"True Ringing" Artifacts in Unapodized FTS Measurements

Aronne Merrelli, David Tobin, Robert Knuteson,
Thomas Greenwald, and Hank Revercomb

Space Science and Engineering Center and Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison

Methods to simulate Fourier Transform Spectrometer (FTS) measurements from line-by-line radiative transfer model spectra typically apply a band-limiting function to the high resolution spectrum. We recommend using the actual measured spectral responsivity of the instrument as the band-limiting function, in order to introduce "true ringing" in the simulated measurement that accurately represents the real measurement.

Basic algorithm for simulating FTS from LBL spectra

1. Interpolate monochromatic spectrum to evenly gridded wavenumber scale, covering [0, v_max] and evenly dividing the FTS sampling interval
2. **Multiply monochromatic spectrum by band limiting function**
3. Compute discrete fourier transform to get "monochromatic interferogram"
4. Truncate interferogram at FTS maximum optical path difference
5. Compute inverse discrete fourier transform to get spectrum at FTS resolution
6. **Divide by band limiting function if needed**
7. Extract values at desired FTS sampling interval

The band limiting function: What shape should be used?
The choice of band limiting function is arbitrary. Common examples include:

- Analytic function to taper out-of-band spectra (gaussian, raised cosine)
- Small region of "padding" around FTS band – 50 cm^{-1}

Definition of True Ringing

Two FTS simulated with different band limiting functions will show different ringing artifacts: positive and negative oscillations at every other sampled point.

In order to compare the different band limiting methods, we define a new term, the "True Ringing": this is the ringing artifact present in the FTS spectrum obtained when the sensor responsivity is used as the band limiting function.

We argue that using the sensor's spectral responsivity yields a more accurate representation of the true measurement and removes the arbitrary choice of the band limiting function.

Here we examine the "True Ringing" artifact for the Cross-track Infrared Sounder (CrIS), and compare it to the ringing artifact present for two possible choices for an analytic band limiting function.

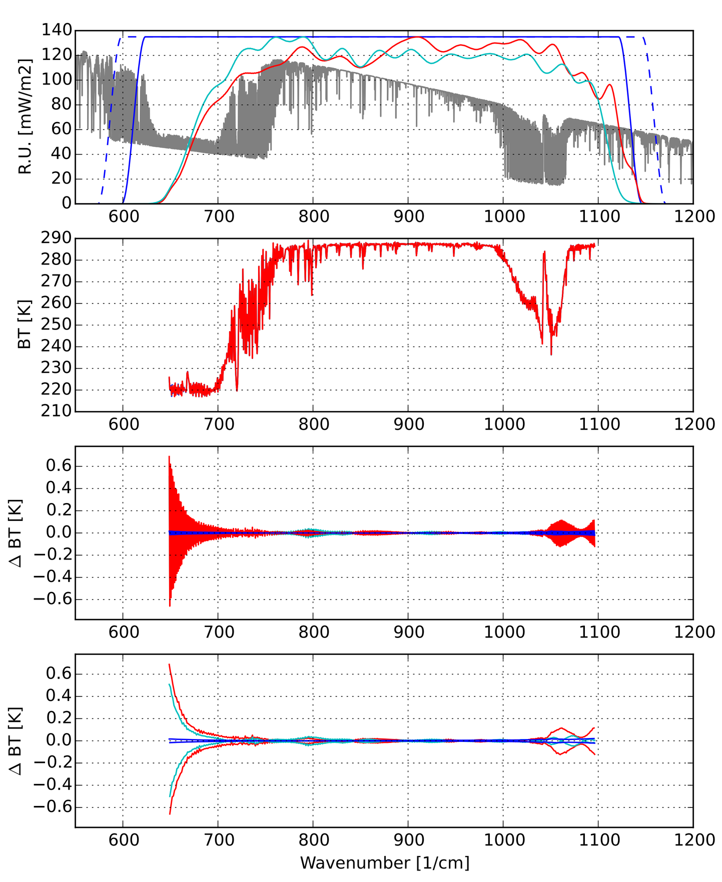
Example: LW CrIS simulation

Monochromatic spectrum (gray), two raised cosine tapers with different separation from CrIS channels (blue: 25 cm^{-1}, blue dashed 50 cm^{-1}) and the measured spectral responsivity for the CrIS LW band (red – SNPP; cyan – JPSS1)

Simulated CrIS LW spectra using various band limiting functions (colors as above)

Ringing artifacts: sensor responsivity minus cosine taper; difference between cosine tapers

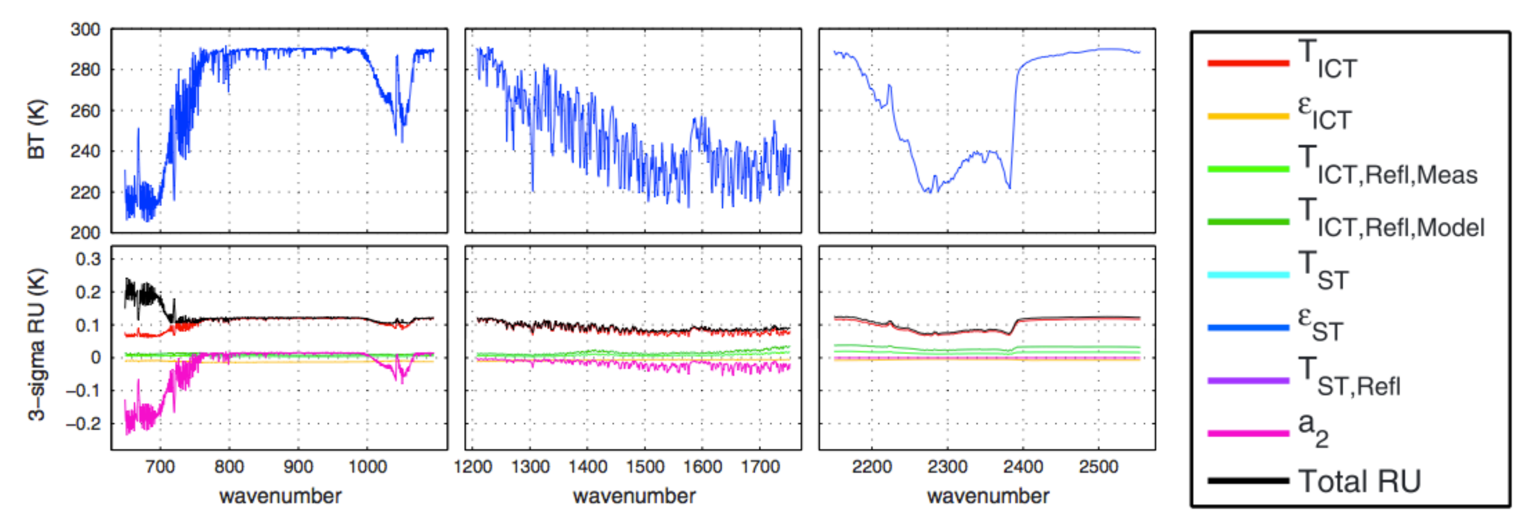
Ringing artifact envelopes: to more easily visualize the different artifacts, plot "every-other-point" as a separate line



Comparison to Radiometric Uncertainty (RU)

The absolute Radiometric Uncertainty (RU) for CrIS is shown below.
The uncertainty is spectrally dependent, but usually in the range 0.1 – 0.2 K

The RU estimate does not include a term for ringing artifacts, which can create bias in the measurements if not correctly modeled. This bias is often larger than the RU (for example, the longwave band edge of the CrIS longwave spectrum)



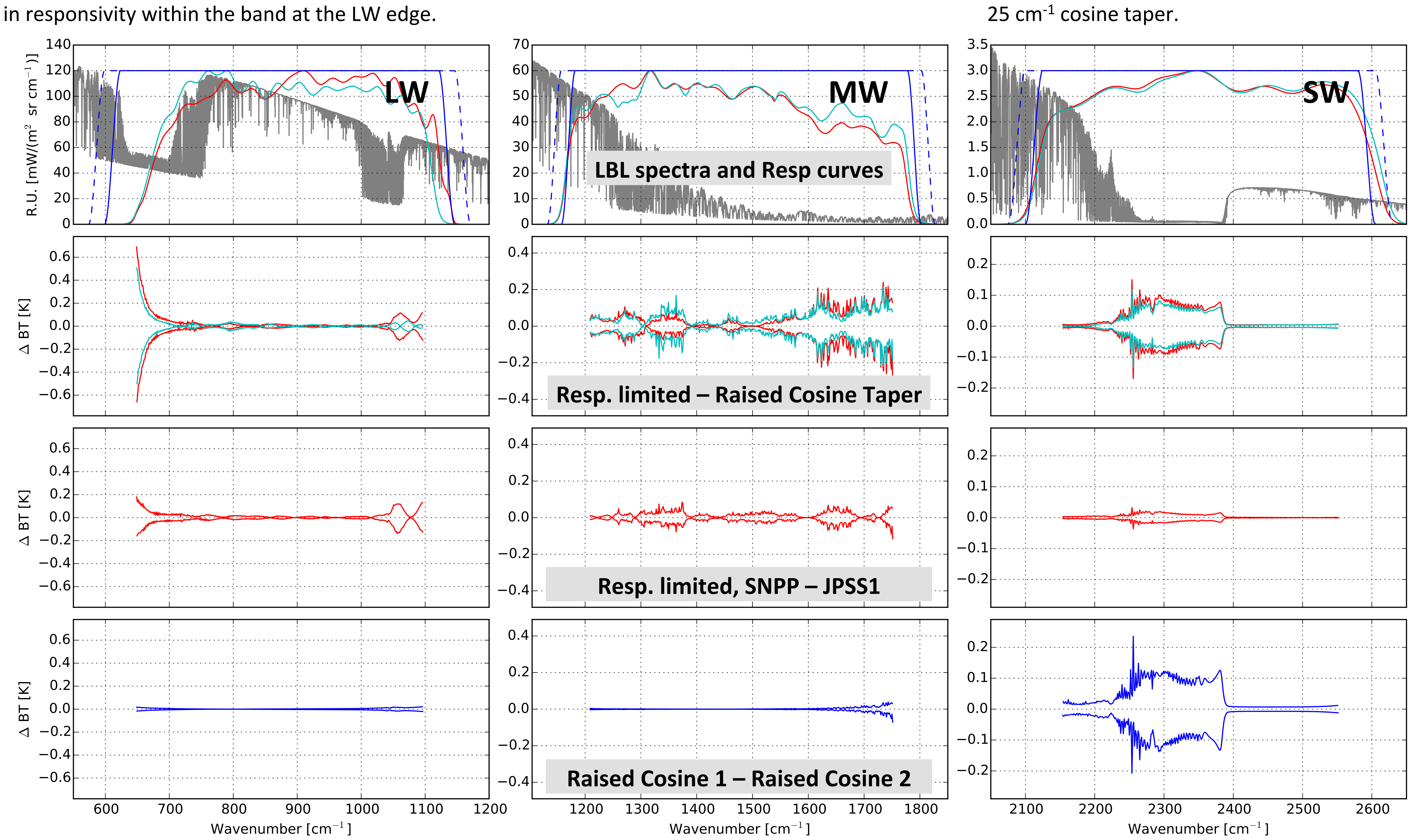
From Figure 8, *Tobin et al.*, JGR, 2013

Results for Full Spectral Resolution CrIS: Comparing the "True Ringing" for SNPP and JPSS1 to spectra simulated with a cosine taper

LW Band: "True Ringing" > 0.5 K at band edge, very different shape from raised cosine. Note large change in responsivity within the band at the LW edge.

MW Band: "True Ringing" envelope > 0.1 K in absorption lines.

SW Band: Difference between cosine tapers is larger than the "True Ringing" relative to 25 cm^{-1} cosine taper.



Reference: *Tobin et al.*, "Suomi-NPP CrIS radiometric calibration uncertainty"
JGR Atmospheres, 2013. doi:10.1002/jgrd.50809

Corresponding author address:
Aronne Merrelli, aronne.merrelli@ssec.wisc.edu

Space Science and Engineering Center
1225 W Dayton St., Madison, WI 53706