Noise Filtering of the Enhanced MODIS Airborne Simulator LWIR Bands

E. Hildum, H. Su, R. Dominguez, J. Myers (UC Santa Cruz/NASA Ames Research Center)

INTRODUCTION

A new cryo-cooled infrared spectrometer was flown on the Enhanced MODIS Airborne Simulator (eMAS) onboard the ER-2 during the SEAC4RS experiment. Several strong coherent noise artifacts are evident in the twelve LWIR bands of eMAS (6.7 - 14um region) in the data collected, which are traced by laboratory measurements to electromagnetic noise emitted by the eMAS Stirling cooler motor (Figure 1.) Most of the noise frequency content is at the motor drive frequency of 60Hz and at its first harmonic at 120Hz. Relative amplitudes of the two components change depending on motor power. The fundamental frequency of the motor is controlled by a crystal clock, as is the scanner pixel sampling. The noise terms are sinusoidal in character. If the precise frequency, amplitude and phase of the two noise terms can be determined, they can be subtracted from the raw data without suppressing real image content at the same spatial frequencies.

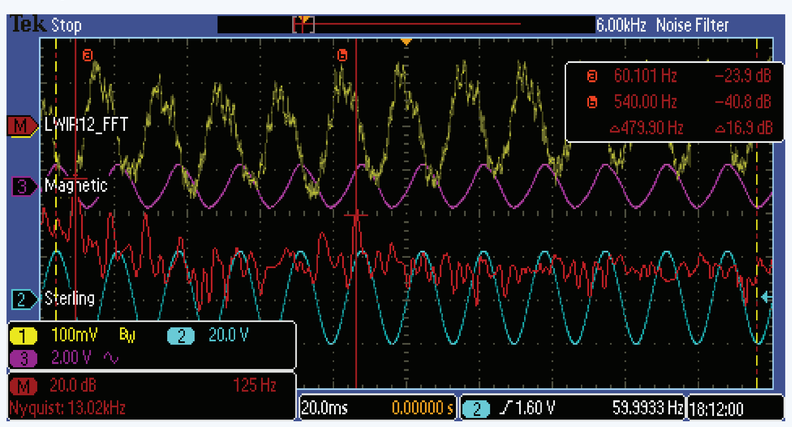

Figure 1: Laboratory EMI Measurements (eMAS Band 30 - 6.7um)
Yellow: LWIR12 Detector Signal (Band 38, 13.9um); Purple: Magnetic field measured near Sterling
Red: FFT; Blue: 60Hz sine wave from sterling driver

METHODOLOGY

Fourier analysis of single scan lines does not have sufficient resolution to separate noise terms from scan frequency harmonics. Extending the data set duration to include many (thousands of) scan lines provides sufficient resolution, but requires dealing with a non-continuous data stream: video data is only recorded for about 1/4 of the scan duration. Also, because pixel sampling is not at a constant frequency (it varies with scan motor speed), the fast-Fourier algorithm is not applicable. A discrete Fourier-like analysis gives reasonable results: visual inspection of the image data is nearly free of noise artefacts and temperature retrievals compare well with other measurements.

For each frequency in a small range about the known interference terms, we compute a point in the correlation function with a sine and cosine wave. In each scan line, we only include samples within an integer number of sine wave periods. Data sets of 2000-4000 scan lines seem to give the best compromise between resolution and problems caused by slow drifts of other parameters (e.g. thermal drift of the crystal oscillators and effort exerted by the Stirling motor). This procedure generates a narrow frequency spectrum about the target region. Fitting a Gaussian line-shape to the top of the noise peaks determines their center frequencies. Using the average of these frequencies, and assuming the 120Hz term is an exact harmonic of the 60Hz term, the sine and cosine correlation function is computed at the average frequency. This gives frequency, phase and amplitude for two waves for each spectral channel, which we then subtract from the raw data (Figure 2.) This filtering technique will be applied to all of the eMAS Level-1B SEAC4RS archive data. There is some residual coherent noise in the system at 540 Hz which appears to be unrelated to the Stirling motor, and is not addressed by this process; however the resulting reduction in NEdT in the IR bands is significant (Figure 3.) Elimination of this 540 Hz artifact would further improve the NEdT figures.

ONGOING WORK

Modifications to the instrument are underway jointly with the Utah State Space Dynamics Laboratory, who built the new IR spectrometer, to mitigate this problem. They will include a redesign

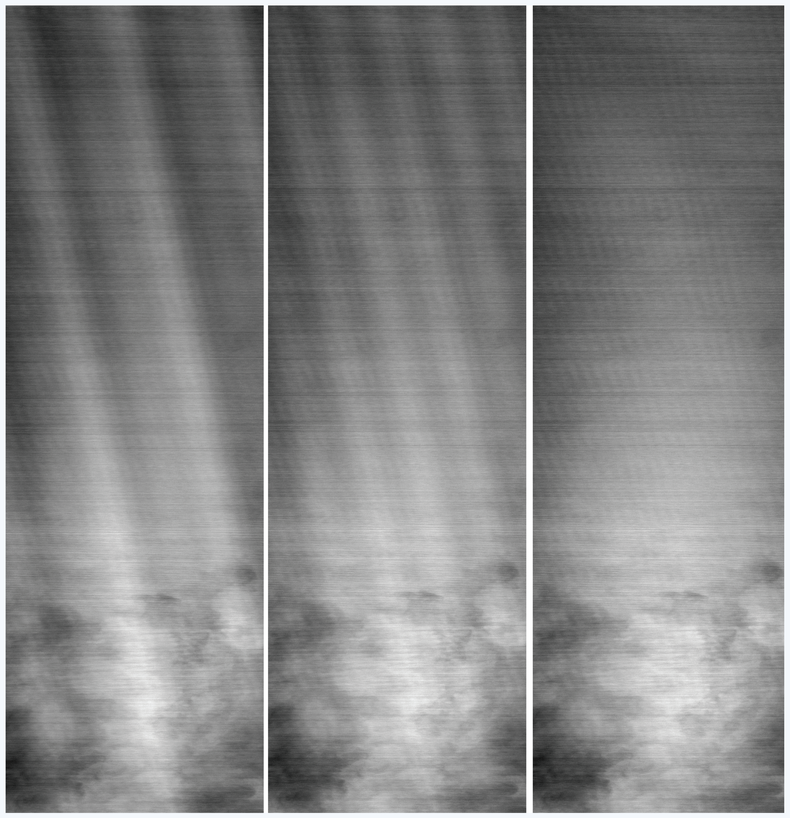

Figure 2. Noise Removal Progression (L.: Raw Data, C.: With 60 Hz Removed, R.: With 60 & 120 Hz Removed. (Note: some residual high frequency noise is not addressed)
eMAS Band 30 (6.7um) 13 Sept. 2013, 18:32 Z

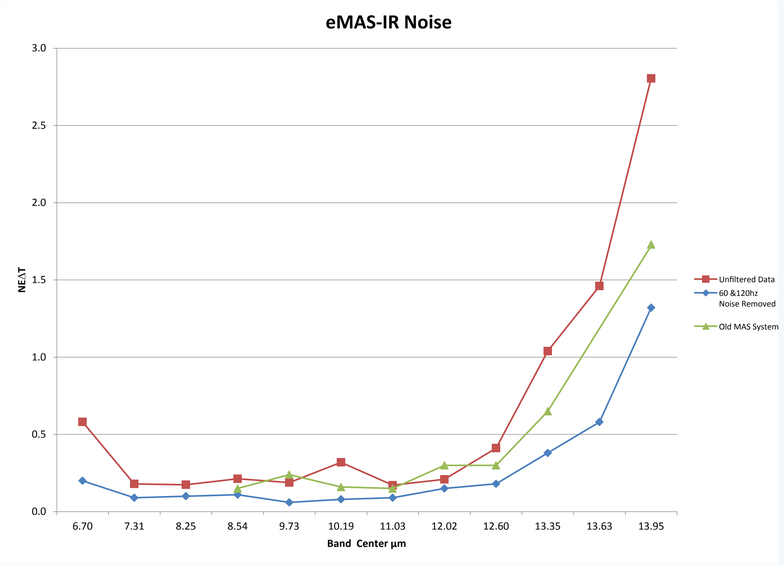

Figure 3. eMAS LWIR NEdT Values with and without Stirling noise artifacts, and legacy LN2-cooled MAS system.

of the analog preamplifiers and power supplies to reduce noise susceptibility, and the further incorporation of Mu-metal shielding at critical points inside the cooled optical bench. The smaller 540 Hz noise artifact, believed to be vibration related, is also being investigated.