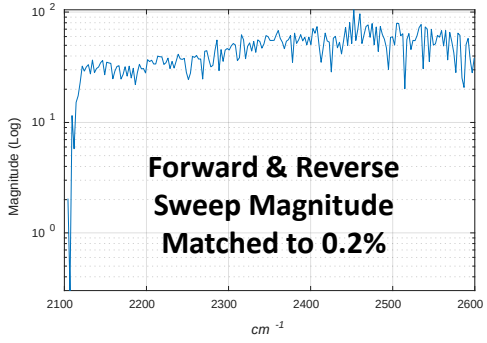
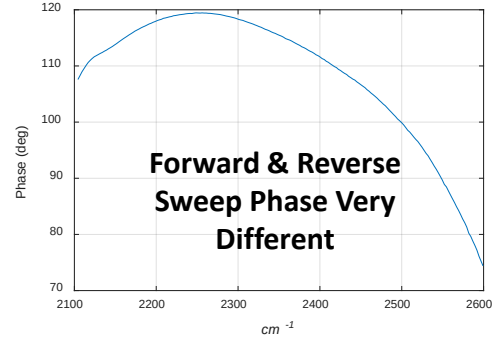
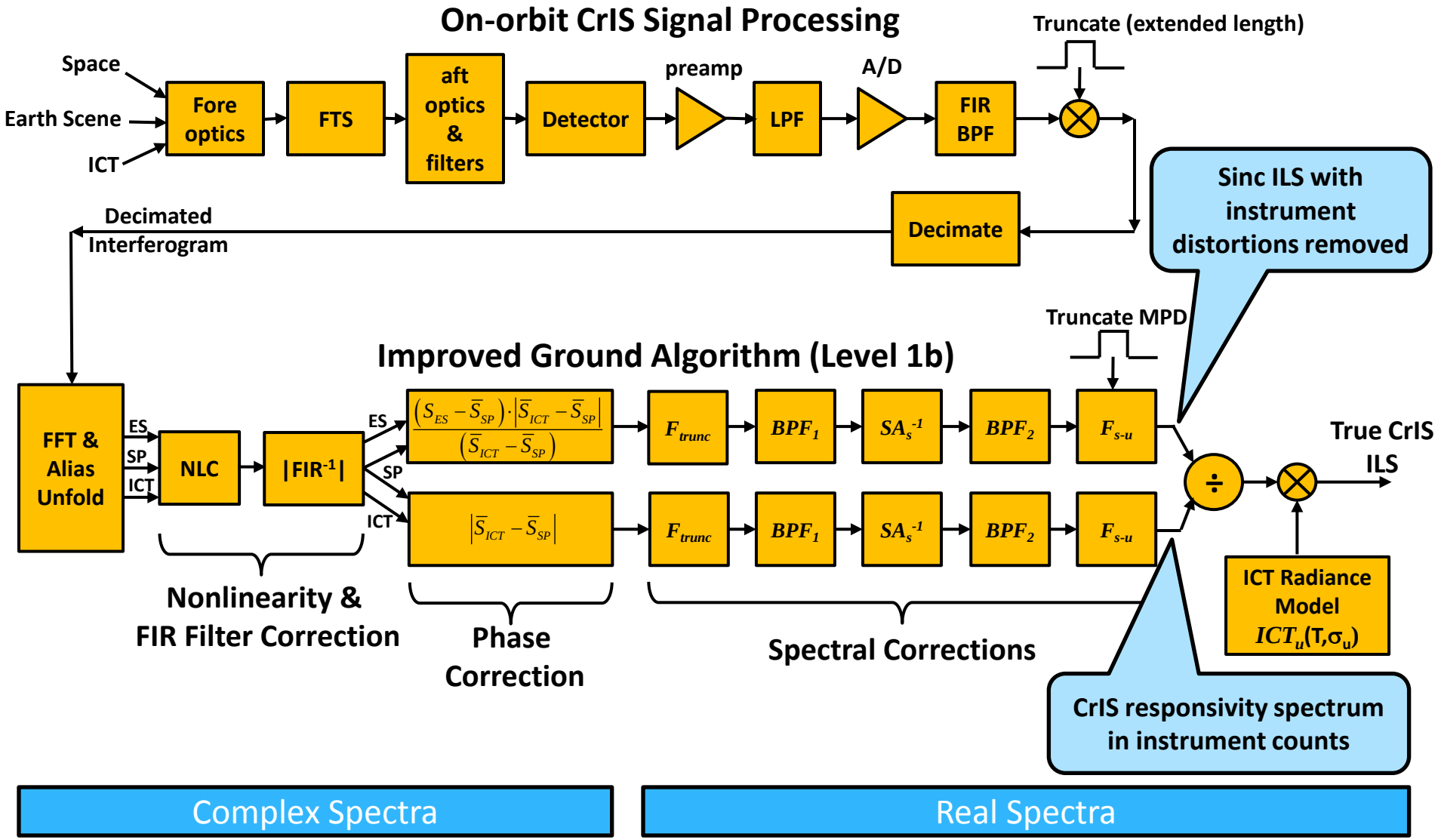
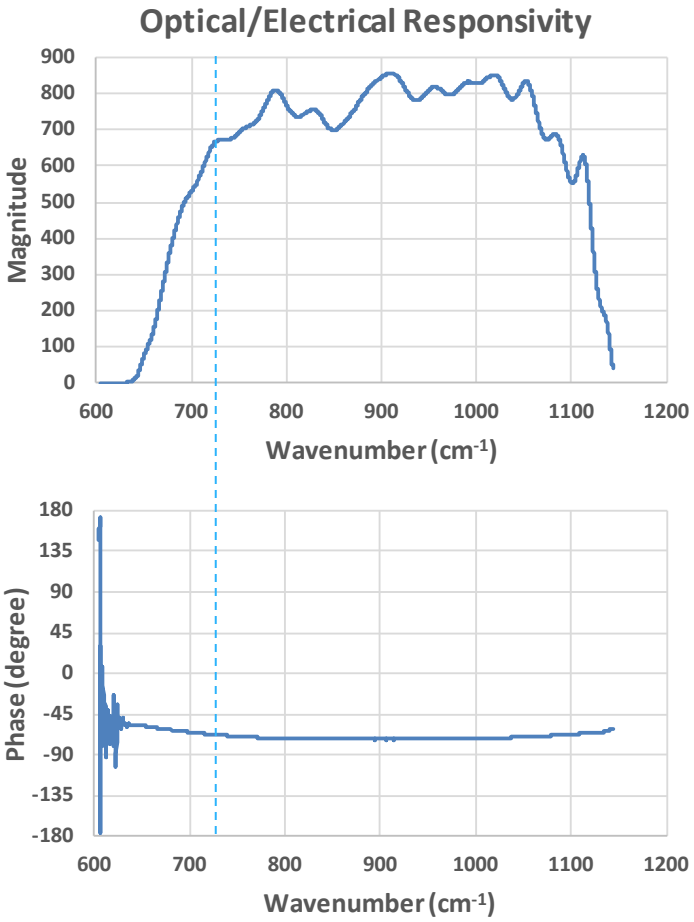
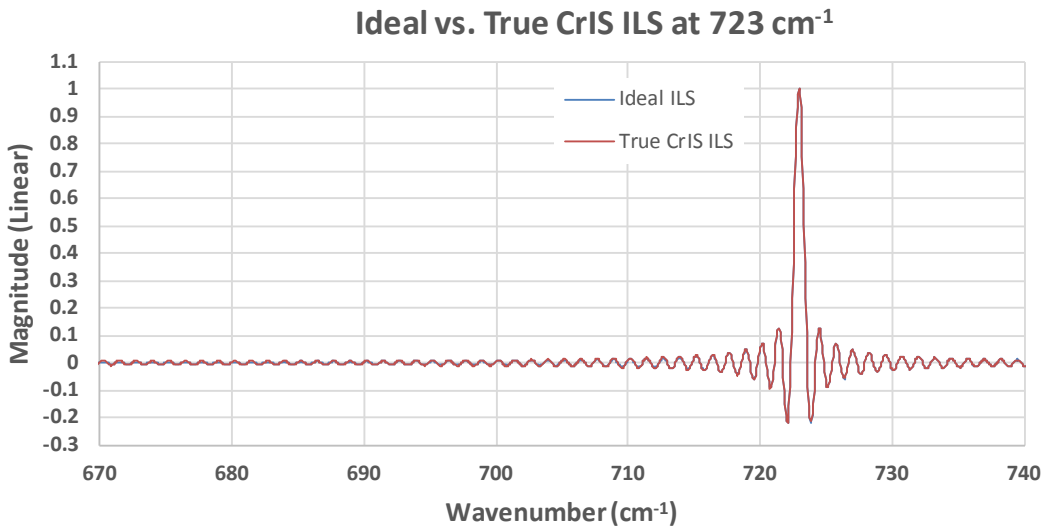
Interferometer Sweep Direction 0			
Interferometer Sweep Direction 1			
Interferometer Sweep Direction Difference			

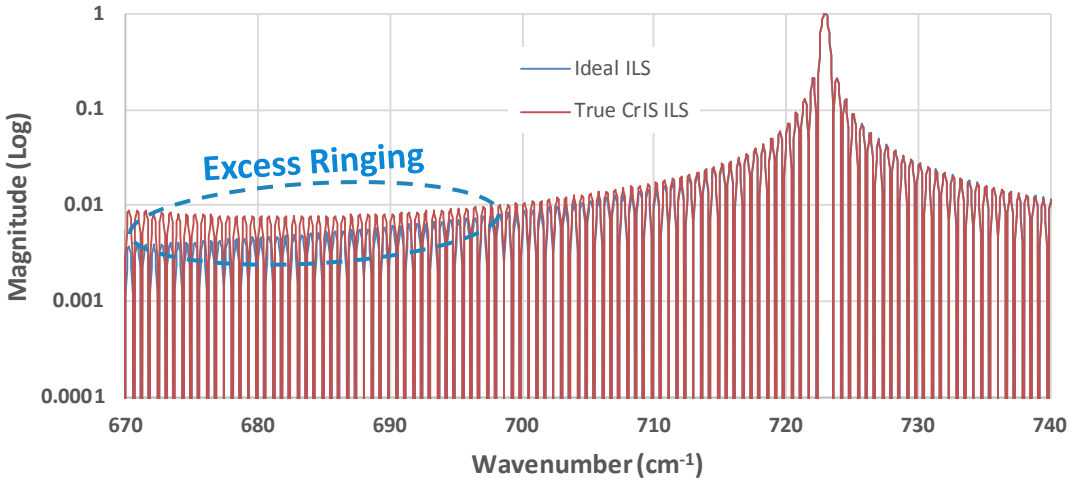
True CrIS Instrument ILS Depends Upon Optical/Electrical Responsivity Properties



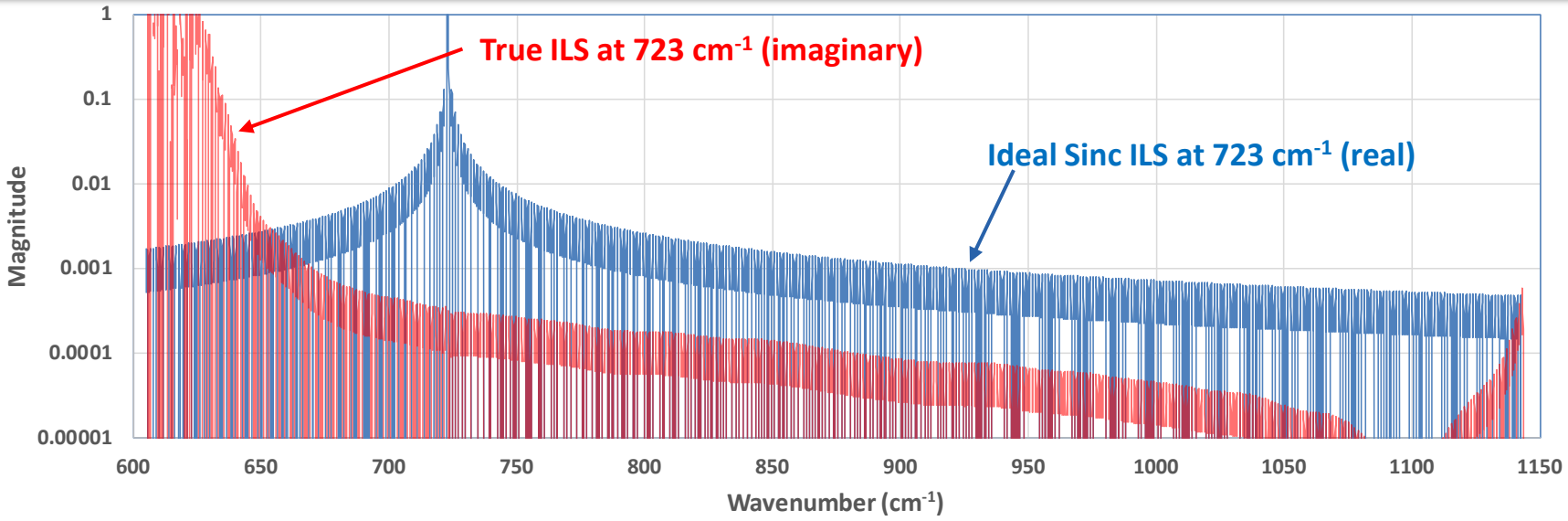
CrIS Optical/Electrical Responsivity Will Impact the Post Calibrated Instrument Line Shape (ILS)

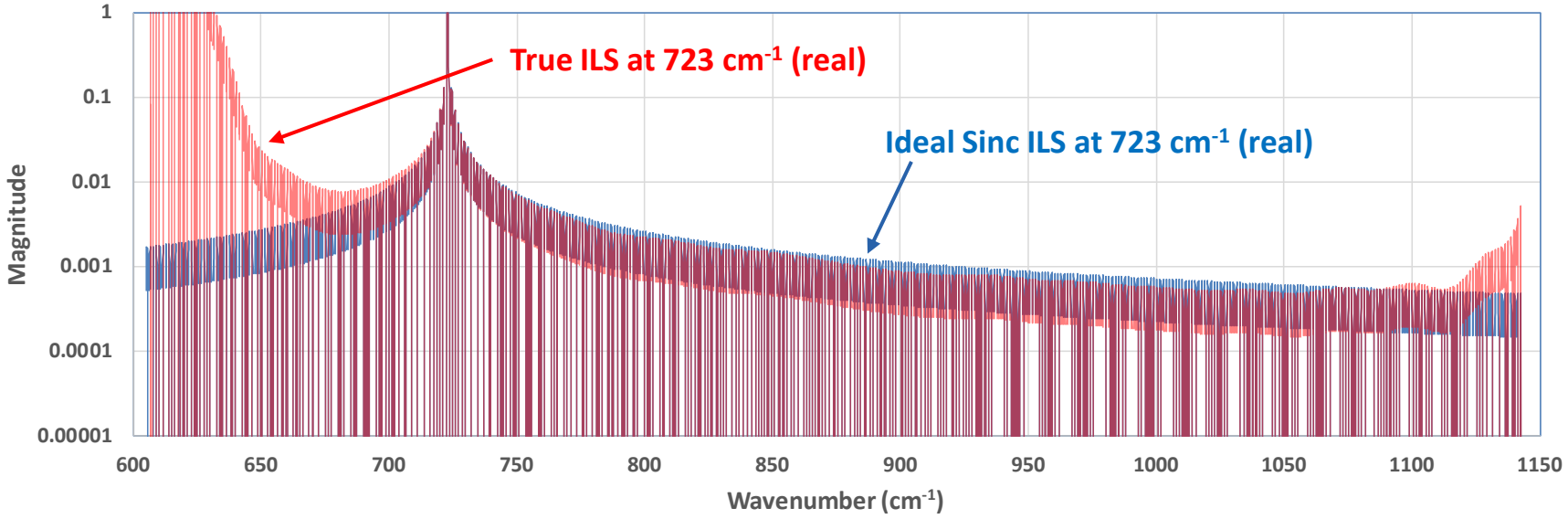






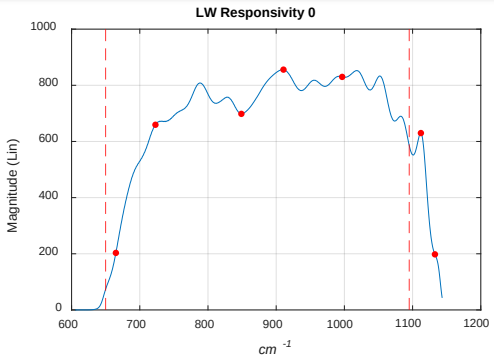
Broadband ILS Comparison at 723 cm^{-1}
(Complex ILS if Phase Correction Not Performed)





True CrIS ILS Sidelobe Error Relative 30 mK Brightness Error

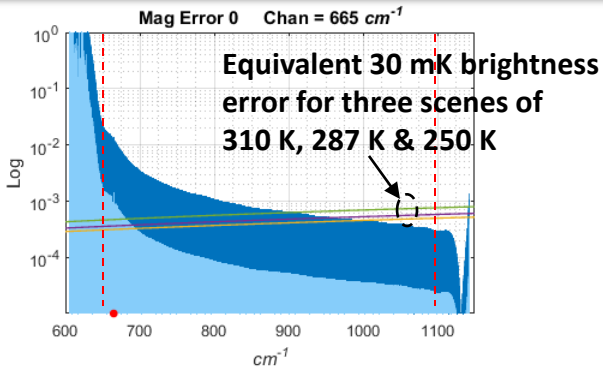
(Phase corrected – 7 Channel Centers – Unapodized & Hamming Cases)



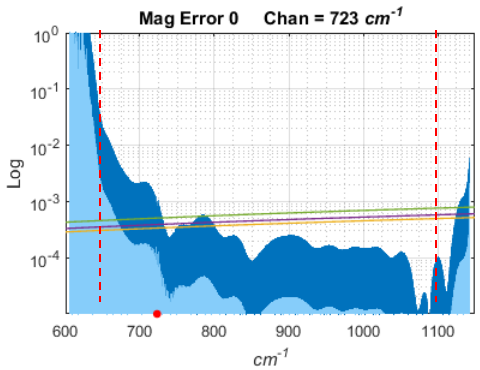
LWIR Band

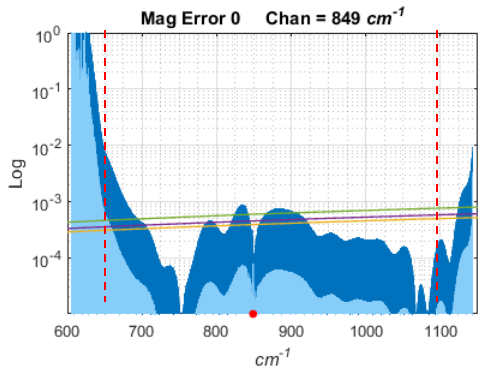
Unapodized

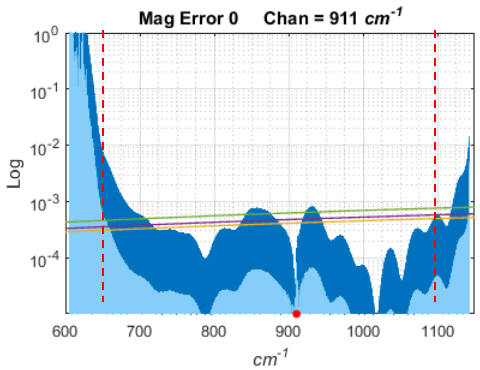
Hammming

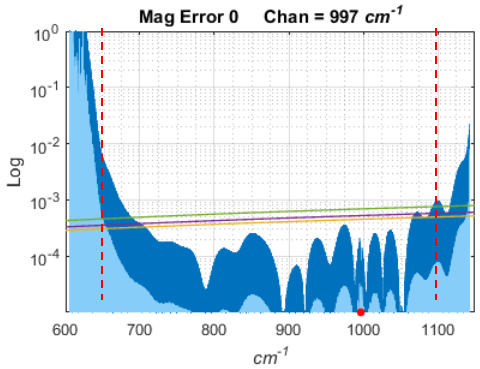


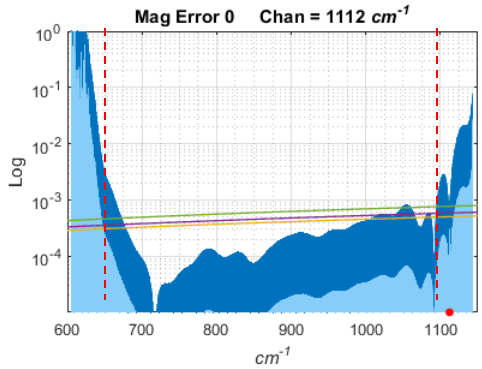
Equivalent 30 mK brightness error for three scenes of 310 K, 287 K & 250 K

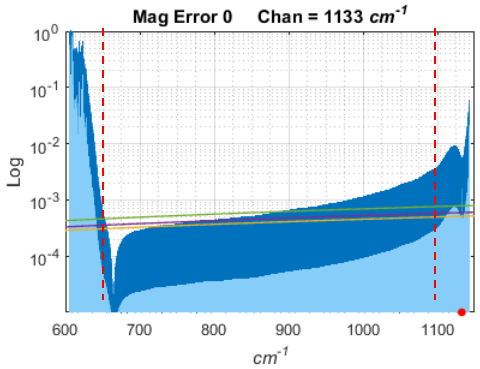






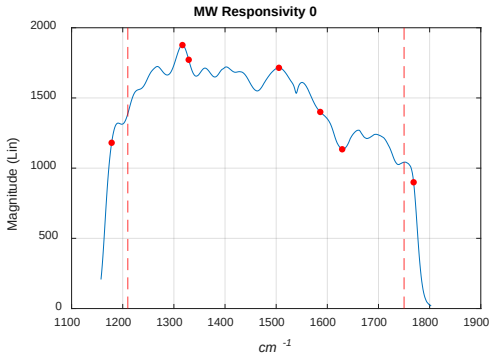






True CrIS ILS Sidelobe Error Relative 30 mK Brightness Error

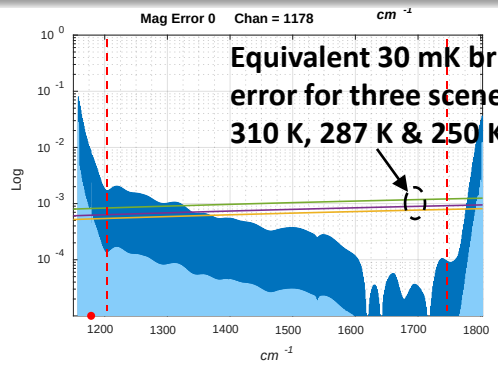
(Phase corrected – 7 Channel Centers – Unapodized & Hamming Cases)

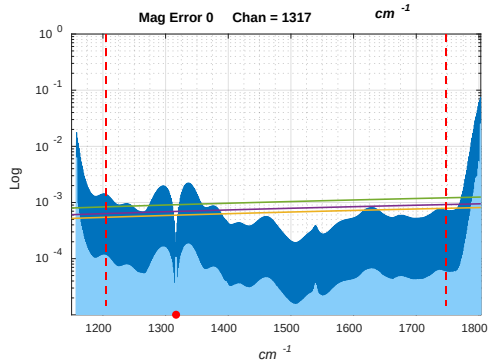


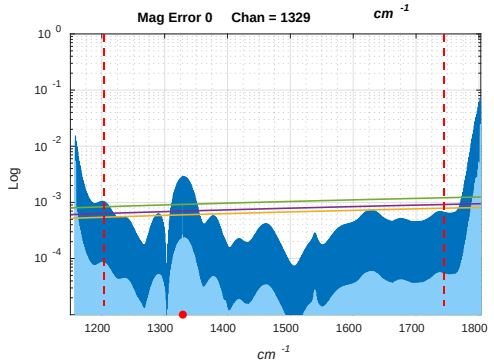
MWIR Band

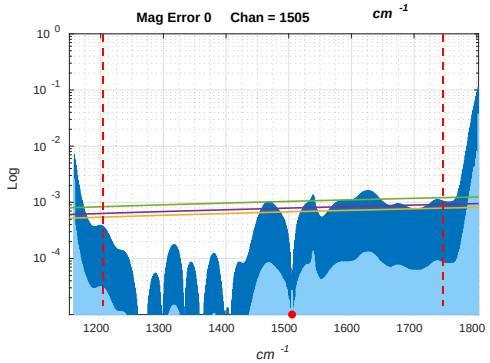
Unapodized

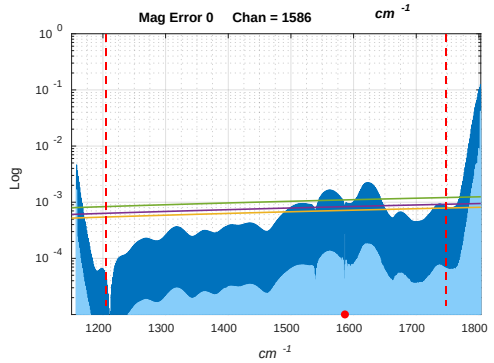
Hammming

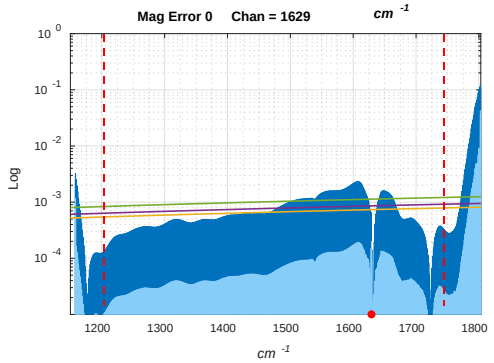


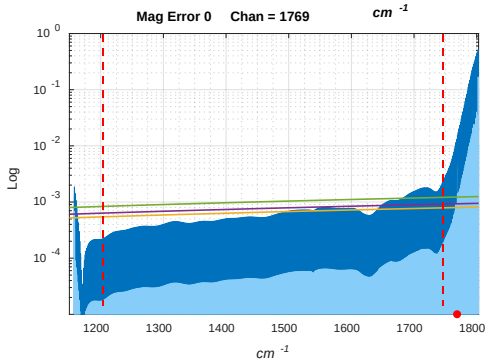






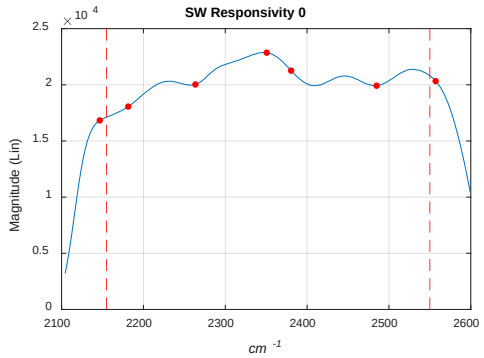






True CrIS ILS Sidelobe Error Relative 30 mK Brightness Error

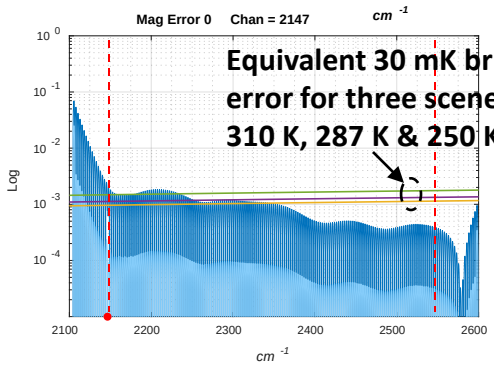
(Phase corrected – 7 Channel Centers – Unapodized & Hamming Cases)

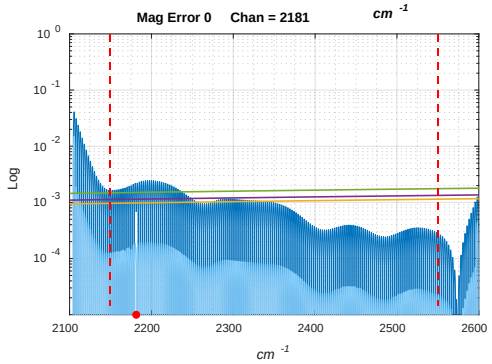


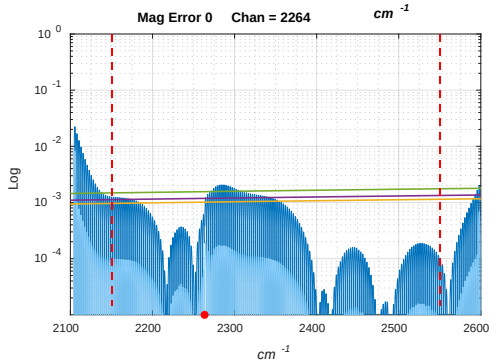
SWIR Band

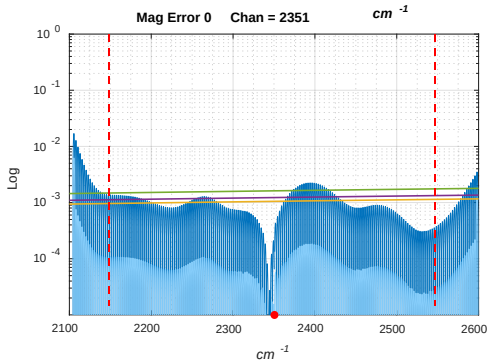
Unapodized

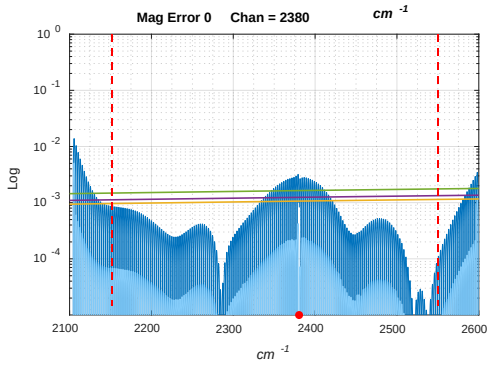
Hammming

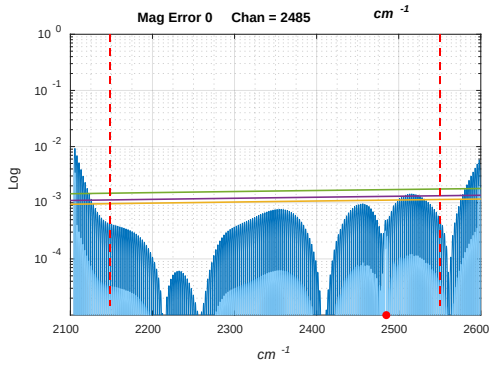


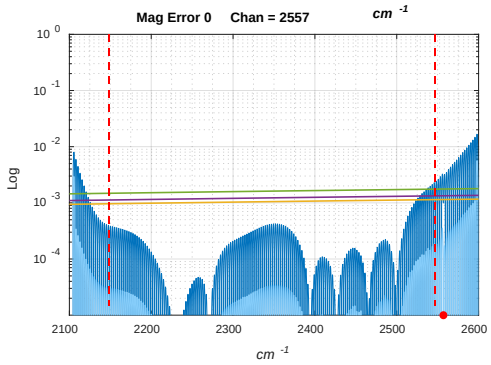












Conclusions

- Phase correction prior to spectral correction makes the CrIS ILS sweep direction independent
- Fully calibrated CrIS SDR has ILS sidelobe response that even under best conditions deviates from an ideal Sinc ILS ("True ringing")
- Hamming apodization brings the "True Ringing" error below an equivalent 30 mK brightness temperature ILS sidelobe error for all earth scene temperatures 250 K – 310 K in the MWIR & SWIR bands & over all LWIR wavenumbers (except 650 – 680 cm^{-1})
- True ringing can be compensated at SDR output & in forward EDR model by multiplying spectrum by the CrIS responsivity magnitude
  - If this is done, Hamming apodization is not needed to meet a 30 mK brightness temperature knowledge error threshold for ILS sidelobes