

## Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Onboard Calibration System

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The AVIRIS instrument uses an onboard calibration system to provide auxiliary calibration data. The system consists of a tungsten halogen cycle lamp imaged onto a fiber bundle through an eight position filter wheel. The fiber bundle illuminates the back side of the foreoptics shutter during a pre-run and post-run calibration sequence. The filter wheel contains two neutral density filters, five spectral filters and one blocked position. This paper reviews the general workings of the onboard calibrator system and discusses recent modifications.

### INTRODUCTION

AVIRIS is an airborne sensor which measures high spatial resolution image data of the earth in 224 spectral channels in four spectrometers (A, B, C, and D) covering the range from 380 to 2500 nm. These data are spatially, spectrally and radiometrically calibrated (Vane, 1987, Chrien 1990, Chrien 1993b). Modifications to AVIRIS have resulted in substantial improvements in signal-to-noise ratio, calibration accuracy and operability of the sensor (Chrien, 1991, Chrien 1993a). Validation experiments are conducted to verify instrument performance and calibration in flight (Green, 1993a). The onboard calibration data can be used to correct for variations in the AVIRIS radiometric response (Green 1993b). Recent modifications to the onboard calibration system are discussed.

### CALIBRATION REQUIREMENT

Imaging spectrometers are used to measure the contiguous spectral signature of the upwelling radiance reflected and emitted from the surface of the earth and its atmosphere. The information contained in this data is in general a non-linear mixture of atmospheric molecular absorptions and particle scattering signatures, surface reflected molecular absorption signatures and bidirectional reflectance properties and source spectral characteristics such as solar spectral radiance and surface temperatures. The scientific study of any one of these effects requires a separation of these complex interactions.

The instrument calibration of an imaging spectrometer removes an additional (and unnecessary) complication to the non-linear unmixing problem discussed above. In general, the requirement for calibration accuracy is determined by the tolerance of unmixing algorithms to residual calibration errors. This tolerance decreases as the signal-to-noise ratio of an imaging spectrometer increases in order to avoid unmixing that is instrument calibration error limited.

Recent improvements in both the signal-to-noise ratio of the AVIRIS instrument and the unmixing algorithms applied to AVIRIS data have prompted a re-evaluation of its calibration requirements. Of primary interest are improvements to the current instrument radiometric accuracy of 5% absolute and spectral accuracy of 1 to 2 nanometers.

### ONBOARD CALIBRATION SYSTEM

In 1991 the onboard calibrator underwent a major modification (Chrien, 1991) that routed light into the four AVIRIS spectrometers by illuminating the back of the closed foreoptics shutter. A color balance filter (2 mm Schott KG-2) was installed to provide good detector response across the 224 spectral channels of

the sensor. An improved current stabilized lamp drive circuit was also installed. These changes greatly improved the utility of the onboard calibrator data to correct for residual drifts in the radiometric response of the sensor. Since that time a number of additional improvements have been made.

### End of Run Dark Images

The AVIRIS instrument now records 100 lines of dark imagery at the end of each run of data. The fore-optics shutter is closed during this time as it is during end-of-line dark measurements. It is expected that this dark image will provide a data set on which to base coherent noise level measurements and to enable the construction of coherent noise filters for the data. A high resolution counter (HRC) has been added to the engineering telemetry to measure the number of instrument clock cycles between successive lines (which varies due to roll correction). The high resolution counter provides a way to time code detector reads from line to line and may prove useful in filtering time dependent noise sources.

### Onboard Calibration Lamp

Prior to the 1994 flight season the OBC lamp was replaced with a 5000 hour rated lifetime bulb. Unfortunately, during the 1994 flight season the onboard calibrator experienced an excessive number of lamp failures. The first occurred just before shipping AVIRIS to Ames. Two other failures occurred during the flight season. These failures occurred at a fraction of the 5000 hour life of the bulb. Upon visual inspection, no fracture or burn-through of the filament was visible, and indeed, the second lamp that failed in AVIRIS lit right up in the lab.

The failed bulbs were returned to the manufacturer for autopsy, and the cause of failure was found to be degradation of the pigtail-wire-to-lamp-pin crimp-weld connections owing to corrosion. The corrosion arose from chemical byproducts from the heat degradation of shrink tubing placed over the crimp-welds before the lamp was potted in its metal base. This corrosion caused the wire-to-pin connections to rise in resistance beyond what the OBC constant-current power supply could handle (owing to an upper limit on the voltage it was able to supply to the bulb and wires combination), and hence the bulbs failed to light. The bulb intensity was probably unstable for some time before the resistance due to the crimp-weld rose so far as to preclude the lamp from lighting at all.

The corrosion explanation fit well with the observed lamp behavior before failure, and with lamp "filament" resistance measurements after failure. The manufacturer uses teflon tubing for all its higher-wattage lamps, but for this 10 watt lamp typical electronic-cabling-variety shrink tubing was used. The manufacturer did not foresee the lamp base getting very hot, but we had taken steps to make sure that the lamp did get to at least 250 degrees C in order to keep the lamp's internal halogen cycle effective and hence maximize the life and the light output stability of the bulb. The manufacturer has fabricated new lamps for the AVIRIS OBC application which incorporate the high temperature tolerant teflon tubing around the crimp-welds. We expect these to survive our nominal operating temperature.

Also included in this year's changes is a conversion from a constant-current power supply to a constant-light-output power supply. We have mounted a silicon photodiode/amplifier hybrid (Model #UDT-455) on the top of the OBC lamp housing. The lamp filament is imaged onto the photodiode active area through a 543nm narrow-pass filter. The resulting signal is fed back to the lamp power supply to maintain constant light output from the bulb.

Currently an investigation of lamp stability over operating temperature is underway. Historical data show that the temperature internal to the OBC remains between 20° C and 30° C over the course of a flight season. Narrow-banding the light hitting the detector minimizes the effect of the silicon photodiode's spectrally-dependent responsivity drift with temperature.

### Spectral Calibration Filters

Four new spectral filters have been designed for the onboard calibration source filter wheel. The filter wheel has been modified to accommodate the additional filters. The new filters consist of a birefringent material sandwiched between linear polarizers to make a single stage Lyot filter. The transmission of a Lyot filter varies as the cosine squared of one over the wavelength depending on the filter retardance. The four filters are designed to have a period of approximately 20 nanometers at the short wavelength end of each AVIRIS spectrometer. This insures that there will be sharply sloping spectral features across the entire 0.4 to 2.5  $\mu\text{m}$  spectrum.

The spectral transmittance of the four filter set is shown in Figure 1. Measured data is shown for the first three filters which cover the 0.4 to 1.9  $\mu\text{m}$  range, while the predicted performance is shown for the fourth 1.7 to 2.5  $\mu\text{m}$  filter. A temperature sensor placed on the filter wheel housing updates the engineering telemetry once per second with a 0.3°C precision.

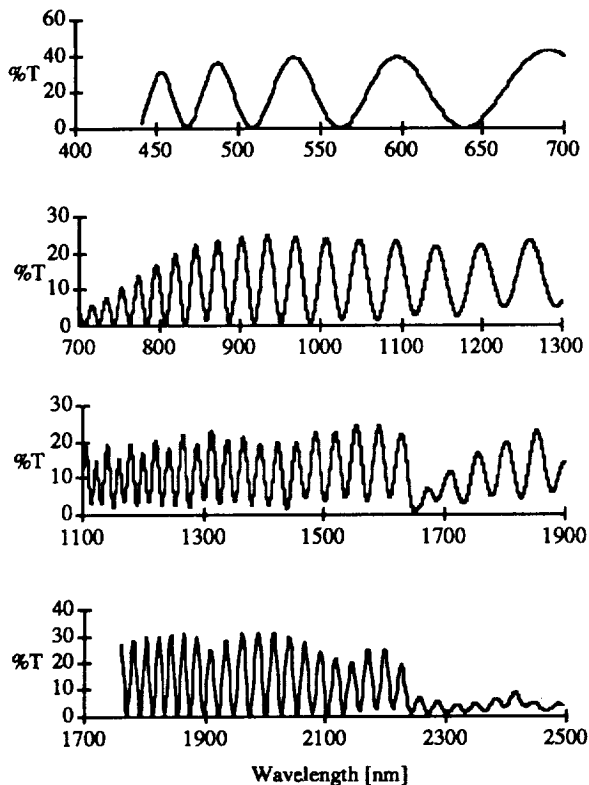


Figure 1. Lyot spectral calibration filter set

The data from the onboard calibrator is converted to spectral transmittance by dividing the Lyot minus Dark filter wheel spectra by the High minus Dark spectra. The sharply sloping transmittance features provide high sensitivity to spectral shifting inflight. Preliminary analysis shows that a 0.1 nm shift in spectral response is detectable using these filters.

### REFERENCES

- Chrien, T. G., R. O. Green, and M. L. Eastwood, "Accuracy of the Spectral and Radiometric Laboratory Calibration of the Airborne Visible/Infrared Imaging Spectrometer", Proc. SPIE Conference on Aerospace Sensing, Imaging Spectroscopy of the Terrestrial Environment, Orlando, Florida, 16-20 April, 1990.
- Chrien, Thomas G., Michael L. Eastwood, Charles M. Sarture, Robert O. Green, and Wallace M. Porter, "Current Instrument Status of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)", Proc. Third AVIRIS Workshop, JPL Publication 91-28, Jet Propulsion Laboratory, Pasadena, CA, pp. 302-313, 1991.
- Chrien, Thomas G., R. O. Green, "Instantaneous Field of View and Spatial Sampling of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)," Summaries of the Fourth Annual JPL Airborne Geoscience Workshop, JPL Publication 93-26, Vol. 1, Jet Propulsion Laboratory, Pasadena, CA, 1993a.
- Chrien, Thomas G., R. O. Green, C. M. Sarture, C. Chovit, M. L. Eastwood, and B. T. Eng, "Airborne Visible/Infrared Imaging Spectrometer (AVIRIS): Recent Improvements to the Sensor," Summaries of the Fourth Annual JPL Airborne Geoscience Workshop, JPL Publication 93-26, Vol. 1, Jet Propulsion Laboratory, Pasadena, CA, 1993b.
- Green, Robert O., James E. Conel, Mark Helmlinger, Jeannette van den Bosch, Chris Chovit and Tom Chrien, "Inflight Calibration of AVIRIS in 1992 and 1993," Summaries of the Fourth Annual JPL Airborne Geoscience Workshop, JPL Pub. 93-26, Vol. 1, Jet Propulsion Laboratory, Pasadena, CA, 1993a.
- Green, Robert O., "Use of Data from the AVIRIS Onboard Calibrator," Summaries of the Fourth Annual JPL Airborne Geoscience Workshop, JPL Publication 93-26, Vol. 1, Jet Propulsion Laboratory, Pasadena, CA, 1993b.
- Vane, Gregg, T. G. Chrien, E. A. Miller, and J. H. Reimer, "Spectral and radiometric calibration of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)," Proc. SPIE, 834, (1987).

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