Calibration Validation of the AVIRIS Portable Radiance Standard

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1.0 INTRODUCTION

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) is a spectrally, radiometrically, and spatially calibrated instrument (Green et al., 1998). The approach to AVIRIS calibration has evolved and been reported since the initial calibration in 1987 (Chrien et al., 1990, 1995, 1996). This paper reports the results of a comparison between the AVIRIS portable radiance standard and the Landsat transfer radiometer. This comparison was conducted in support of radiometric cross-calibration of the instruments used on the Earth Observer-1 (EO-1) program.

2.0 AVIRIS PORTABLE RADIANCE STANDARD

The AVIRIS portable radiance standard, shown in Figure 1, consists of a 1000-W calibrated, tungsten-coiled filament, quartz-halogen (GE type DXW) lamp, a 30-cm square Lambertian reflecting panel, and a mechanical fixture. The lamp is mounted vertically with the identification number down and facing away from the panel. The panel is also mounted vertically such that a normal line from the center of the panel intersects the center of the lamp filament. The distance between the center of the panel and the center of the lamp filament is 50.0 cm.

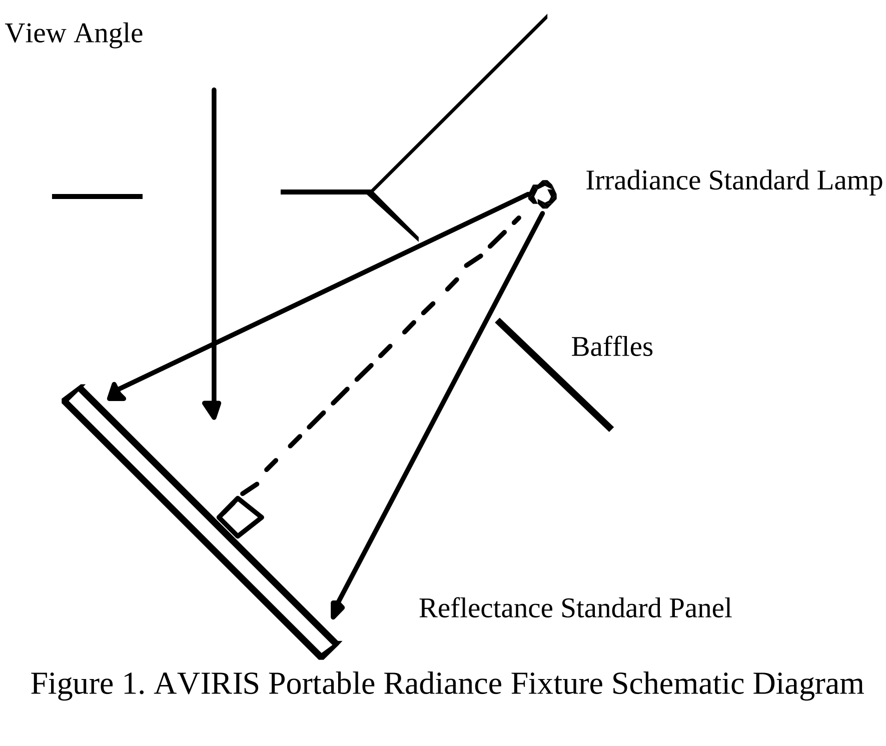

Figure 1. AVIRIS Portable Radiance Fixture Schematic Diagram

The fixture also holds a number of baffles which are designed to minimize the amount of indirect illumination of the panel. A shutter mechanism, which blocks the primary lamp-to-panel path, is used to assess any residual indirect light present. The typical ambient light correction term (light on the panel when direct path is blocked) is less then 1 percent of the total illumination from the lamp.

The panel is viewed at a 45-degree angle as shown in Figure 1. The spectral radiance, $L(\lambda)$, as viewed from this direction is computed from the lamp irradiance at 50 cm, $E(\lambda)$ and the panel reflectance, $R(\lambda)$, using equation 1.

$$L(\lambda) = E(\lambda)*R(\lambda)/\pi \qquad \text{Eq. 1.}$$

The lamp is purchased from a vendor who also provides a National Institutes of Standards and Technology (NIST) traceable spectral irradiance calibration. The spectral irradiance is sampled at a limited number of wavelengths. These points are spline interpolated to 1 nm spectral samples. Care is taken to avoid interpolation artifacts which can cause periodic errors in the splined data. The irradiance uncertainty is estimated from vendor data. Figure 2 shows the lamp irradiance at 50 cm and the associated irradiance uncertainty expressed as a percent. All vendor instructions for operation of the lamp are followed, including periodic verification of the lamp power supply output current of 8.0 A.

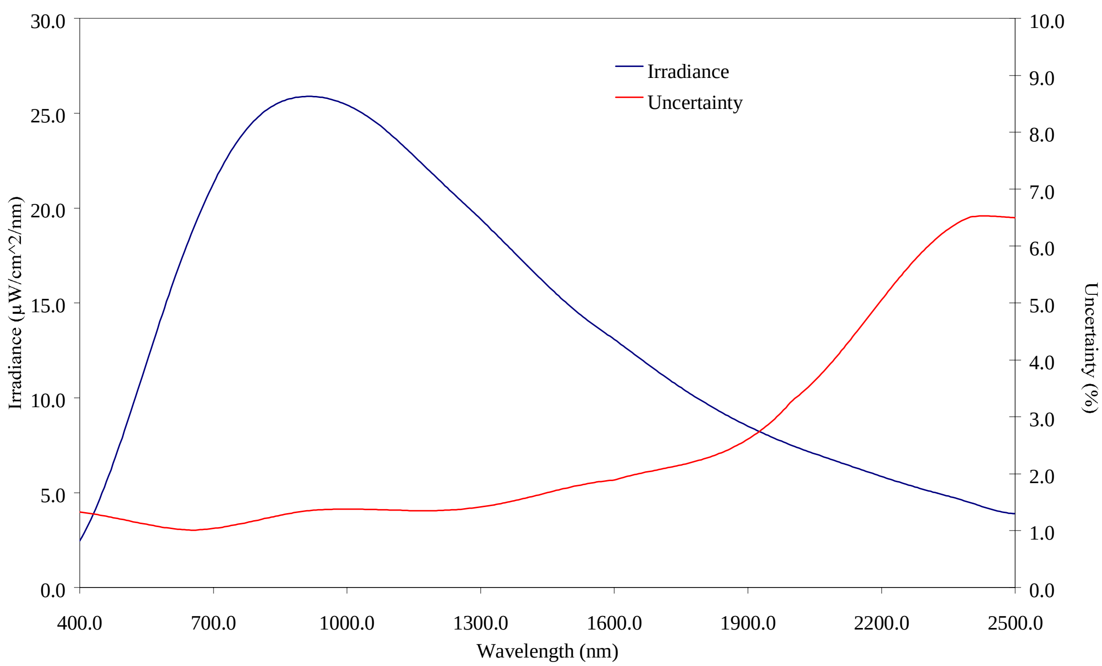

Figure 2. Spectrum of irradiance lamp source with uncertainty.

The panel is purchased from a separate vendor, which provides the panel spectral reflectance as measured using a {8°, hemispherical} Bidirectional Reflectance Distribution Function (BRDF) configuration. A correction factor of 1.01 is applied to the

{8°, hemispherical} reflectance to convert it to a {0°,45°} reflectance. The corrected reflectance is shown in Figure 3 with a vendor estimated reflectance uncertainty.

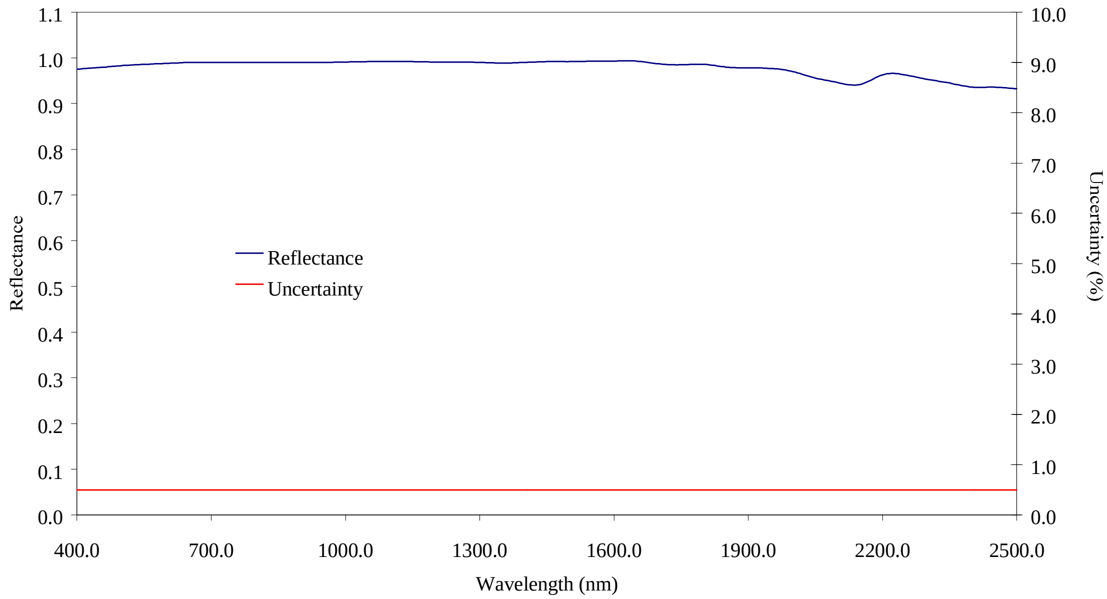

Figure 3. Panel reflectance as a function of wavelength, corrected to {0°, 45°} BRDF.

An additional correction term is used to compensate for non-uniformity in the panel irradiance field. The dominant source of radiance variation is from two effects. The first effect is a lamp-to-panel distance variation. The second effect is from a change in the projected angle across the panel. The non-uniformity correction term is determined by integrating the computed panel radiance across the field-of-view of the sensor as projected onto the panel. When the 10- by 18-cm AVIRIS aperture is pointed at the portable panel, the non-uniformity correction term is 0.977. Equation 2 shows how these terms are applied to compute the corrected radiance when using the panel to calibrate the AVIRIS instrument. Figure 4 shows the corrected panel spectral radiance with associated uncertainty prediction.

$$L_{corrected}(\lambda) = [0.977]*E(\lambda)*[1.01*R_{\{8°,\ Hemi\}}(\lambda)/\pi] \qquad \text{Eq. 2.}$$

The AVIRIS portable radiance standard has evolved over time to this form. While apparently simple, the exact design and position of the baffles are critical to the quality of the radiometric standard. In addition, the calculations of the radiance must be adjusted for (1) panel non-uniformity based as integrated over the area of the panel viewed by the instrument to be calibrated, and (2) view angles other than the computed {0°, 45°} BRDF view angle.

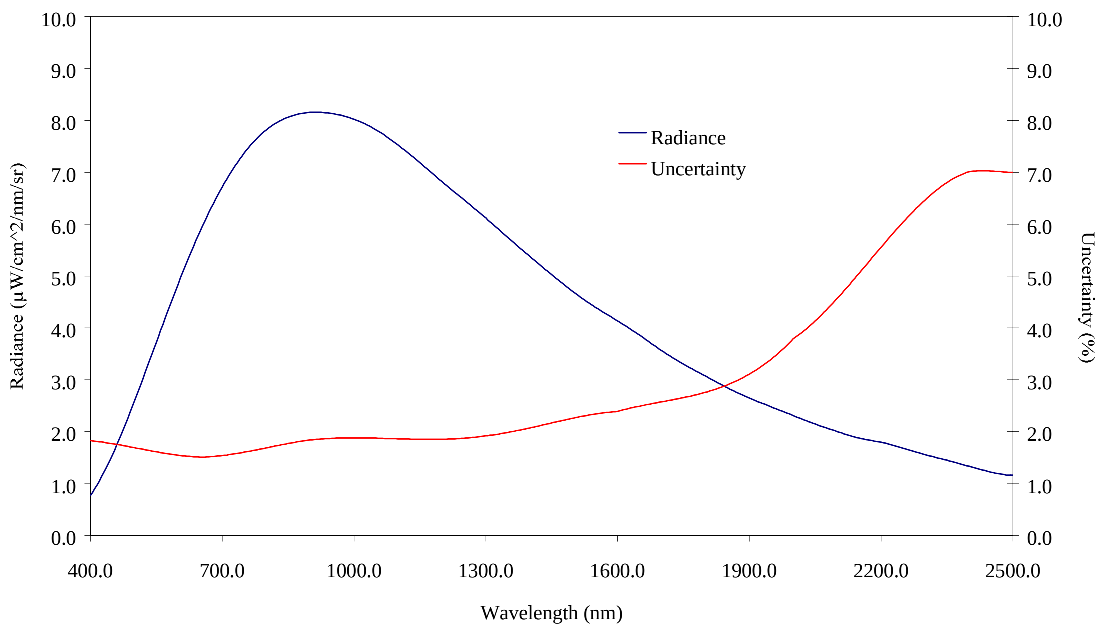

Figure 4. Spectral radiance from AVIRIS portable radiance standard with estimated uncertainty.

3.0 VALIDATION OF THE AVIRIS RADIOMETRIC CALIBRATION STANDARD

On June 30, 1999 the AVIRIS portable radiance standard was measured by the Landsat Transfer Radiometer (LXR) in support of a EO-1 cross-calibration exercise. The LXR is calibrated by NIST and was used to monitor the calibration of Landsat 7 during development (Markham, 1999). The LXR has six channels in the visible and near infrared portion of the spectrum. The spectral response and radiometric calibration of each channel is accurately known. For validation the LXR viewed the AVIRIS radiometric calibration standard. The radiance reported for each LXR channel was recorded.

In order to directly compare the LXR measured radiance and the spectral radiance of the AVIRIS portable radiance standard, the two must be placed on the same spectral scale. This is done using the spectral response curve of each of the LXR bands to weight the computed spectral radiance of the portable standard. This is shown in equation 3, where $L_{LXR\_channel\_N}$ is the radiance level expected in LXR channel N, and $R_{LXR\_channel\_N}$ is the spectral response of LXR channel N.

$$L_{LXR\_channel\_N} = \int_0^\infty R_{LXR\_channel\_N}(\lambda) L(\lambda) d\lambda \Big/ \int_0^\infty R_{LXR\_channel\_N}(\lambda) d\lambda \qquad \text{Eq. 3}$$

For LXR channel 1 the AVIRIS portable radiance standard agreed to 2.27 percent. Figures 5 to 10 show the comparison for LXR channels 2 through 6. Table 1 shows a summary of the results. Agreements ranging from 1.08 to 2.27 percent were found. This shows that the AVIRIS radiometric standard and the LXR are in accord at the 1 to 2 percent level in this portion of the spectrum.

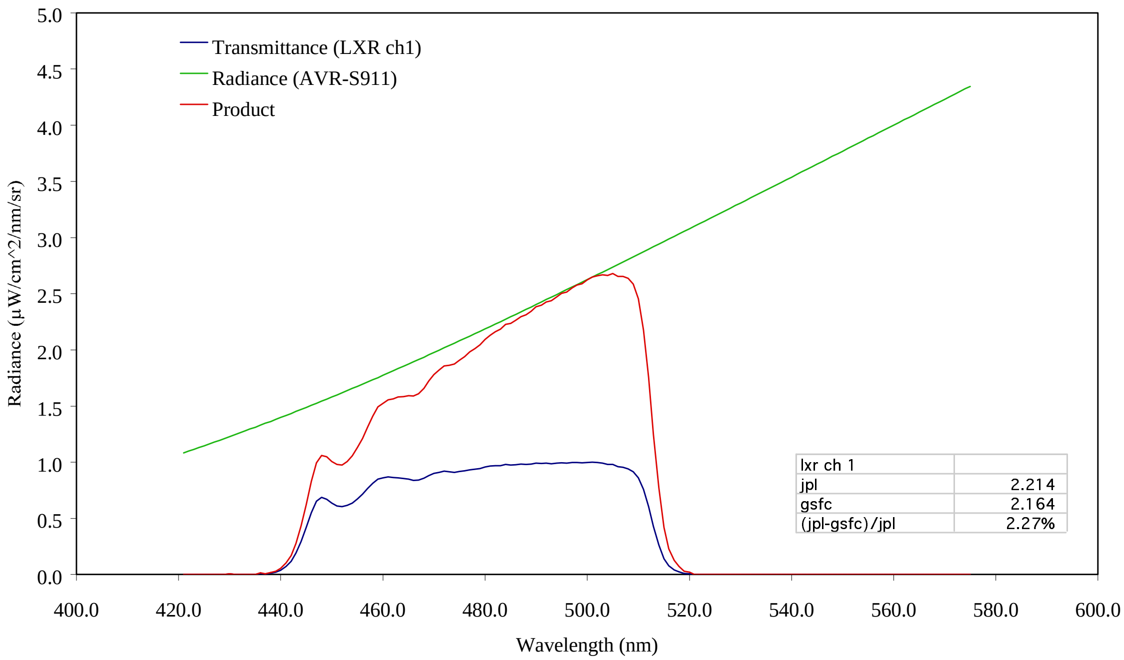

Figure 5. Comparison of the AVIRIS radiometric standard to the Landsat Transfer Radiometer Channel 1.

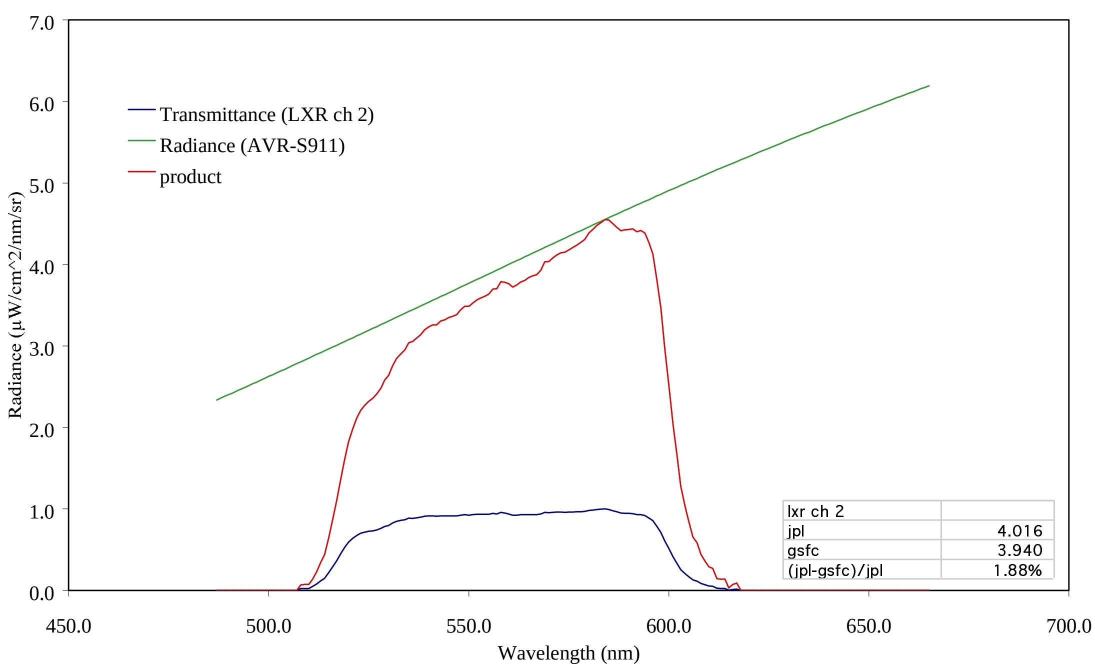

Figure 6. Comparison of the AVIRIS radiometric standard to the Landsat Transfer Radiometer Channel 2.

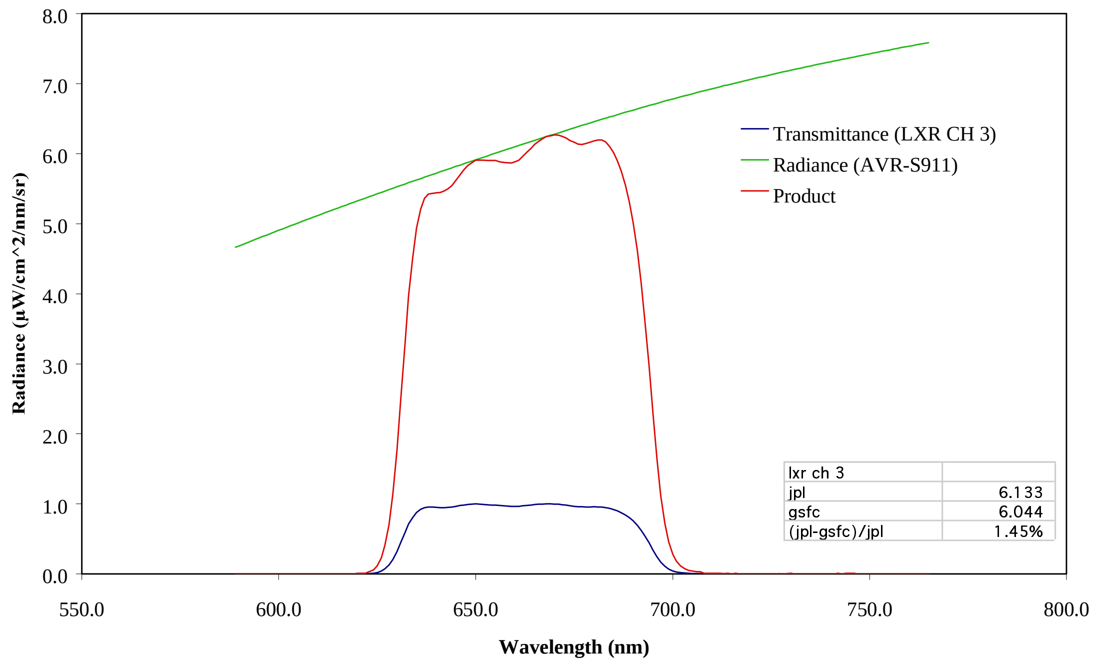

Figure 7. Comparison of the AVIRIS radiometric standard to the Landsat Transfer Radiometer Channel 3.

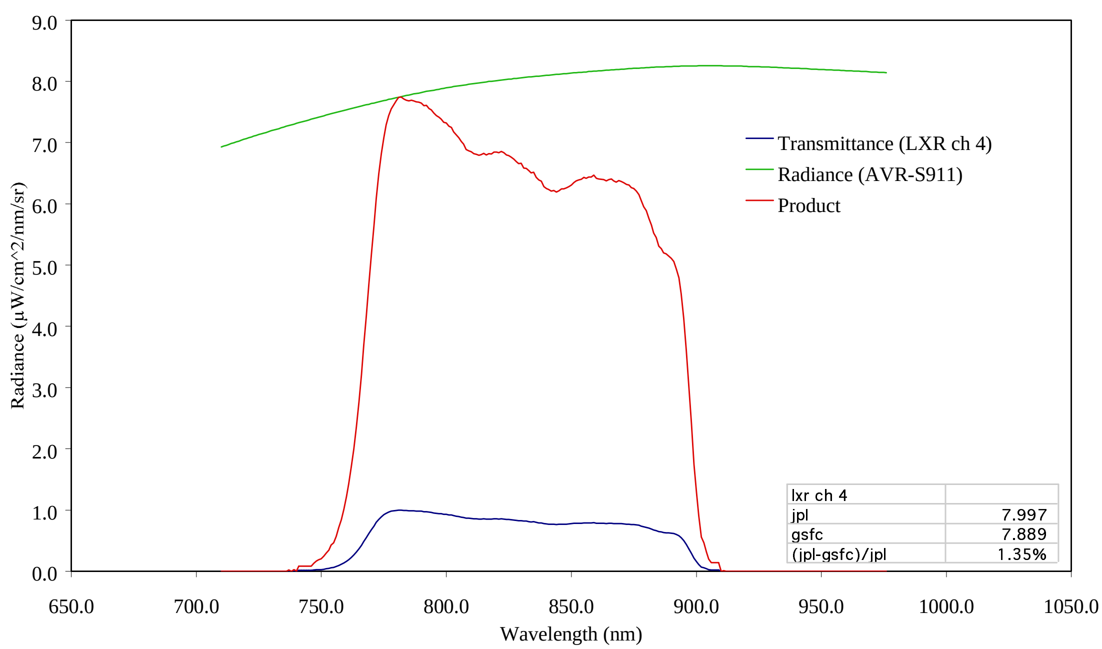

Figure 8. Comparison of the AVIRIS radiometric standard to the Landsat Transfer Radiometer Channel 4.

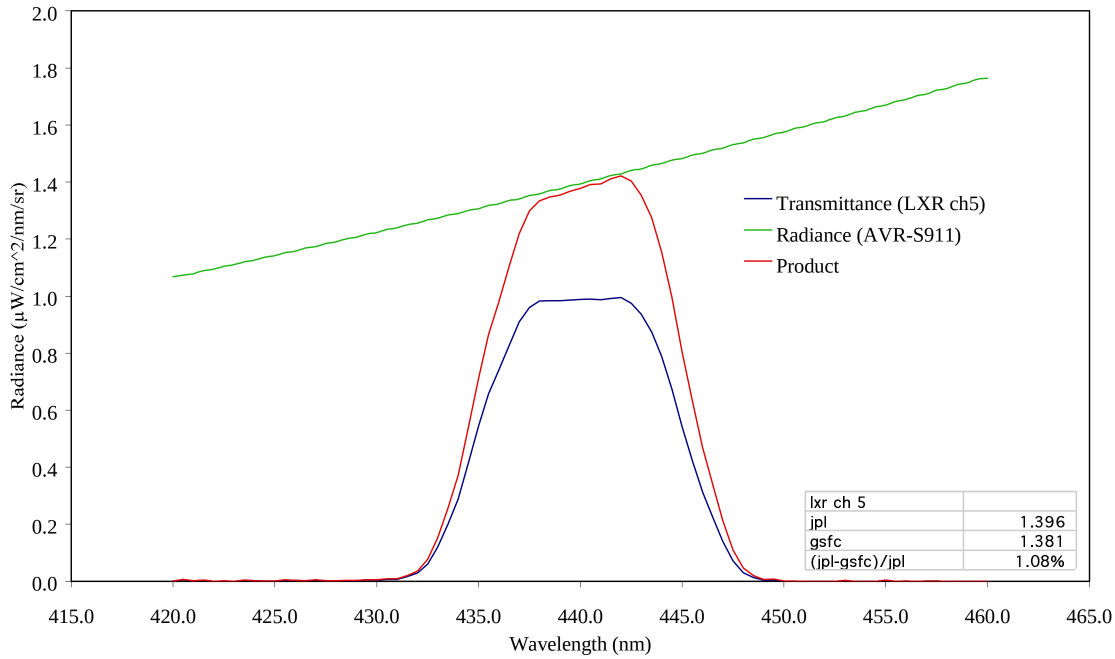

Figure 9. Comparison of the AVIRIS radiometric standard to the Landsat Transfer Radiometer Channel 5.

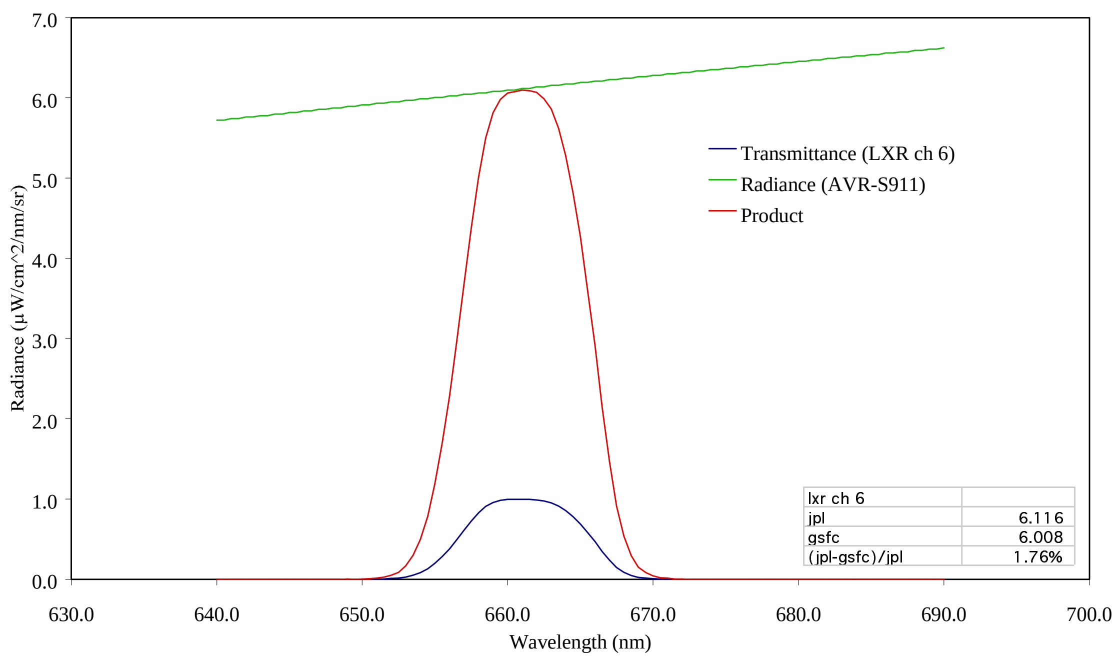

Figure 10. Comparison of the AVIRIS radiometric standard to the Landsat Transfer Radiometer Channel 6.

Table 1. Results of the comparison of the AVIRIS and LXR radiometric calibration standards

Channel	Wavelength, nm	LXR Value	AVIRIS Value	Percent Difference
LXR 1	480	2.164	2.214	2.27
LXR 2	560	3.940	4.016	1.88
LXR 3	660	6.044	6.133	1.45
LXR 4	830	7.889	7.997	1.35
LXR 5	440	1.381	1.396	1.08
LXR 6	660	6.008	6.116	1.76

4.0 CONCLUSION

The AVIRIS portable radiance standard has been described. This radiometric standard is based on an irradiance standard lamp and reflectance panel held by an optimized calibration fixture. The predicted radiance from the AVIRIS radiometric calibration standard has been reported based on the lamp and panel calibration. The predicted accuracy varies from near 1 percent in the visible portion of the spectrum to 6.5 percent at 2500 nm. The simplicity of design allows AVIRIS to be calibrated both in the laboratory and in the aircraft hanger while onboard the Earth Resources 2 (ER-2) aircraft.

In the summer of 1999 a validation of the AVIRIS radiometric calibration standard was orchestrated with the Landsat standard LXR. The LXR viewed the AVIRIS standard and the predicted radiance was compared with the LXR reported radiance. The LXR has 6 channels ranging from 440 to 830 nm in the spectrum. The agreement between the AVIRIS standard and the LXR ranged from 1.08 percent to 2.27 percent. This result shows that the AVIRIS and Landsat standards are in accord at this level for this portion of the spectrum. There is an ongoing effort to compare AVIRIS spectral, radiometric, and spatial calibration standards and approach with those used by other instrument. In addition, work continues to develop more simple and direct methods of imaging spectrometer calibration.

5.0 REFERENCES

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