Special Projects in Radiometry (SPIR) is a division dedicated to providing turnkey systems in spectral radiometry and optical remote-sensing instrumentation. Our team includes over 80 highly qualified engineers, scientists and technicians.

Expanding ABB Bomem's excellence in building state-of-the-art instru

- Optical instruments for use on aircrafts, balloons or satellites
- Hyperspectral imagers
- Optical calibration systems
- Software for data processing and instrument modeling

Correction of Non-Linearity in FT Remote Sensing Instruments

Mercury Cadmium Telluride (MCT) photoconductive infrared detectors offer state-of-the-art performance in the LWIR spectral range (5-16 µm). These detectors are often used in the manufacture of spectroradiometers that operate in the LWIR atmospheric window (8-12 µm) for remote sensing of distant targets at very low radiance emissions. They offer impressive sensitivity, allowing high resolution spectral measurements of wide ranges of targets at moderate temperatures. However, the non-linearity associated with these detectors causes significant radiometric errors in quantitative spectroscopic measurements.

In Fourier Transform spectroscopy, this non-linear response gives rise to a change of effective responsivity with flux, and also creates undesirable spectral artifacts that cannot be corrected by simple scaling.

ABB has developed an advanced method for correcting non-linearities in an MCT detector and the associated electronics of a Fourier transform spectroradiometer. The method consists of a signal processing approach computed in software on measured interferograms. All it needs is the two standard calibration measurements, plus one supplementary measurement of calibrated blackbody in the expected temperature range.

The ASCM Non-Linearity Correction Algorithm

The non-linearity correction method developed by ABB is designated as the *Adaptive Scaling Correction Method (ASCM)*. It is based on original interferogram measurements that are corrected while processing data generated by the instrument, before the calibration equations are applied. The non-linear behavior is modeled by a series expansion. The essential feature of the algorithm is an iterative characterization step that extracts the non-linear coefficients describing the non-linear response of a given detector, based on hot, cold, and intermediate measurements (one each) of a blackbody reference. Once the system has been characterized, the computed set of coefficients is applied for purposes of correcting any subsequent measurements of the same detector operating under similar conditions. The method has been tested on an ABB MR200, and various results obtained are discussed below.

Since the ASCM has proved to work independently of field stop size, it can be applied for any subsequent range of incident fluxes. This is because the characterization step leads to a transfer function directly relating non-linear and linear fluxes. The method therefore enables correction for a wide range of blackbody calibration and scene temperatures that can depart significantly from those used during other processes, such as characterization.

Short-Range MCT Experimental Results

Figure 1 depicts the calibrated spectrum of a blackbody measurement at 600°C, using a classic two point calibration with cold and hot calibration references of 300°C and 900°C respectively. The dashed line in this figure represents the theoretical blackbody distribution at measurement temperature. A large radiometric error is evident when no non-linear correction is performed. This discrepancy leads to a mean relative error of 18%, linearity of the MCT detector. This type of error is not generally present with measurements made, for example, using an InSb detector.

Figure 2 presents the same calibrated spectra following non-linearity correction that is computed on the displayed wavenumber range. It is evident that the spectrum distribution now closely matches that of the theoretical blackbody distribution, as indicated by the mean relative error of 0.15 % over the entire given range.

The ASCM correction has proved to be transferable at other field stop openings and at other correction temperatures besides those used during characterization.

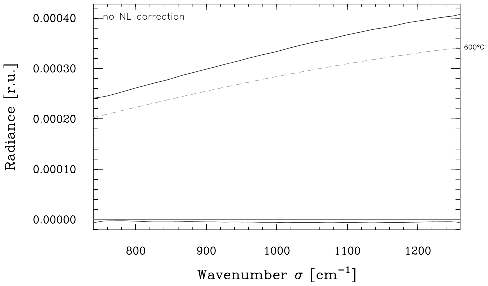

Figure 1: Calibrated spectrum at *T*=600ºC with respect to theoretical blackbody at same temperature. <*E*>=18.0%

Wide Range MCT Experimental Results

Other tests were conducted using a wide band MCT detector. Correction for such a detector is more difficult to achieve, especially because of the spectral artifacts that are superimposed over the entire spectral range. As an example, a large radiometric error of 23.6% is observed in Figure 3, where computations are made using the same reference temperatures as in the short range example and with a field stop opening of 9.4 mm. The vertical lines plotted in the spectrum define H^2O and CO^2 regions where absorption lines distort the spectrum.

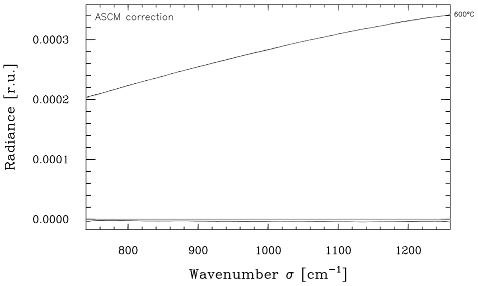

Figure 2: Calibrated and NL-corrected spectrum at *T*=600ºC. <*E*>=0.15%

Figure 4 depicts the calibrated spectrum of a blackbody at 800°C, measured at a smaller field stop opening (4.5 mm) and using the same cold and hot calibration references at 600°C and 900°C respectively. The residual mean radiometric error is reduced to 0.57%.

A number of correction coefficient transferability tests were conducted for cases of varying calibration temperatures, filed stop openings, and spectral optimization ranges. The transferability has been shown to be somewhat less accurate than with the cold filtered narrow band MCT detector. However, reduction of the radiometric error by factors ranging between 2 and 10 was observed. The exact improvement obtained depends greatly on the combination of the above referenced experimental conditions and the selected spectral range.

Other tests were performed using a propane flame in order to verify the ASCM's efficiency when applied to non-blackbody measurements. These tests confirmed that this method can be used to successfully characterize a given detector and correct the non-linearity of any subsequent measurements in predetermined ranges.

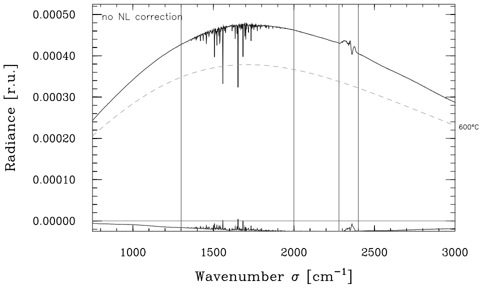

Figure 3: Calibrated spectrum at *T*=600ºC with respect to theoretical blackbody at same temperature. <*E*>=23.6%

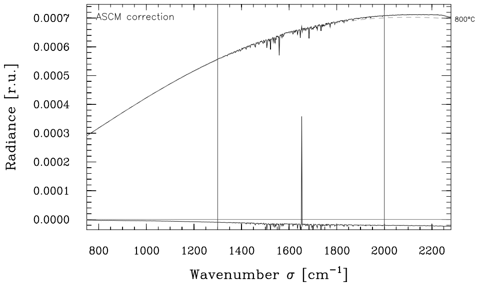

Figure 4: Calibrated and NL-corrected spectrum at *T*=800ºC. <*E*>=0.57%

To summarize, we have derived an algorithmic method by which non-linearities in a spectrometer can be compensated for and that also offers significant correction accuracy while requiring relatively low resources and little time. Experimental results obtained in the case of a cold filtered MCT detector have shown that the relative radiometric error of photoconductive MCT detectors can be brought into the same range as that of the accuracy obtained with InSb detectors. Similar results have been obtained in tests using a wideband detector, with appropriate spectral range selection within the detector limits.

ABB Bomem Inc.
585 Charest Blvd. East, Suite 300
Québec City, Quebec G1K 9H4 Canada
Phone: 418-877-2944
North America: 800-858-3847
Fax: 418-877-2834
E-mail: ftir@ca.abb.com