SI-traceable calibration of a transmissometer for visibility measurement

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ABSTRACT

This work demonstrates an indoor calibration of a transmissometer with a 75 m-baseline for measurement of visibility in MOR (Meteorological Optical Range) unit using a set of filters of which regular luminous transmittance values have been calibrated using SI-traceable spectral transmittance scale of KRISS.

INTRODUCTION

A transmissometer is widely used for visibility measurement at airports and weather observatories, which measures MOR based on atmospheric extinction coefficient measurement [1, 2]. By definition of MOR, the instrument should be traceable to regular luminous transmittance scale of SI-derived units. As a pre-deployment verification, in this work, we performed a calibration of a 75 m-baseline transmissometer in a large-scale indoor light-tight room using ND filters and dielectric coated windows whose luminous transmittance had been calibrated.

REFERENCE ARTEFACTS FOR SCALE TRANSFER

First, we need reference artefacts to transfer the luminous transmittance scale to the transmissometer. The calibration is performed by using a set of neutral density (ND) filters (OD 0.1 ~ 2.5) and a set of high-transmission quartz glass plates, whose detailed descriptions are shown in Table 1.

Table 1. Luminous transmittance reference artefacts

Arterfact type	Dimension	Description
Absorptive ND filters	50 mm × 50 mm	OD = 0.1 ~ 2.5 (13 EA)
Uncoated quartz window	50 mm × 50 mm	T = 93.2 %
AR coated quartz windows	50 mm × 50 mm	T = 95.3 %, 96.1 %, 97.8 %, 99.2 %, 99.5 %

The regular luminous transmittance values of the filters and windows had been assigned traceable to the KRISS spectral transmittance scale, which ranges from 0.2 % to 99.5 % as shown in Fig 1. Table 2 shows calculated luminous transmittance values and equivalent MOR values with their uncertainties for those transfer artefacts. Note the relation between spectral transmittance and luminous transmittance is formulated as Eq. (1) and the MOR value can be calculated from the transmittance value and the baseline value (B) of the transmissometer as expressed in Eq. (2).

$$T_v = \frac{\int_{380}^{780} T(\lambda) S_A(\lambda) V(\lambda) d\lambda}{\int_{380}^{780} S_A(\lambda) V(\lambda) d\lambda} \tag{1}$$

$$MOR = -\frac{3B}{\ln T} \tag{2}$$

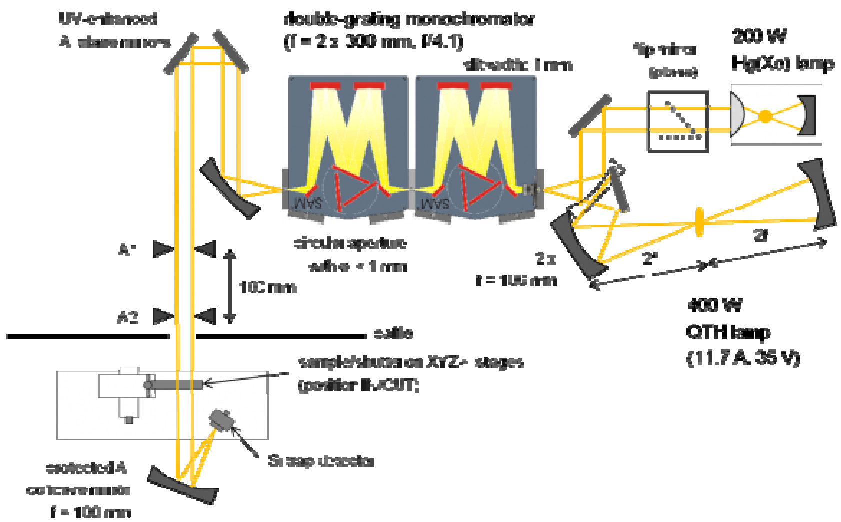

Figure 1. KRISS regular spectral transmittance measurement facility.

Table 2. Regular luminous transmittance and equivalent MOR values of the transfer artefacts

Filter ID	luminous transmittance, T_v	combined uncertainty, T_v	equivalent MOR	combined uncertainty, MOR (m)
Glass	93.2 %	0.105 %	3203.3	51.38
OD 0.1	80.4 %	0.090 %	1026.5	5.28
OD 0.15	71.0 %	0.080 %	655.5	2.17
OD 0.2	64.2 %	0.072 %	506.7	1.30
OD 0.3	50.9 %	0.058 %	332.3	0.57
OD 0.4	40.7 %	0.046 %	249.8	0.33
OD 0.5	33.3 %	0.038 %	204.1	0.22
OD 0.6	26.1 %	0.030 %	167.3	0.15
OD 0.7	21.1 %	0.025 %	144.4	0.12
OD 0.9	12.9 %	0.015 %	109.4	0.07
OD 1.0	9.1 %	0.011 %	93.7	0.06
OD 1.3	4.5 %	0.005 %	72.4	0.04
OD 1.5	2.7 %	0.003 %	62.3	0.03
OD 2.0	0.9 %	0.001 %	47.2	0.02
OD 2.5	0.2 %	0.001 %	37.0	0.02
BS 99	99.5 %	0.110 %	41367.4	16863.88
AR2	99.2 %	0.110 %	29250.0	8450.27
BS 97	97.8 %	0.110 %	10310.0	1064.80
BS 95	96.1 %	0.110 %	5691.7	330.31
AR1	95.3 %	0.105 %	4665.3	213.69

TRANSMISSOMETER TO BE CALIBRATED

The transmissometer to be calibrated consists of a loosely collimated light source (transmitter) based on a white LED (CCT ~ 5000 K) and a luminous intensity detector (receiver) with a CIE 1924 $V(\lambda)$ spectral response. The light source is placed apart from the detector by 75.0 m ± 0.1 m, and a mounting fixture for the calibration artefacts (filters and windows) is placed in the vicinity of the light source.

CALIBRATION PROCEDURE

The calibration was performed in an indoor environment which ensures the maximum visibility of MOR > 50 000 m. Before calibration, we first adjusted the detector offset to make the transmittance readout to be 0 % under blocking the light source, and adjusted the detector gain to make the transmittance readout to be 100 % under unblocking the light source. Then, we successively placed the calibration artefacts on the mounting fixture and recorded transmittance readouts of the transmissometer. We compared the measured results with the SI-traceable luminous transmittance values of the calibration artefacts and obtained the error (DUT-REF) with the uncertainty as the calibration results. In addition, the calibration was repeated twice more under external background illumination of ~4500 lx which simulates the illuminance level at the shady place in a sunny day in order to investigate the effect of background illumination on the transmissometer readouts.

CALIBRATION RESUTS

As a result of calibration, we obtained the transmittance error (Fig. 2) and the MOR error (Fig. 3) with their uncertainties for 3 cases of the background illumination (no external illumination, external illumination onto the transmitter, and external illumination onto the receiver). For example, the calibration under no external illumination showed the transmittance error Δ_T = –0.0 % at T = 99.5 % with uncertainty U(Δ_T) = 0.3 % (expanded uncertainty with k = 2), and Δ_T = 0.0 % at T = 0.2 % with uncertainty U(Δ_T) = 0.01 %. These results correspond to the MOR error Δ_{MOR} = -896 m at MOR = 41367 m with uncertainty U(Δ_{MOR}) = 22355 m and Δ_{MOR} = -0.9 m at MOR = 37 m with uncertainty U(Δ_{MOR}) = 0.7 m, respectively.

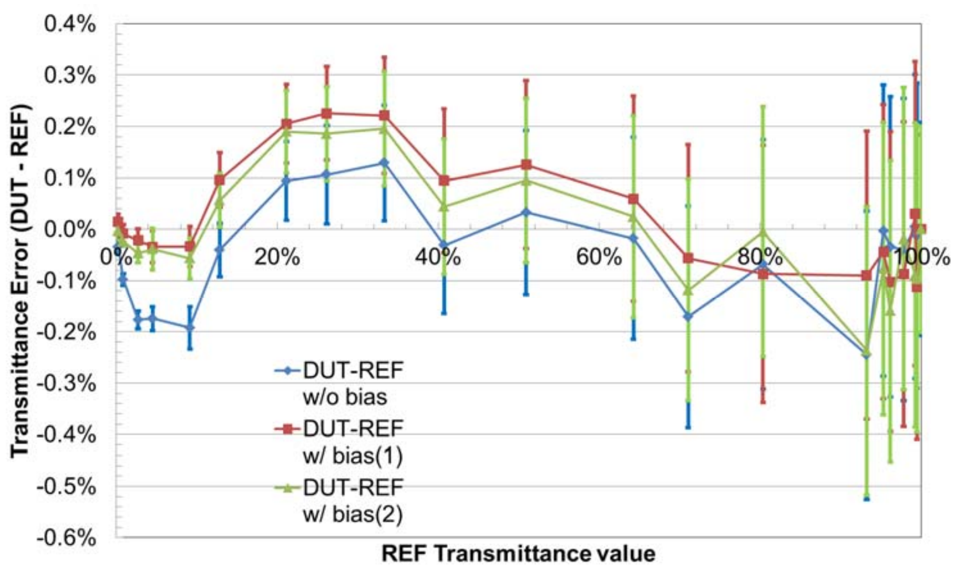

Figure 2. Transmittance calibration results: no external illumination (blue), external illumination onto

the transmitter (green), and external illumination onto the reciever (red)

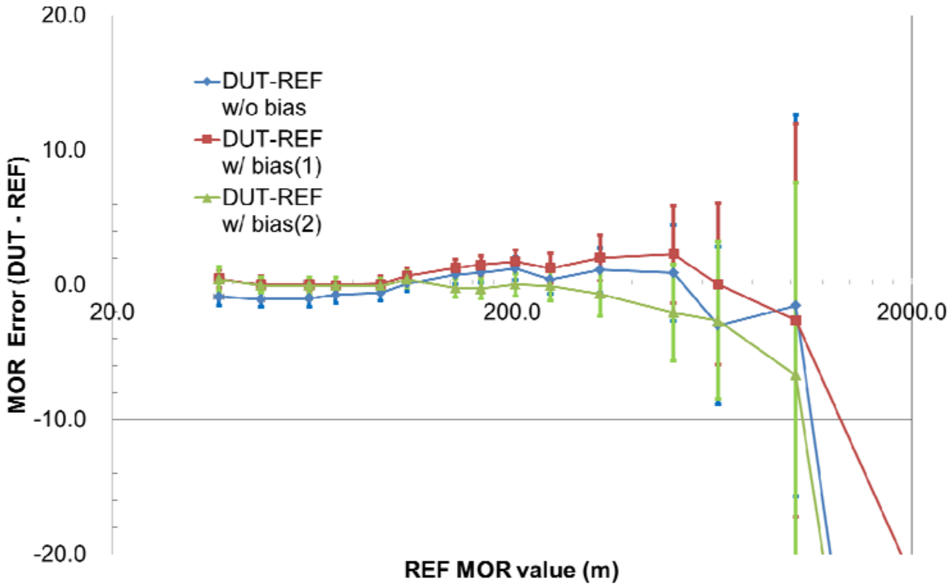

Figure 3. MOR calibration results: no external illumination (blue), external illumination onto the transmitter (green), and external illumination onto the reciever (red)

ACKNOWLEDGEMENT

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