Evaluation of the Direct Normal Irradiance retrieval with a Rotating Shadow Band EKO Grating Spectroradiometer

Mário Pó, Kees Hoogendijk, Will Beuttell,
Shibayama Kazunori, Eiji Takeushi
EKO Instruments Co., Ltd, Japan

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Beyond Accuracy.

1 Motivation

The advanced performance monitoring of CPV systems requires continuous spectral direct normal irradiance (DNI) data. Spectral DNI can be measured by continuously tracking the Sun with a collimated spectroradiometer.

In a rotating shadow band (RSB) configuration, a narrow band alternates its position to shade and un-shade a fixed detector, allowing a continuous measurement of both in plane global and diffuse irradiance, and the determination of the DNI.

A RSB spectroradiometer configuration offers an alternative to tracking, which lowers the costs associated with the instrumentation required, and, since only one detector is used, it also minimizes discrepancies associated to sensor calibration.

We explore a rotating shadow band configuration for the EKO MS-711 spectroradiometer to measure the global, diffuse, and direct components of spectral irradiance.
discrepancies associated to sensor calibration when measuring the spectral irradiance components.

Figure 1. MS-700, MS-710, MS-711 and MS-712 mounted on an EKO STR-32G tracker

Figure 2. EKO MS-711 with shadow band configuration

Table 1. EKO MS-711 main specifications

Wavelenght Range	300 to 1100 nm
Optical Resolution FWHM	< 7nm
Wavelenght Accuracy	+/- 0,2 nm
Directional Response	< 5 %
Temperature Response -10°C to 50°C	< 2 %
Temperature Control	25 ± 2 °C
OperatingTemperature Range	-10 to 50 °C
Exposure Time	10 to 5000 msec
Field of View	180 °

2 Experimental Site & Setup

The test results presented in this work were performed during a measurement campaign at the National Oceanic and Atmospheric Administration (NOAA) Mauna Loa Observatory (MLO), on Hawaii island (Latitude: 19.5362° North Longitude: 155.5763° West), and took place from 29th of October to 5th of November 2016. The MLO facility is located at a remote high-altitude site, above the planetary boundary layer (3397 m a.s.l.).

Measurements of the spectral DNI were performed every 1-min by four different EKO MS series spectroradiometers. The spectroradiometers were set up with collimating tubes to narrow the field of view of the instruments aperture to 5°, and assembled on an EKO STR-32G tracker to automatically follow the Sun (Fig. 1). Measurement of the spectral GHI and DHI was carried by one MS-711 spectroradiometer coupled with the recently developed EKO MB-22 rotating shadow band (Fig. 2).

To reduce the amount of uncertainties associated in comparing different instrument types, only the data acquired by the collimated and RSB MS-711 spectroradiometers were considered for the analysis, instruments specs summarized in Table 1.

The 1st and 3rd position of the RSB are used respectively to measure the spectral GHI and DHI, and, by relating the two measurements to the solar zenith angle (SZA), the spectral DNI can then be estimated (1).

The 2nd and 4th positions are then used to estimate the amount of diffuse irradiance lost due to the RSB sky coverage, and correct the DHI (2).

$$DNI_\lambda = \frac{GHI_\lambda - DHIcorr_\lambda}{\cos(SZA)} \quad (1)$$

$$DHIcorr_\lambda = DHI_\lambda + \left(GHI_\lambda - \frac{IRR2_\lambda + IRR4_\lambda}{2}\right) \quad (2)$$

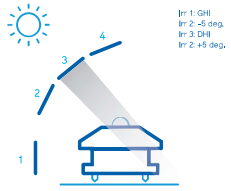


Figure 3. Rotating shadow band sweeping steps

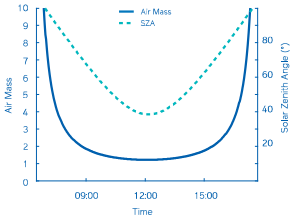
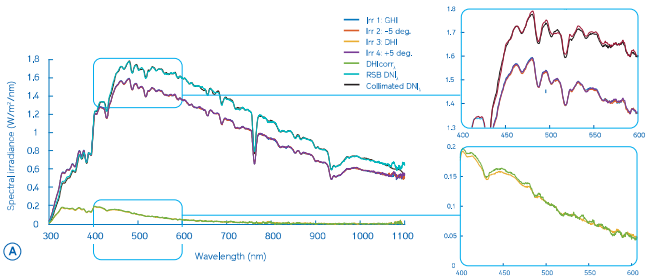


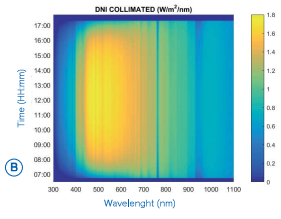
FIGURE 4. Clear sky day of 2nd of November 2016, where the SZA at solar noon reaches 34,64°

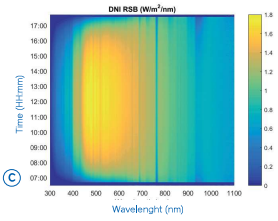
3 Data Comparison

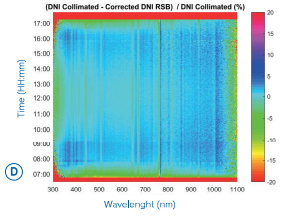
For the measurement performance analysis of the RSB configuration, we analyse the clear sky days.

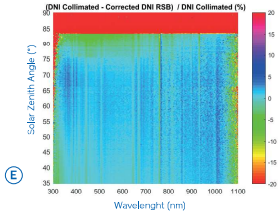
FIGURE 5: Exemplary data from clear sky day 02/11/2016
A. Solar noon spectral irradiance data: 1st position, global horizontal irradiance measurement; 2nd position, shadow band at -5° from the Sun disk; 3rd position, diffuse horizontal irradiance measurement; 4th position, shadow band at +5° from the Sun disk
B. Measured collimated DNI spectral irradiance data
C. Estimated DNI with RSB data for clear sky day
D. Comparison of DNI measurements between MS-711 with rotating shadow band and MS-711 with collimation-tube
E. EKO MS-711 DNI measurements comparison between rotating shadow band and collimation-tube configurations











4 Conclusion

The preliminary results of the DNI estimations obtained from a MS-711 spectroradiometer with RSB show very good agreement with the DNI measurements from a collimated MS-711.

The corrections applied for the systematic error improve the results and minimize the deviations, particularly for the short wavelengths.

Overall the deviations between the RSB and collimated configurations range from 2% to 5%.

Discrepancies outside this range observed for SZA greater than 75°.

For more information please contact:
Dr. Mario Po
mario.po@eko-eu.com

www.eko-eu.com