

A TRACEABLE GROUND TO ON-ORBIT RADIOMETRIC CALIBRATION SYSTEM FOR THE SOLAR REFLECTIVE WAVELENGTH REGION

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ABSTRACT

This paper describes the combination of a Mie scattering spectral BSDF and BTDF albedo standard whose calibration is traceable to the NIST SIRCUS Facility or the NIST STARR II Facility. The Space-based Calibration Transfer Spectroradiometer (SCATS) sensor uses a simple, invariant optical configuration and dedicated narrow band spectral channel modules to provide very accurate, polarization-insensitive, stable measurements of earth albedo and lunar disk albedo. Optical degradation effects on calibration stability are eliminated through use of a common optical system for observations of the Sun, Earth, and Moon. The measurements from space would be traceable to SI units through preflight calibrations of radiance and irradiance at NIST's SIRCUS facility and the invariant optical system used in the sensor. Simultaneous measurements are made in multiple spectral channels

covering the solar reflective wavelength range of 300 nm to 2.4 microns. The large dynamic range of signals is handled by use of single-element, highly-linear detectors, stable discrete electronic components, and a non imaging optical configuration. Up to 19 spectral modules can be mounted on a single-axis drive to give direct pointing at the Earth and at least once per orbit view of the Sun and Moon. By observing the Sun on every orbit, the most stringent stability requirements of the system are limited to short time periods. The invariant optical system for both radiance and irradiance measurements also give excellent transfer to-orbit SI traceability. A US patent No. 8067738 was awarded to D. F. Heath for the SCATS instrument in November 2011.

Emerging instrumental requirements for remotely sensing tropospheric trace species have led to a rethinking by some of the paradigm for Système International d'Unités (SI) traceability of the spectral irradiance and radiance radiometric calibrations to spectral albedo (sr^{-1}) which is not a SI unit. In the solar reflective wavelength region the spectral albedo calibrations are tied often to either the spectral albedo of a solar diffuser or the Moon.

This new type of Mie scattering diffuser (MSD) is capable of withstanding high temperatures, and is more Lambertian than Spectralon™. It has the potential of covering the entire solar reflective wavelength region. Laboratory measurements have shown that the specular reflectance component is negligible, and indicate that internal absorption by multiple scattering is small. This MSD, a true volume diffuser, exhibits a high degree of radiometric stability which suggests that measurements at the National Institute of Standards and Technology (NIST) could provide a spectral albedo standard. Measurements have been made of its radiometric stability under a simulated space environment of high energy gamma rays, high energy protons, and UV radiation from ambient down to the vacuum ultraviolet H Lyman alpha at 121.6 nm for its eventual use in space as a solar diffuser.

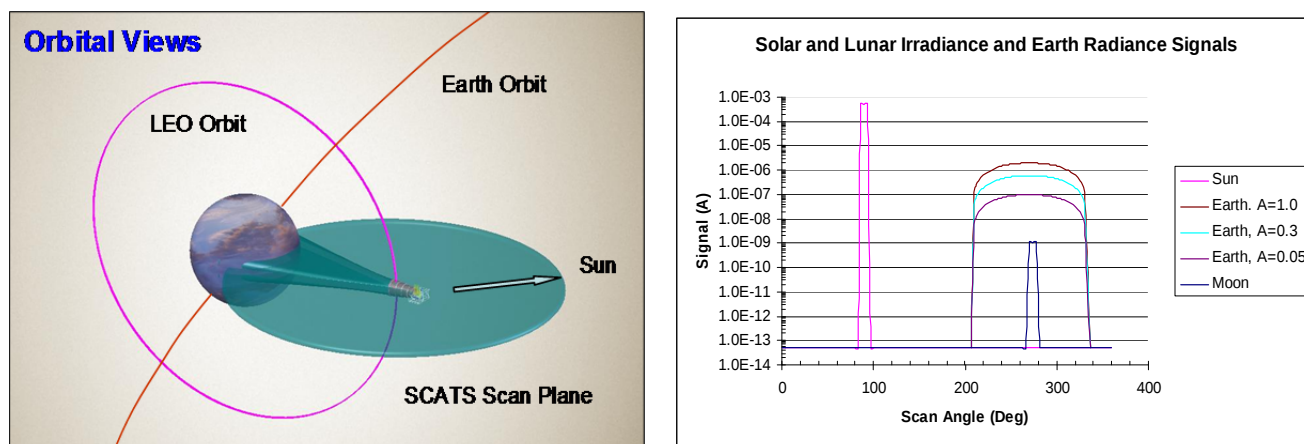


Figure 1. The SCATS scan is perpendicular to the orbital plane. Solar and lunar measurements are made using the orbital motion to scan through the Sun or the Moon. The figure on the right shows an example of calculated signals for solar, lunar (full phase), and earth observations for albedos of 1.0, 0.3, and 0.05.

Laboratory measurements have demonstrated that the addition of a fiber optic mini spectrograph can eliminate the problem of interpolation of the spectral radiances between the central wavelengths of the SCATS photometer channels to a high degree of accuracy. Calculations indicate that the radiometric calibration of the mini spectrograph can be tied to measurements of the lunar irradiances which are also measured by SCATS relative to the Sun. A Mie scattering diffuser is used to depolarize the radiation incident on the entrance aperture of the mini CCD spectrograph. Calculations of the depolarization properties of Mie scattering diffusers have been made by Biscout et al., (1994).

The SCATS measurements are used to derive the primary radiometric calibration of the spectral measurements from the mini spectrograph.

An example of the typical diffuse reflectance, diffuse transmittance, specular reflectance, and direct transmittance are shown in Figure 2 for a 3.0 mm thick MSD. A paper by Heath and Georgiev (2011) contains detailed measurements of BSDF and BTDF over a wide range of wavelengths and sizes of MSDs over a significant wavelength range in the solar reflective wavelength region.

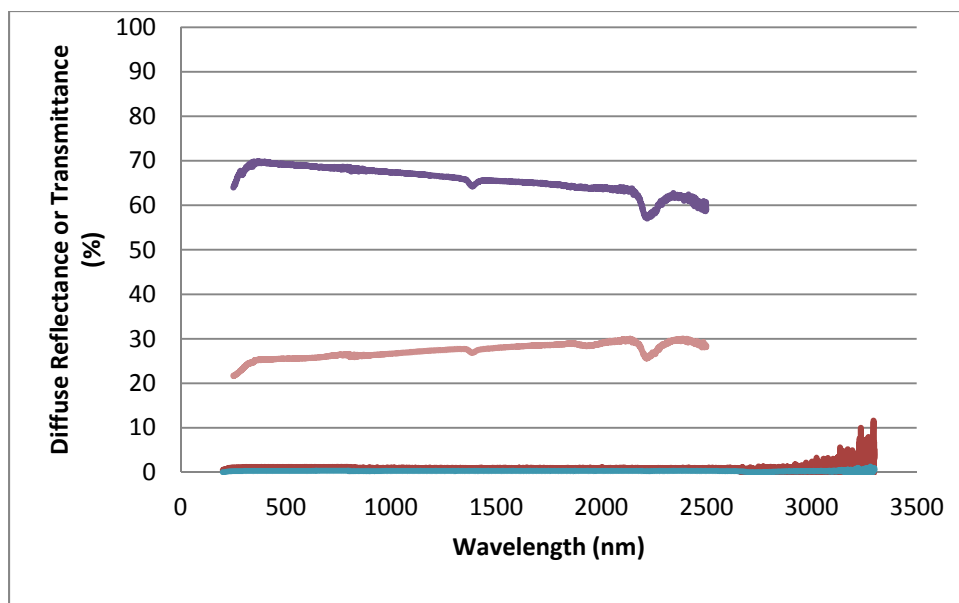


Figure 2. Measurements are shown for diffuse reflectance (top curve), diffuse transmittance (2nd curve from top), and specular reflectance and direct transmittance (overlapping curves at the bottom). The absorption bands are due to OH.

The long wavelength transmission limit at about 3.7 μm is limited by the absorption of silicon. The spectrometer which was used to make the measurements is not capable of covering the wavelength regions beyond that shown in this figure. An important feature is that this type of MSD can be used as a calibration standard in both diffuse reflectance and transmittance modes.

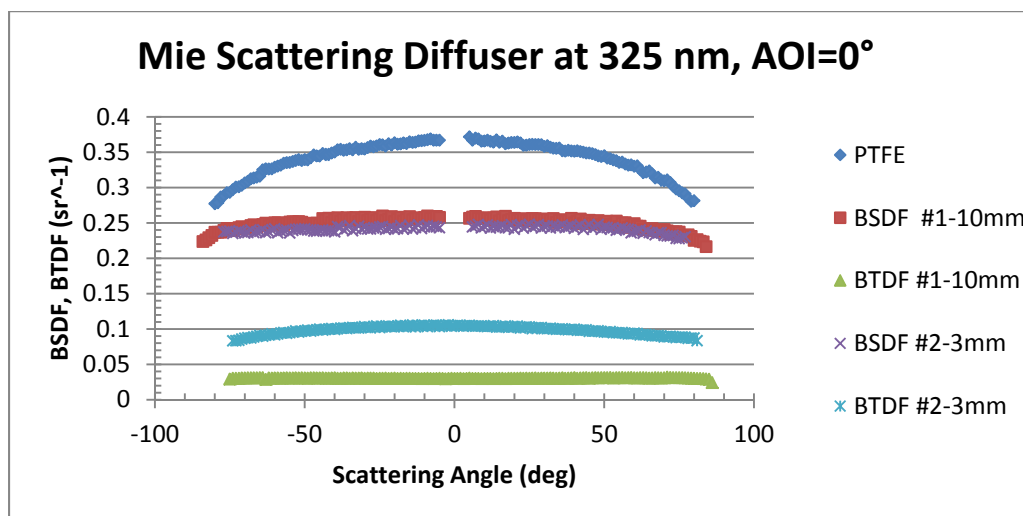


Figure 3. A comparison is shown between the BSDF PTFE a.k.a. SpectralonTM and 3 and 10 mm thick MSDs. Also shown are the corresponding BTDF values for the MSDs. This figure also illustrates the higher Lambertian scattering properties of the MSDs over PTFE.

In summary measurements to date suggest that Mie scattering diffusers should be useable as spectral albedo standards which are traceable to NIST characterization measurements, and should be

useable for the inter-calibration of remote sensing instruments prior to on-orbit operation. In space the SCATS instrument has the capability of providing Earth radiance and lunar irradiance measurements relative to the solar irradiance. The technology that is described uses no attenuating apertures or screens, and the frequency of possible solar irradiance measurements suggests a sub 1.0% measurement uncertainty a multi year operating lifetime.

References

Bicout, D., C. Brosseau, A.S. Martinez, and J.M. Schmitt, "Depolarization of multiply scattered waves by spherical diffusers: Influence of the size parameter," Phys. Rev. E 49, pp 1767-1770, 1994.

Heath, D.F., and G. Georgiev, "Characteristics of a New Type of Mie Scattering Volume Diffuser and its Use as a Spectral Albedo Calibration Standard for the Solar Reflective Wavelength Region," Proc. of SPIE Vol. 8153 Proceedings Earth Observing Systems XVI, 81530V-1, 2011.

Georgiev, G.T., and J.J. Butler, "Long-term calibration monitoring of Spectralon diffusers BRDF in the air-ultraviolet," Appl. Optics, 46, pp. 7892-7899, 2007.